Ministry of Environment

WEEE/E-waste Management Report

Phnom Penh Municipality

Kingdom of Cambodia

Prepared by the Ministry of Environment (MoE)
Supported by UNEP-DTIE

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Table of Contents

List of Tables

List of Figures

EXECUTIVE SUMMARY

Inventory studies carried out as part of activity 1 show that E-waste generation potential ranges from 6792 metric tons in 2008 to 22,443 metric tons in 2019. Further, the results of extensive field work highlighted that the E-waste trade value chain consists of stakeholders, who use twelve processes during E-waste management. These processes are carried out in an environmentally unsound manner, which need to be addressed both at national and city level. These findings are in line with CEA report, which stated that an action plan for the environmentally sound management of E-waste should be prepared and implemented in Cambodia. It is expected that the projected E-waste is going to arrive at different stakeholders in future who will use the twelve identified processes for dismantling and recycling. The mapping of these processes in the trade value chain shows that these processes are part of level 1 and 2 E-waste management and consist of primary and secondary E-waste generators. Therefore, there is a need for environmentally sound management of these processes while planning for future interventions within municipal boundary of PPM. Some of the specific needs, which have been identified as per CEA report, which are relevant from E-waste management perspective in PPM include need to strengthen, monitor and manage imported EEE; Need to improve operating practices of repairing and dismantling of EEE, which are being done manually; Need for proper E-waste collection and transportation system; Need for proper occupation health and safety system in E-waste management. An effort has been made to address these needs by building the national capacity to assess the specific needs.

In the above context, MoE, Government of Cambodia has received a support from UNEP-DTIE-IETC to implement the project, "E-waste Management in the Phnom Penh Municipality". The project has started in earlier 2009, after the official signing by the representatives of MoE and UNEP-DTIE-IETC. The local capacity building effort through this project is aimed at training national and local government personnel including small businesses and private sector. The objective of the proposed project is to formulate, design and implement an integrated E-waste management pilot project in PPM. After augmentation of local capacity, the level of effort could be scaled up to the national level and replicated in other countries.

The current capacity building effort is being targeted on E-waste management by using the second manual published by UNEP before the project team starts work on activity 2. This activity included study of E-waste recycling/ other recycling infrastructure (formal/informal) and its capacity, study of E-waste toxic footprint by inventorizing E-waste recycling sites in case recycling occurs in informal sector in Phnom Penh city and study of the feasibility of the level of treatment of E-waste in formal sector in Phnom Penh City. The same project team, which was trained for activity 1 was again trained for activity 2. The three day training program was conducted from 8th to 10th April 2009. The three day agenda of the training program was divided into eight sessions. There were three sessions, which were conducted on the first day. The first session was devoted to perspective of E-waste management. The second session focused on current practices of E-waste management followed by national and social policies/regulations/laws/institutions in developed countries. The objective of imparting this training was to give an exposure to participants about existing regulatory framework in developed countries. In the third session, national and social policies/regulations/laws/institutions in developing countries and initiatives taken by different agencies were discussed. It was intended to develop the capacity of participants to assess and evaluate the existing regulatory framework so that they can identify the elements required to regulate E-waste in Cambodia. Two sessions were

conducted on the second day. The first session focused on the collection system followed by description of stages and technologies for E-waste. Collection systems focused on collection channels like retailer take back and storage, producer take back and storage, municipal collection and storage, other collection points, collection infrastructure, guiding principles for design and formulation of technical specifications of E-waste collection points and E-waste treatment systems. Training on E -waste treatment technology included description of first level E-waste treatment, second level E -waste treatment, CRT treatment technology, available process technology and 3rd level E-waste treatment. Three sessions were conducted on the third day. The first session focused on the training of financing mechanism of E-waste management in developed countries. This included training on E-waste financing models, fee structure, funding for supply chain, financial guarantee, financing of E-waste management in developing countries, analysis, case study, proposed E-waste treatment facility, E-waste scenario, E-waste treatment technology, risk profiling and financial analysis. A case study from the E-waste manual 2 supported by relevant movie clips were used to strengthen the existing knowledge base of the participants.

The project team carried out study of E-waste Management system including the assessment of proposed technology, development of specifications, financial viability and planning for future interventions in PPM. The major findings and outcome are summarized below.

At the moment, retailer's/ producer's take back system and producer's/ retailer's transportation system is non existent in PPM. Further, there is no exclusive municipal collection and transportation system for E-waste in PPM. There is a limited usage of existing municipal solid waste collection and transportation system for E-waste in PPM while dismantler's in informal sector have their collection and transportation system. There are two types of E-waste collection system in PPM. Type 1 involves the intervention of waste picker and type 2, involves the intervention of dismantler. Both the mechanism collect and transport mixed type of E-waste and its fractions. Both the mechanism use significant manual handling of E-waste. No occupational health and safety practices are visible during E-waste collection and transportation. E-waste collection and transportation system appear to be market driven without regulatory controls.Tracer tracking carried out by project team indicates that there is no company/enterprise in formal sector in PPM that collects/purchases E-waste from households and offices in Cambodia. Cambodia has no modern technology to carry out repair/ dismantling /refurbishing. Most E-waste residues generated from repairing and/or dismantling shops are disposed in dustbin and later at urban dumpsite by domestic waste collection service. Some areas where waste-collection trucks are not available, such kind of E-wastes are disposed improperly at sites close to/behind the repairing/dismantling shops, and are finally burnt.

The location of the toxic footprint can be correlated to the location of hubs of formal and informal sectors on the major streets in PPM e.g. areas like Chamkamorn and Toul Kok, serve as two major hubs for TV and PCs repair/ refurbishment and dismantling. Chamkamorn, Toulkok and Meanchay also serve as major repairing/ refurbishing centre for washing machine.

The project team assessed that current E-waste collection, transportation, treatment and disposal in PPM are inadequate both in terms of capacity and environmentally sound management. Since the existing toxic footprint covers areas, which are commercial along the main streets of PPM, its expansion is likely to further impact air, water and soil conditions in its area of influence. Therefore, a need for environmentally sound management of E-waste has been identified in order to reduce its volume as well as its toxic footprint. In this context, an E-waste management system & technology evaluation has been carried out. The criteria for planning / design / implementation, which have been identified by the project team for environmentally sound E-waste management system in PPM, are given below.

1. ICT will continue to drive the E-waste management system including E-waste recycling in the country.

2. E-waste collection and transportation mechanism in PPM is diverse in nature ranging from hand driven cart to light commercial vehicles.

3. Both the households and the commercial sector look for best monetary and exchange value of their old product. Therefore, any E-waste management system should factor in the salvage value of the waste product. The best monetary and exchange value of the old product can be determined by understanding the E-waste composition and its recyclability described below.

4. Recyclability of E-waste is driven by electric component, copper and precious metal recovery. Therefore, E-waste collection, transportation and treatment are different from conventional solid waste collection, transportation and treatment system due to its composition and recyclability.

The consumer behavior indicates that the only viable mechanism under the existing regulatory mechanism appears to be to capture E-waste at the point of generation. Since the majority of E-waste is generated in the commercial sector e.g. corporates/ business/ BPOs etc., and both the households and commercial sector prefers the best value of their waste, it is recommended that the E-waste collection facilities should be at retailers and at commercial sector e.g. corporates/ business/ BPOs etc. Salient features of this collection mechanism are given below.

1. There is a need for separate collection facilities for ICT and white goods.

2. Location of collection facilities need to be near E-waste collection hubs. This need is projected on account of following reasons.

    - Ensure minimal movement of products
    - Efficient collection mechanism
    - Minimize manual handling
    - Avoid unsorted municipal waste

3. Each of the retailer's/ market association/ group can identify a place/ area as E-waste collection point. This place can serve as a place where retailers/ consumers can get value of their old product. The authorized E-waste recycler can collect from retailer's collection facilities and transport E-waste to their recycling facility.

4. E-waste from households can be routed through already existing municipal waste collection mechanism. Each of the localities can identify a place/ area as E-waste collection point in their premises. This place can serve as a place where retailers/ consumers can get value of their old product. There is a need to initiate public awareness campaign to collect E-waste at authorized collection facility and only give to authorized recycler for treatment and disposal.

5. The research literature cites that the efficiency of E-waste collection system ranges from approximately 60% to even less than 30% even in the most efficient system functioning under EPR in EU. This indicates that leakages exist even in the most efficient system.

6. There is a need for authorizing E-waste recyclers/ dismantlers in PPM. This will assist to divert E-waste from commercial sector e.g. corporates/ business/ BPOs using existing mechanism to authorized recycler.

The proposed E-waste treatment technology has been described based on first and second level of treatment. These levels have been proposed considering two levels of treatment occurring in PPM. Out of the two levels, the major part of treatment is occurring at first level only, while the second level is occurring to a minimal extent. However, E-waste inventory estimate encourages recommending second level treatment after 2019.

It may be noted that even in the best of E-waste collection scenario with 90% coll-ection efficiency, Cambodia will not be able to generate adequate quantity of E-waste till 2030 to sustain an integrated metal recovery facility, which will require about 300,000 tons per annum of input raw material. In such scenario, hydrometallurgical/ electrolysis appears to be the viable third level option for precious metal recovery in Cambodia beyond 2030.

E-waste Management System Specifications

The volume of E-waste item to be collected and transported till 2020 based on E-waste inventory estimates in Phnom Penh ranges from 4490 m^3 to 32923 m^3 for washing machine, 5140 m^3 to 6925 m^3 for personal computers, 9m^3 to 46m^3 for mobile phones, 2918 m^3 to 9573 m^3 for refrigerator, 1458 m^3 to 5976 m^3 for Air Conditioners and 1557 m^3 to 2618 m^3 for washing machine. This is based on 50% availability of E-waste for recycling. Depending upon the type of E-waste, different types of bins/ cages have been identified and recommended. The collected E-waste in container will be lifted manually, through fork lifts, placed into small trucks/ container carriers and transported from the collection facility to E-waste treatment facility. E-waste collection frequency is dependent on E-waste inventory and inventory maintained at recycling facility. The forklifts and trucks to lift containers are required for safe transport of E-waste from collection locations to recycling facility. It has been recommended that the responsibility of E-waste collection will be that of the either recycler or collection agency. Further, the collection centers at commercial/ corporate/ business centers can use the above specifications of the bins to collect and store E-waste. As the volume of the E-waste starts increasing, collection facilities will be required at retailer and household level. The design criteria will be dependent on the area requirement in order to capture E-waste from a respective catchment. Again inventory from the catchment will determine the bin requirement and the area required for storing bins and collection frequency of the bins will determine the basis for area of collection facility.The specifications of E-waste treatment facility will depend on the E-waste collection efficiency in PPM. The specifications for proposed E-waste recycling facility vary from 5,000 tons per annum to 7,500 tons per annum based on 50% collection efficiency by 2019. The tentative total area requirement for catering to such type of facility has been estimated to be about 4 acres or about 15,600 sq meters as per international best practices and design criteria of plant and equipment supplier. Out of this total area, processing area is about 25%, area for administration 5%, area for storing raw material to be about 30% and for finished product to be about 15% and open area is about 25 %. First and second level treatment could be either manual or semi-automatic using conveyor system. The specification of shredder in the 1^{st} and 2^{nd} level treatment determines the equipment specifications. Tentative shredder specifications include input feed of 3 to 4 tons per hour with an output of size between 4 - 5 mm.

Depending on the collection efficiency and availability of the input raw material, the facility can start with one shredder of half the capacity followed by the second. There is huge variation in the prices of the treatment system starting from US$ 789700 to US$ 3.1 million depending on type of technology. The output from the E-waste recycling system will be sold/ exported to metal recyclers outside Cambodia. E-waste export market is expected to follow the same trend as that of global market for precious metals. Therefore, price risks related to E-waste fractions are associated with price variations in global metal markets and commodity exchanges e.g. London Metal Exchange, London Bullion Market etc. The analysis of the price graphs indicates that metal market peaks and bottoms out in a ten year period. E-waste purchase price in PPM has ranged from US$ 1/kg to US$ 4/kg during the last ten year period. A financial analysis for the 7500 tons per annum E-waste recycling facility in PPM has been carried out based on capital and operating cost estimates, local land prices, labor costs, customs duty, equipment costs, electricity costs and current interest rates. It has been proposed that the capital costs will be in the form of debt and equity in a ratio of 70:30. The financial viability indicators e.g. IRR shows viability of the project. NPV is positive and decreases with high cost of capital. But the financial indicators are not strong enough to attract private investment because IRR value is much lower than 25% and payback period is 5 years. The project is most sensitive to land prices followed by interest rates, and customs duty. This analysis also indicates that if lower quantities of PC are dismantled then financial viability goes down significantly. It shows that for waste white goods treatment and disposal, the combination of incentives should be higher. Financial viability is also sensitive to price fluctuations i.e. prices with respect to both input raw material as well as output. A comparative analysis of financial analysis indicators shows that viability improves with the improved capacity utilization. Capacity utilization depends upon the availability of the raw material. In order to make the project more viable an efficient E-waste collection and transportation system and a set of incentives like lower interest rate or duty exemption or subsidy on land may be planned.

The major risks anticipated is the availability and quality of raw material, scale of operation and expected yield on account of efficiency of E-waste collection system. The fundamental basis to design conventional E-waste collection and transportation infrastructure and E-waste treatment facility requires assessment of the lowest and highest volume of E-waste to be collected during the planned period. This is carried out based on E-waste capture rate. E-waste capture rate can be assessed by implementing a pilot project for E-waste collection and transportation, which has been conceptualized in third report.

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.0 Introduction

Inventory studies show that E-waste generation potential ranges from 6792 metric tons in 2008 to 22,443 metric tons in 2019. Further, the results of extensive field work highlighted that the E-waste trade value chain consists of stakeholders, who use twelve processes during E-waste management. These processes are carried out in an environmentally unsound manner, which need to be addressed both at national and city level. These findings are in line with CEA report, which stated that an action plan for the environmentally sound management of E-waste should be prepared and implemented in Cambodia. In this context, the following sections describe the identified needs, objectives, approach and methodology and capacity building effort to address these needs within municipal limits of PPM. Further, the format of the report describes the outcome of this effort.

1.1 Need for Proper E-waste Planning & Management in Phnom Penh City

It is expected that the projected E-waste is going to arrive at different stakeholders in future who will use the twelve identified processes for dismantling and recycling. The mapping of these processes in the trade value chain shows that these processes are part of level 1 and 2 E-waste management and consist of primary and secondary E-waste generators. Therefore, there is a need for environmentally sound management of these processes while planning for future interventions within municipal boundary of PPM. Some of the specific needs, which have been identified as per CEA report, which are relevant from E-waste management perspective in PPM are given below.

- Need to strengthen, monitor and manage imported EEE
- Need to improve operating practices of repairing and dismantling of EEE, which are being done manually.
- Need for proper E-waste collection and transportation system. Currently, E-waste residues are improperly disposed in dustbin and at dumpsite mixed with other urban wastes.
- Need for proper occupation health and safety system in E-waste management.

An effort has been made to address these needs by building the national capacity to assess the specific needs as described below.

1.2 Project on “Waste Electronic and Electric Equipment/ E-waste Management in Phnom Penh City

In the above context, MoE, Government of Cambodia has received a support from UNEP-DTIE-IETC to implement the project, “E-waste Management in the Phnom Penh Municipality”. The project has started in earlier 2009, after the official signing by the representatives of MoE and UNEP-DTIE-IETC. The local capacity building effort through this project is aimed at training national and local government personnel including small businesses and private sector. The following sections describe project objectives, brief approach and methodology and description of training programs.

1.2.1 Project Objectives

The objective of the proposed project is to formulate, design and implement an integrated E-waste management pilot project in PPM. After augmentation of local capacity, the level of effort could be scaled up to the national level and replicated in other countries. Specific objectives of the proposed pilot project are given below.

- Build the national and local capacity in Cambodia on inventorization and management of E-waste by undertaking various activities, including the inventory of E-waste and a pilot project to process E-waste in and environmentally sound manner with optimum level of recovery for recycling.

- Bring out the guidelines and training materials for dissemination for other developing countries to replicate similar projects and capacity building process.

1.2.2 Brief Approach and Methodology

The current capacity building effort is being targeted on E-waste management by using the second manual published by UNEP before the project team starts work on activity 2 described below.

Activity 2: Study of E-waste recycling structure

- Study of E-waste recycling/ other recycling infrastructure (formal/informal) and its capacity
- Study of E-waste toxic footprint by inventorizing E-waste recycling sites in case recycling occurs in informal sector in Phnom Penh City
- Study of the feasibility of the level of treatment of E-waste in formal sector in Phnom Penh City

The project team, which was imparted training, included the following personnel.

1) Dr. CHRIN Sokha, MoE – Team Leader
2) Mr. Sophal Laska, MoE
3) Mr. Sreng Sophal, MoE
4) Mr. Pet Pichhara, MoE
5) Mr. Te Ith Leang, MoC
6) Mr. Sreng Sokvung, MIME
7) Mr. Tes Norarith, DoE of PPM
8) Mr. Khuy Kuyny, DoE of PPM
9) Mr. Hak Mao, CEA
10) Mr. Chin sothun, CEA
11) Mr. Uon Sokuntea, CEA
12) Mr. Yim Mongtoeun, RUPP

1.2.3 Training Program

The three day training program was conducted from 8th to 10th April 2009. Dr. Mushtaq Ahmed Memon – UNEP-DTIE-IETC and Mr. Amit Jain – Consultant conducted this training program as faculty members. The three day agenda of the training program was divided into eight sessions as described in appendix 1 and summarized below.

Day 1
There were three sessions, which were conducted on the first day. The day started with the discussion on the roles and responsibilities of the different participants and stakeholders and outline of the Training on E-waste Manual, Volume II. The first session was devoted to perspective of E-waste management. The discussions focused on the findings of the first field training program and identification of the E-waste trade value chain in PPM. The second session focused on current practices of E-waste management followed by national and social policies/regulations/laws/institutions in developed countries. The objective of imparting this training was to give an exposure to participants about existing regulatory framework in developed countries. In the third session, national and social policies/regulations/laws/institutions in developing countries and initiatives taken by different agencies were discussed. It was intended to develop the capacity of participants to assess and evaluate the existing regulatory framework so that they can identify the elements required to regulate E=waste in Cambodia. There were interactive discussions on current and future challenges for Kingdom of Cambodia in general and Phnom Penh city in particular.

Day 2
Two sessions were conducted on the second day. The first session focused on the collection system followed by description of stages and technologies for E-waste. Collection systems focused on collection channels like retailer take back and storage, producer take back and storage, municipal collection and storage, other collection points, collection infrastructure, guiding principles for design and formulation of technical specifications of E-waste collection points and E-waste treatment systems. Training on E –waste treatment technology included description of first level E-waste treatment, second level E –waste treatment, CRT treatment technology, available process technology and 3rd level E-waste treatment.

Day 3
Three sessions were conducted on the third day. The first session focused on the training of financing mechanism of E-waste management in developed countries. This included training on E-waste financing models, fee structure, funding for supply chain, financial guarantee, financing of E-waste management in developing countries, analysis, case study, proposed E-waste treatment facility, E-waste scenario, E-waste treatment technology, risk profiling and financial analysis. A case study from the E-waste manual 2 supported by relevant movie clips were used to strengthen the existing knowledge base of the participants. Photo album of the class room training session and field work is given in appendix 2.

1.3 Format of Report

The outcome of the second training session, field activities, and inventory study within the municipal limits of Phnom Penh has resulted in the development of this report. This report describes the E-waste recycling structure within the municipal boundaries of Phnom Penh as an outcome of activity 2. The report consists of six chapters. Chapter 1 gives background information, approach and methodology, training and its outcome and format of the report. Chapter 2 describes E-waste recycling/ other recycling infrastructure (formal/informal) and its capacity in the context of existing regulatory framework. This chapter further describes E-waste toxic footprint by locating E-waste recycling sites in informal sector in Phnom Penh City. Chapter 3 describes the proposed E-waste management system & technology evaluation for Phnom Penh. Chapter 4 describes the tentative specifications and the need for pilot study. Chapter 5 describes the feasibility of the level of treatment of E-waste in formal sector in Phnom Penh City. Chapter 6 describes conclusions and recommendations.

CHAPTER 2: E-WASTE MANAGEMENT IN PPM

2.0 Introduction

E-waste management in PPM has been described in terms of its components, which include collection, sorting & transportation, treatment and disposal system. All the components have been described in terms of existing practices, scale, location and capacity of existing and predicted system under "business as usual" scenario. E-waste treatment and disposal system describe the repair, refurbishing and dismantling system both in formal and informal sectors. Further, toxic footprint both in terms of hazardous content, disposal and locations within PPM has been described. The following sections describe each of these items including the basis and future projections from the planning perspective.

2.1 Components of E-waste Management

There are three major components of E-waste management systems. These are:

1. E-waste collection, sorting and transportation system
2. E-waste treatment system
3. E-waste disposal system.

In developed countries, E-waste collection system consists of producer/ retailer take back system, municipal collection system and recycler's/ dismantler's collection system as shown in figure 2.1. Since E-waste is hazardous in nature, it is collected, sorted, stored and transported under controlled conditions. Each of the agencies has its own E-waste collection and storage centers. The collection means will vary, following distances, rural or urban patterns, and the size of collected appliances. Some categories will require specific collection routes like flatbed collection (for fridges and other reusable household appliances).

An efficient E-waste collection and transportation system will ensure reuse, recycle and adequate E-waste management including avoiding damage or breaking components that contain hazardous substances. The major factors, which determine the efficiency of collection system, are given below.

- accessible and efficient collection facilities
- ensure minimal movements of products
- minimize manual handling
- aim to remove hazardous substances
- separate reusable appliances
- adequate and consistent information to the users.

According to available literature, in EU, E-waste in general is being sorted/ separated into five groups as given below depending on different material composition and treatment categories. This facilitates efficient collection, recycling and data monitoring for compliance.

1. Refrigeration equipment —Due to ODS usage, this has to be separated from other E-waste

2. Other large household appliances — because of their shredding with end-of-life vehicles and other light iron, they need to be separated from other waste
3. Equipment containing CRTs —the CRTs need to remain intact because of health and safety reasons. Therefore, TVs and computer monitors will have to be collected separately from other waste and handled carefully
4. Lighting (linear and compact fluorescent tubes) — this needs to be deposited in a special container (due to Mercury) to ensure it does not contaminate other waste and that it can be recycled
5. All other E-waste — This equipment can be collected in the same container because there are no recycling or health and safety reasons

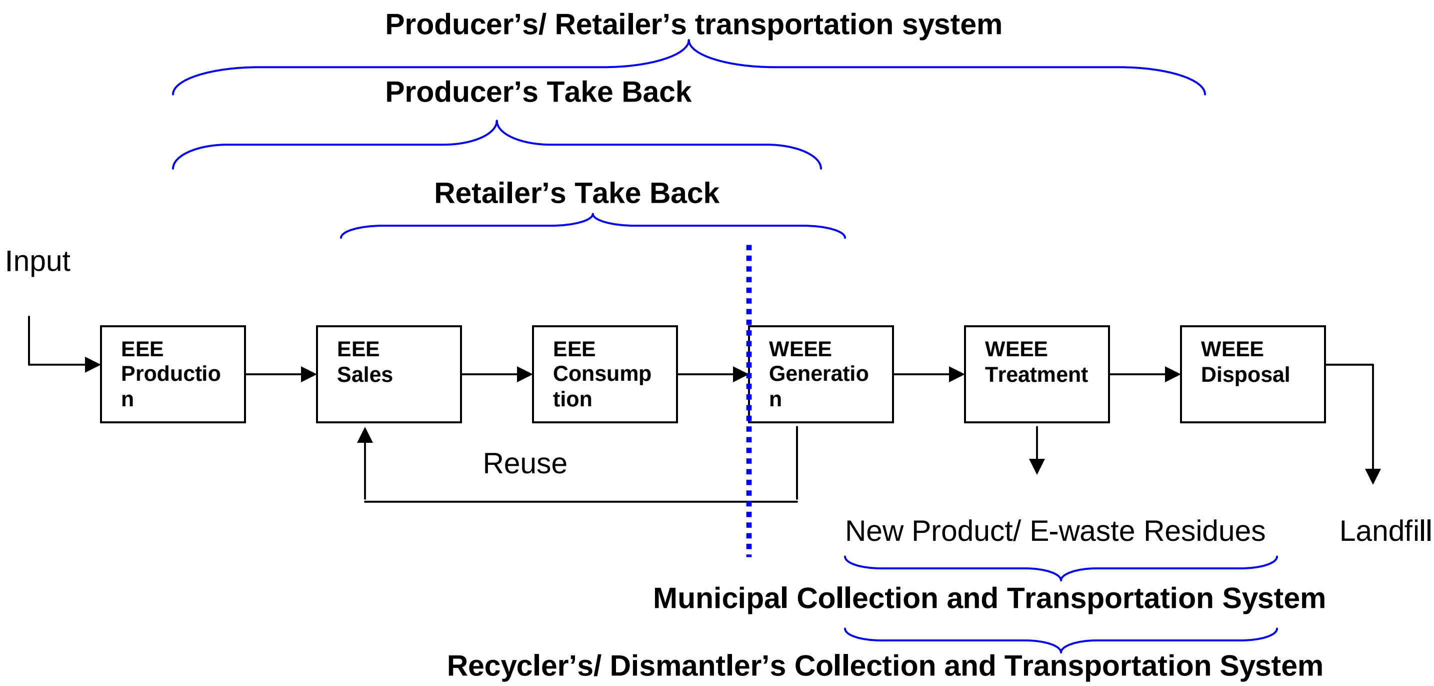


Figure 2.1: E-waste Collection Systems

At the moment, retailer's/ producer's take back system and producer's/ retailer's transportation system is non existent in PPM. Further, there is no exclusive municipal collection and transportation system for E-waste in PPM. There is a limited usage of existing municipal solid waste collection and transportation system for E-waste in PPM while dismantler's in informal sector have their own collection and transportation system as shown in figures 2.2 and figure 2.3. In the municipal system, dustbins are utilized for E-waste disposal while waste pickers use hand carts for transportation of E-waste. Further, vehicles from municipal solid waste transportation company pick E-waste residues from the bins for disposal at waste dump site. Dismantler's in the informal sector use vehicles to transport E-waste from the point of generation to the junkshop or for the place of dismantling as shown in figure 2.3.

Figure 2.2: Municipal Dustbins Usage for E-waste collection and transportation

Figure 2.3: Existing Informal Sector E-waste collection and transportation

Therefore, there are two types of E-waste collection system in PPM. Type 1 involves the intervention of waste picker as shown in figure 2.2 and type 2, which involves the intervention of dismantler. Other features of both types of collection and transportation system are described below.

1. These collection systems indicate the difference in scale of E-waste collection and transportation within the same geographical boundaries.

2. Both the mechanism collect and transport mixed type of E-waste and its fractions.

3. No separate collection and transportation mechanism exist for individual E-waste item.

4. Both the mechanism use significant manual handling of E-waste.

5. No occupational health and safety practices are visible during E-waste collection and transportation.

6. E-waste collection and transportation system appear to be market driven without regulatory controls.

The features described above identify the gaps in the existing E-waste collection and transportation system, which will form the basis of future interventions in E-waste management. Some of these interventions could be pilot tested before designing the scaled up E-waste collection and transportation system.

2.2 E-waste Treatment and Disposal System in PPM

“Material Flow” along the “Life Cycle” of electrical and electronic equipment including the phase of obsolescence within a “Geographical Boundary” forms the basis of E-waste generation in cities. This E-waste generation requires adequate treatment and disposal in an environmentally sound manner. In this context, E-waste trade value chain in PPM has been studied at three levels. At first level, the conceptual E-waste trade value chain has been established. This conceptual E-waste trade value chain is based on assumption that all the stakeholders are organized in formal sector and all the processes are occurring in an environmentally sound manner. At second level, the conceptual life cycle of E-waste and its flow has been customized as per geographical distribution of identified process within geographical boundaries of PPM. At third level, its organization in formal, semiformal and informal sector has been studied.

Conceptual E-waste material flow chain is shown in figure 2.4.

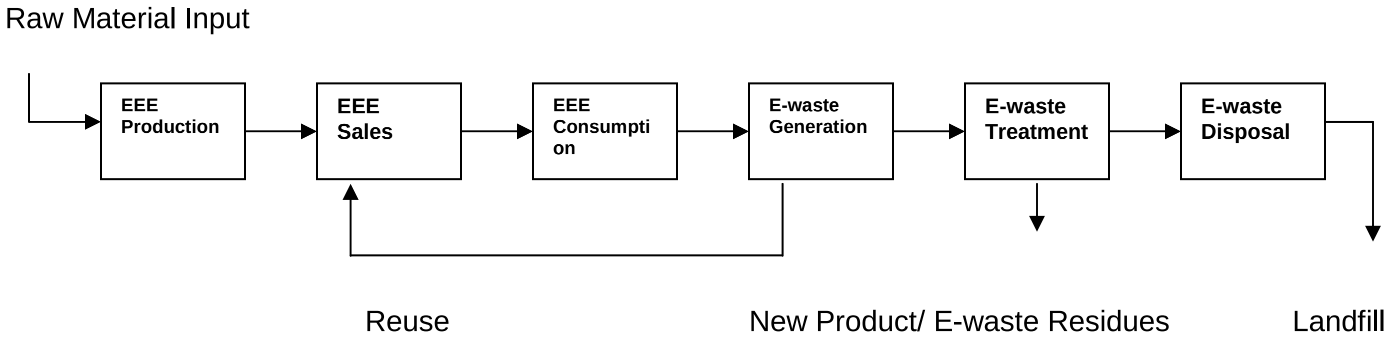


Figure 2.4: Conceptual Life Cycle of Electrical and Electronic Equipment

1. EEE production: import/ manufacturing of EEE
2. EEE sales
3. EEE consumption (stock)
4. E-waste generation
5. Re-use / down cycle
6. E-waste treatment/ Re-cycle
7. Secondary raw material / disposal

The conceptual E-waste material flow chain, after its application to E-waste flows through twelve processes in PPM has been modified and shown as E-waste trade value chain in figure 2.5. It is a five-step value chain covering all the stakeholders.

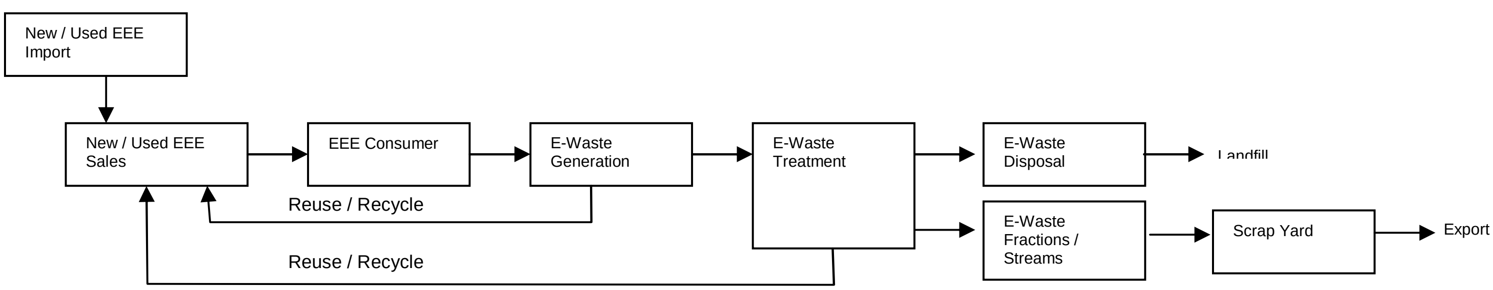


Figure 2.5: E-Waste Trade Value chain in PPM

These stakeholders are organized in formal and informal sectors. It has been found that E-waste generated arrives at first from the formal/ organized markets like manufacturers, importers, offices, and semi-organized markets, where E-waste from domestic consumers comes either in exchange schemes or as discarded items. The recyclable parts of computers, mobile phones, AC, TV, refrigerators and washing machine are sold to waste pickers and dismantlers while the other parts that cannot be repaired are disposed in dustbins as domestic wastes. The waste pickers generally sell their collected E-waste residues both from dustbins as well as from formal/organized sector to scrap yard owners for export. The transition of E-waste trade value chain from formal to semiformal and informal sector in PPM is shown in figure 2.6.

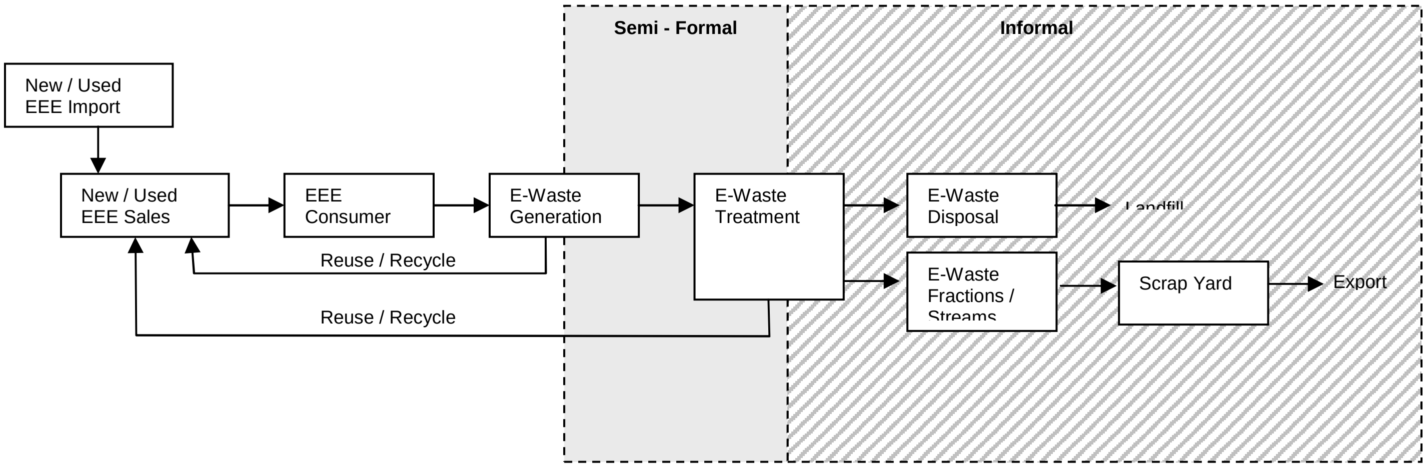


Figure 2.6: Sectoral Organization of E-Waste Trade Value Chain in PPM

The tracer tracking for each E-waste item along the E-waste trade value chain within the geographical boundary of PPM has been studied to identify and establish the capacity of existing E-waste treatment and disposal system.

Tracer tracking of TV is shown in figure 2.7. Broken and/or non-functioning TV is at first checked to identify problems prior to its repair, dismantling and disposal. There are two major stakeholders, which are repair and junk shops, where some major treatment and disposal activities occur. Firstly, these places are used for buying and selling E-waste scrap. Secondly, it is a place for dismantling second-hand TV that can not be used any more. Before selling to the junkshops, TVs are dismantled and separated by types such as plastic cases, printed circuit board, copper, aluminum, iron etc. at repair shops. Further, Plastic cases are chopped by machine into small pieces at junk shops/ yards and exported to other countries. The other parts are also broken down or separated from TV at these places. These parts are sold separately at different prices.

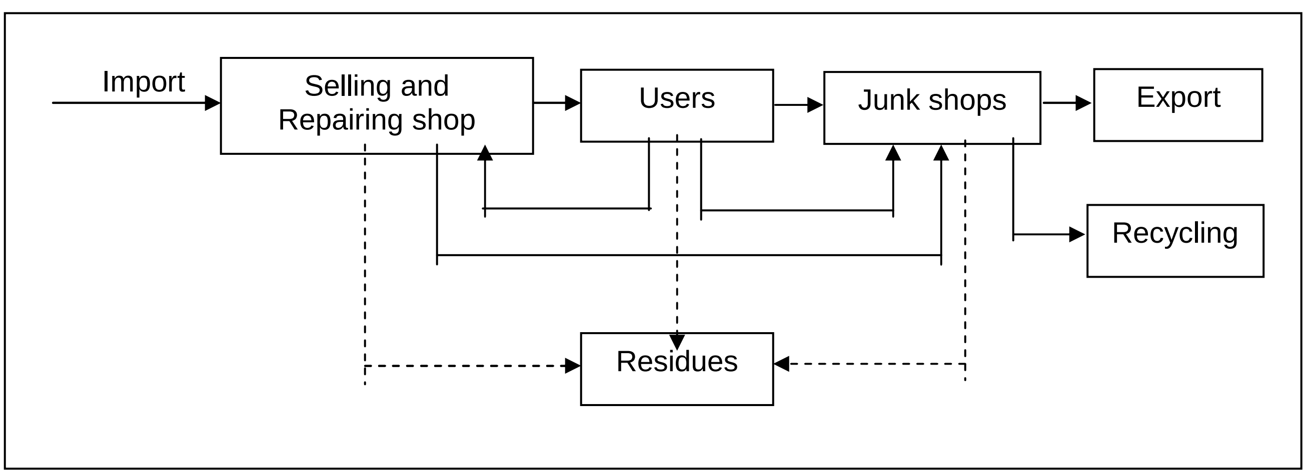


Figure 2.7: TV Tracer Tracking

Tracer tracking of PC is shown in figure 2.8. Owners of PC selling shops also perform the function of repairing non-functioning computers prior to selling. These stakeholders also buy used-computers from local users to carry out repair and reselling. Repaired computers are commonly warranted for one year. Those computers, which cannot be repaired, are dismantled to extract usable parts (as spare-parts), or sold to junkshop. At junkshop, valuable parts are taken out, e.g. plastic, wires, copper, iron, aluminum, screen and batteries (UPS) and sold at different prices to different customers.

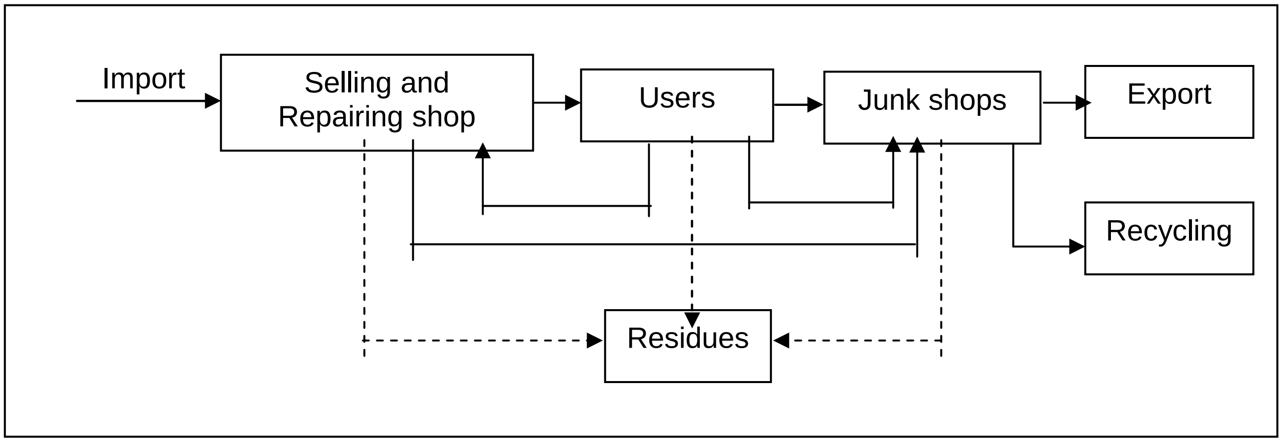


Figure 2.8: PC Tracer Tracking

Tracer tracking of MP is shown in figure 2.9. Tracer tracking of MP shows that shops in PPM generally sell both brand-new and second-hand items with additional functions of repairing and dismantling process. The broken parts during MP repair/ dismantling are mostly screen and IC. The broken parts of the mobile phones are sold to E-waste buyers (e.g. junkshop) or disposed at urban dumpsite through waste collection company, M/s CINTRI.

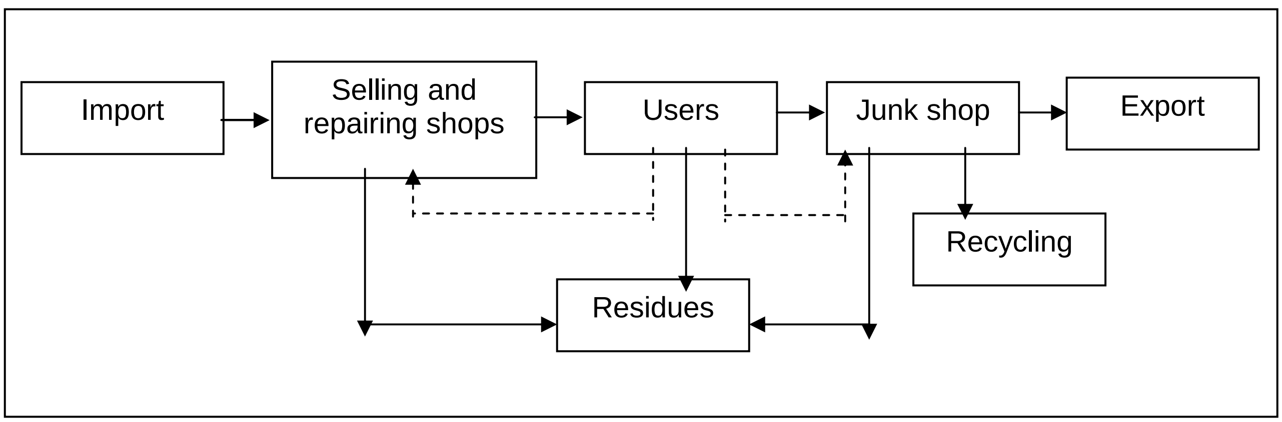


Figure 2.9: MP Tracer Tracking

Tracer tracking of refrigerators, air-conditioners and washing machines are shown in figure 2.10. Most of the shops in PPM are selling washing machines, air conditioners and refrigerators at one place. Some of them sell both brand-new and second-hand items together. Shop owners also buy used items and/or non-functioning items for repairing and selling. In the process of repairing, the mechanic checks the used condition of washing machines, airconditioners, and refrigerators. If some parts are found to be un-useable, they repair it and if it is found non repairable, they dispose it by selling it to waste buyers or dispose it into dustbins. At junkshops, the items, which cannot be repaired, are further dismantled to take out valuable items/ parts like plastic, iron, aluminum and printed circuit board, prior to disposal. All of these scrap items are finally sold abroad according to the international market demand.

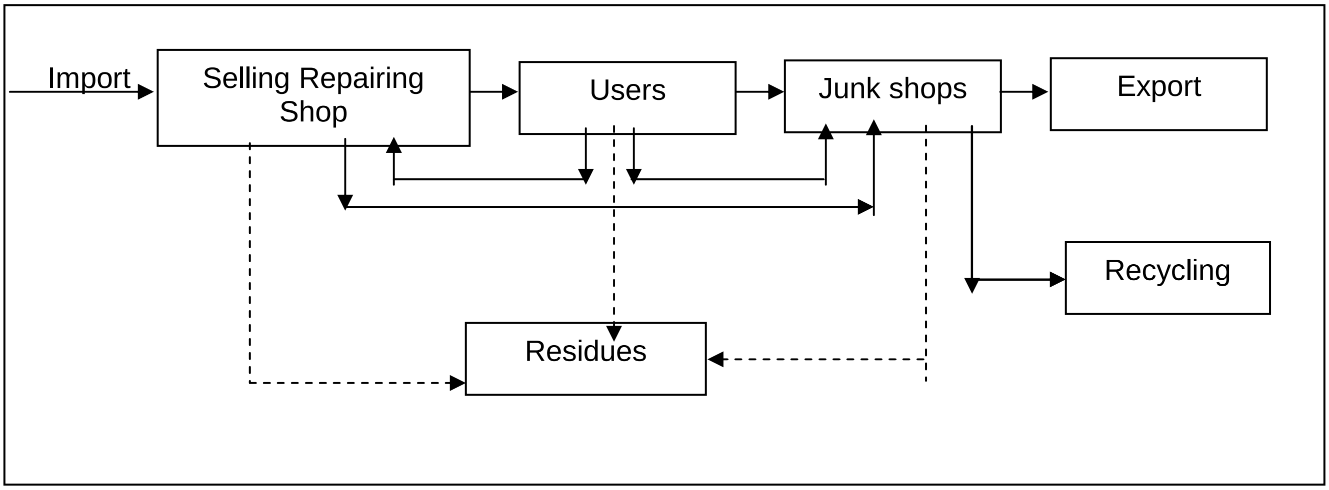


Figure 2.10: Washing machine, Air-con and Refrigerator Tracer Analysis

Tracer analysis indicates that there are two levels of E-waste treatment. At the first level, E-waste is repaired and resold or exported. At the second level, it is dismantled and its dismantled parts are reused or disposed.

2.3 Capacity of Existing E-waste Treatment and Disposal System

The capacity of existing repair/re-furbishers and dismantlers in PPM has been assessed both qualitatively and quantitatively. The qualitative description includes the observed practices of E-waste repair/ refurbishment and dismantling being carried out in PPM. The quantitative estimation has been carried out based on the existing and projected volume of reusable parts, recyclable materials and residues.

There is no company/enterprise in formal sector in PPM that collects/purchases E-waste from households and offices in Cambodia. Cambodia has no modern technology to carry out repair/ dismantling /refurbishing. Its sector expertise is very limited and, therefore, the repairing processes of few items like TV, air-con, mobile phone, refrigerator, computer, washing machine, and other EEE are carried out using simple techniques. Some of these techniques include:

- Using the testing facility to identify non-functioning/broken parts of EEE/UEEE or identify useable parts (spare-parts) for next usage.

- Withdrawal/removal of non-functioning/broken parts, cleaning and installing spare-parts, and connecting them afterward. In the case of withdrawal /removal of useable parts (from dismantled process), these parts are used with others to make them functional.

- Re-testing is done to emphasize whether repaired EEE/UEEE functions or not. If not, re-testing and repairing is done once more.

Dismantling is usually applied to non-functioning/broken UEEE which needs careful repair by using sophisticated techniques. Reusable parts recovered from dismantling process are kept separately (by types) for selling to repair shops on demand basis. Besides reusable parts, recyclable materials are bought by collectors. As described above, waste collectors sell these recyclable parts/wastes to scrap yard owners for export while the remaining E-waste fractions are disposed as municipal waste. The outcome of the survey carried out by the project team showed that most E-waste residues generated from repairing and/or dismantling shops are disposed in dustbin and later at urban dumpsite by domestic waste collection service. Some E-wastes generation from households are also disposed by this method. Some areas where waste-collection trucks are not available, such kind E-wastes are disposed improperly at sites close to/behind the repairing/dismantling shops, and are finally burnt.

An assessment of the E-waste fractions consisting of reusable parts, recyclable materials and residues generated in 2009 and 2019 has been carried out based on the inventory estimates, outcome of the field work carried out during 2009 and CEA estimates for the year 2006-07. The average estimates of reusable parts, recyclable materials and residues generated has been described in table 2.1.

Table 2.1: Percentage E-waste Fractions generated during repair/ refurbishment & Dismantling

E-Waste Item/ E-waste Fractions	Reusable (%)	Recyclable (%)	Residues (%)
TV	51.5	41.6	6.9
PC	62.5	35.3	2.2
MP	60.8	33.0	6.3
Refrigerator	54.9	38.8	6.3
Air Conditioner	55.3	42.5	2.3
Washing Machine	60	20	20

The existing capacity of repair/ refurbishers and dismantlers in PPM has been estimated based on E-waste processing and E-waste fractions generation. The generation of existing and projected E-waste fractions in metric tons has been estimated by considering that the existing repair/refurbishment and dismantling activities will continue in informal and semi formal sector in PPM without any intervention. These estimates as summarized in table 2.2 have been arrived at by using the data from table 2.1 considering E-waste item wise inventory in the year 2009 and 2019.

Table 2.2: Existing and Projected E-waste Fractions (metric tons)

E-waste Items/ E-waste Fractions	2009			2019		
	Reusable	**Recyclable**	**Residues**	**Reusable**	**Recyclable**	**Residues**
TV	980.54	792.05	131.37	5517.54	4456.88	739.24
PC	1706.69	964.62	59.39	2247.85	1270.48	78.23
MP	26.17	14.22	2.69	90.38	49.09	9.30
Refrigerator	548.70	387.79	62.97	1716.15	1212.87	196.94
Air Conditioner	490.83	377.56	19.99	1908.53	1468.10	77.72
Washing Machine	525.39	175.13	175.13	842.30	280.77	280.77

Expected capacity increase of E-waste repair/ refurbisher and dismantler in informal and semiformal sectors in PPM required to cater to projected E-waste inventory from 2009 to 2019 has been assessed and summarized in table 2.3 considering business as usual scenario without any intervention.

Table 2.3: Expected Capacity Increase of Informal and Semiformal Sector

E-waste Item	Capacity Augmentation (%)
TV	463
PC	32
MP	245
Refrigerator	213
Air Conditioner	289
Washing Machine	60

Table 2.3 indicates that existing E-waste repair/ refurbishment and dismantling capacity is inadequate for catering to expected E-waste inventory in 2019 in PPM. Further, it indicates that both informal and semiformal sector is expected to significantly increase in volume under business as usual scenario.

2.4 Toxic Footprint

The increase in capacity of semiformal and informal sectors will lead to increase in environmental impacts. It is expected that environmental impacts will also increase in the same proportion as that of the expected increase in volumes.

An assessment of the possible toxic footprint has been carried out both in terms of hazardous content and expected disposal locations in PPM. The impact of hazardous content has been estimated by mapping the possible hazardous content of some of the E-waste items versus their threshold value obtained through literature review and the way of disposal of the E-waste residues both during E-waste repair/ refurbishing and dismantling operations occurring at different locations in PPM. The findings of the assessment have been summarized in table 2.4 and table 2.5. These findings indicate that majority of E-waste fractions are being disposed as municipal waste either in the dustbins or in the open or inside the premises. Therefore, the location of this footprint can be correlated to the location of major hubs of formal and informal sectors on the major streets in PPM in areas described in table 2.6 and shown in figure 2.11. Chamkamorn and Toul Kok serve as two major hubs for TV and PCs repair/ refurbishment and dismantling. Chamkamorn, Toulkok and Meanchay also serve as major repairing/ refurbishing centre for washing machine. Therefore, these locations form majority of toxic footprint from E-waste in PPM.

Table 2.5: Site locations of toxic footprints in PPM

Major Location	Type of E-business
Chamkamorn	Dismantling of AC
	Dismantling of PC
	Dismantling of Mobile Phone
Meanchay	Dismantling of washing machine
Toul Kok	Dismantling of AC/refrigerator
	Dismantling of PC
	Dismantling of TV
	Dismantling of Mobile Phone

2.5 Conclusions

The increase in E-waste inventory is expected to trigger expansion of E-waste collection, transportation, treatment capacity both in formal and informal sector. It can be concluded that current E-waste collection, transportation, treatment and disposal in PPM is inadequate both in terms of capacity and environmentally sound management. The expansion of E-waste treatment is expected to significantly increase the E-waste toxic footprint within PPM. Since the existing toxic footprint covers areas, which are commercial along the main streets of PPM, its expansion is likely to further impact air, water and soil conditions in its area of influence. Therefore, there is a need for environmentally sound management of E-waste in order to reduce its volume as well as its toxic footprint.

Table 2.4: Way of residue disposal (repair process)

EEW by types	Toxic Content (% of total product/ absolute)	Threshold (% / absolute limit)	Way of disposal (in percent)	Miscellaneous
TV				
Glass			Disposal as Municipal waste (88.90%)	
			Give away (1.85%)	
			Other (9.25%)	Throw away , sharp objects at the fence- top, put at their own lands
Glass with lead (CRT)	Lead Oxide 6.61% Cadmium 0.03% Chromium 0 Antimony Trioxide 0.17%	5% 0.10% 0.10% 1.00%	Disposal as Municipal waste (94%)	
			Pay for disposal (1.50%)	Asking a motor- taxi/ tri-cycles' drivers to take those wastes to dispose at dumpsite with agreed-payment while waste collection service do not provide
			Give away (3%)	
			Other (1.50%)	Throw away, put at their own lands
Mixture of different types of materials	Phthalate Plasticizer in wires and other electrical items	0.5%	Disposal as Municipal waste (100%)	
PC				
Glass			Disposal as Municipal waste (60%)	
			Other (40%)	Throw away, dispose in slot, put at their own lands
Glass with lead (CRT)	Lead Oxide 5.26% Cadmium 0.02% Chromium 0 Antimony Trioxide 0.13%	5% 0.10% 0.10% 1.0%	Disposal as Municipal waste (100%)	
Rechargeable battery	Cadmium, Lead, Mercury, Nickel, Zinc, and Manganese		Disposal as Municipal waste (66.70%)	
			Other (33.30%)	Throw away, dispose in slot, put at their own lands

Mixture of different types of materials	Phthalate Plasticizer in wires and other electrical items Germanium 0.0016% Gallium 0.0013% Beryllium 0.0157% Mercury 0.0022%	0.5% 20% 20% 0.10% 0.25%	Disposal as Municipal waste (100%)	
MP				
Rechargeable battery	Nickel-metal hydride (Ni-MH), lithiumion (Li-Ion), nickel-cadmium (Ni-Cd), or lead acid. Ni-MH and Ni-Cd batteries contain nickel 10%, cobalt 4%, zinc, cadmium (25% of the weight of battery), and copper. Li-Ion batteries use lithium metallic oxide (4%) and carbon-based materials (4%).		Disposal as Municipal waste (88.70%)	
			Pay for disposal (6.45%)	Asking a motor- taxi/ tri-cycles' drivers to take those wastes to dispose at dumpsite with agreed-payment while waste collection service do not provide
			Other (4.85%)	Throw away, dispose in slot, put at their own lands
Mixture of different types of materials	Arsenic 0.062 mg/l Barium 2.33 mg/l Cadmium 0.004 mg/l Chromium 0.07 mg/l Lead 87.4 mg/l Mercury 0.006 mg/l Selenium 0.093 mg/l	Arsenic 5 mg/l Barium 100 mg/l Cadmium 1 mg/l Chromium 5 mg/l Lead 5 mg/l Mercury 0.2 mg/l Selenium 1.0 mg/l	Disposal as Municipal waste (100%)	
Air Conditioner & Refrigerator				
CFC	ODS in coolant 0.71% ODS in insulation foam 1.43%	0.10% 0.10%	Destruct on the premises (33.90%)	
			Do not collect (1.80%)	
Mixture of different types of materials	Phthalate & Plasticizer in rubber and plastic	0.50%	Other (64.30%)	Free discharging into the environment
Washing Machine				
Phthalate & Plasticizer	Rubber 0.28% Wires 0.09%	0.5% 0.5%	Disposal as Municipal waste	

Table 2.5: Way of residue disposal (dismantling process)

EEW by types	Toxic Content (% of total product/ absolute)	Threshold (% / absolute limit)	Way of disposal (in percent)	Miscellaneous
TV				
Glass			Disposal as Municipal waste (95.45%)	
			Pay for disposal (4.54%)	Asking a motor- taxi/ tri-cycles' drivers to take those wastes to dispose at dumpsite with agreed- payment while waste collection service do not provide
Glass with lead (CRT)	Lead Oxide 6.61% Cadmium 0.03% Chromium 0 Antimony Trioxide 0.17%	5% 0.10% 0.10% 1.00%	Disposal as Municipal waste (96.15%)	
			Pay for disposal (3.85%)	
Mixture of different types of materials	Phthalate Plasticizer in wires and other electrical items	0.5%	Disposal as Municipal waste (97.30%)	
			Give away (1.35%)	
			Other (1.35%)	Throw away, dispose in slot, put at their own lands
PC				
Glass			Disposal as Municipal waste (50%)	
			Other (50%)	Throw away, dispose in slot, put at their own lands
Glass with lead (CRT)	Lead Oxide 5.26% Cadmium 0.02% Chromium 0 Antimony Trioxide 0.13%	5% 0.10% 0.10% 1.0%	Disposal as Municipal waste (100%)	
Rechargeable battery	Cadmium, Lead, Mercury, Nickel, Zinc, and Manganese		Disposal as Municipal waste (80%)	
			Other (20%)	Throw away, dispose in slot, put at their own lands

Mixture of different types of materials	Phthalate Plasticizer in wires and other electrical items Germanium 0.0016% Gallium 0.0013% Beryllium 0.0157% Mercury 0.0022%	0.5% 20% 20% 0.10% 0.25%	Disposal as Municipal waste (100%)	
MP				
Rechargeable battery	Nickel-metal hydride (Ni-MH), lithiumion (Li-Ion), nickel-cadmium (Ni-Cd), or lead acid. Ni-MH and Ni-Cd batteries contain nickel 10%, cobalt 4%, zinc, cadmium (25% of the weight of battery), and copper. Li-Ion batteries use lithium metallic oxide (4%) and carbon-based materials (4%).		Disposal as Municipal waste (83.30%)	
			Pay for disposal (11.20%)	Asking a motor- taxi/ tri-cycles' drivers to take those wastes to dispose at dumpsite with agreed- payment while waste collection service do not provide
			Other (5.50%)	Throw away, dispose in slot, put at their own lands
Mixture of different types of materials	Arsenic 0.062 mg/l Barium 2.33 mg/l Cadmium 0.004 mg/l Chromium 0.07 mg/l Lead 87.4 mg/l Mercury 0.006 mg/l Selenium 0.093 mg/l	Arsenic 5 mg/l Barium 100 mg/l Cadmium 1 mg/l Chromium 5 mg/l Lead 5 mg/l Mercury 0.2 mg/l Selenium 1.0 mg/l	Disposal as Municipal waste (100%)	
Air Conditioner & Refrigerator				
CFC	ODS in coolant 0.71% ODS in insulation foam 1.43%	0.10% 0.10%	Destruct on the premises (29%)	
			Other (71%)	Free discharging into the environment
Mixture of different types of materials	Phthalate & Plasticizer in rubber and plastic	0.50%	Disposal as Municipal waste (87.80%)	
			Other (12.20%)	Throw away, dispose in slot, put at their own lands
Washing Machine				
Phthalate & Plasticizer	Rubber 0.28% Wires 0.09%	0.5% 0.5%	Disposal as Municipal waste	

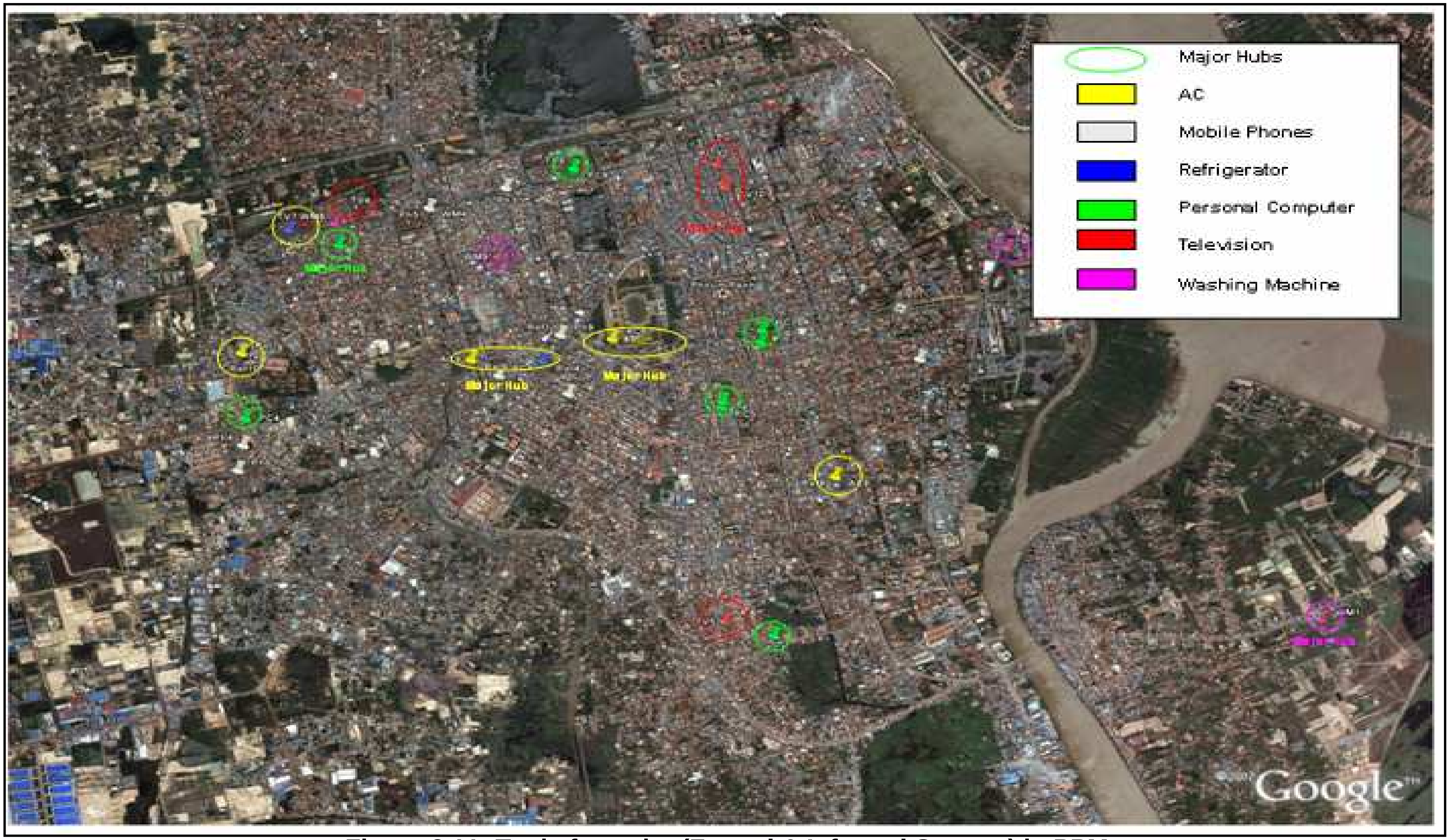


Figure 2.11: Toxic footprint (Formal & Informal Sectors) in PPM

CHAPTER 3: E-WASTE MANAGEMENT SYSTEM & TECHNOLOGY EVALUATION

3.0 Introduction

This chapter describes the E-waste management system and technology proposed for Phnom Penh. The entire treatment rationale for E-waste is driven by "Material Flow", which in turn is driven by consumer behavior related to disposal of E-waste. The following section describes rationale for E-waste treatment in terms of E-waste composition, emissions, recyclability and elements of E-waste management system. Further, description of collection methods, unit operations, input, output and emissions have been described for each level of treatment. Finally, this is compared with best available technology/ E-waste treatment technology currently used in the world and associated risks.

3.1 Consumer Behavior related to E-waste Management in Phnom Penh

Consumer behavior in Phnom Penh has been assessed based on current and projected E-waste inventory and field work carried out as part of inventory assessment. The following features highlight key findings of consumer behavior and its implications on proposed E-waste management system.

1. Consumer behavior is changing on account of improved living standards due to high GDP growth rate. This is leading to greater penetration of EEE items.

2. There are no EEE "take back" schemes, which are in place in Phnom Penh. Therefore, E-waste collection and transportation mechanism in PPM is diverse in nature.

3. Consumers prefer to import second hand branded items in comparison to cheaper new EEE due to affordability and belief in quality of branded item. This gets transformed into shorter lifecycle of second hand items in comparison to brand new EEE.

4. Wherever, municipal waste collection facilities are not available, consumers/ residents dispose their E-waste by transporting them to municipal dust bins or dumpsite or pay for taking away E-waste.

5. E-waste collected from repairing and dismantling hubs is sold to waste collectors and scavengers because they find value in the waste.

6. Consumers in high and medium income segments frequently change their EEE considering updated/ modern design. They pass on their used EEE to second hand shop.

7. Consumers don't consider environmental and health impacts while disposing E-waste. They look for best monetary value out of salvaged E-waste.

8. E-waste collector sell E-waste to scrap yard owners according to demand from overseas markets. Therefore, demand from overseas market drives the

E-waste collection and transportation system, which in turn drives the consumer behavior for E-waste disposal.

9. As per E-waste inventory estimates the contribution of E-waste from information and communication technology (ICT) sector increases from 87 percent to 88 percent and from 62 percent to 64 percent both in terms of number and weight given in table 3.1.

Table 3.1: Contribution of E-waste Inventory Estimates

Year	ICT (% no)	White Goods (% no)	ICT (% tons)	White Goods (% tons)
2009	87.39	12.61	62.87	37.13
2011	88.63	11.37	63.93	36.07
2013	89.95	10.05	66.57	33.43
2015	91.40	8.60	71.04	28.96
2017	92.27	7.73	74.04	25.96
2019	88.63	11.37	64.43	35.57

The major conclusions, which will drive the development (planning / design / implementation) of E-waste management system in PPM, are given below.

5. ICT will continue to drive the E-waste management system including E-waste recycling in the country.

6. E-waste collection and transportation mechanism in PPM is diverse in nature ranging from hand driven cart to light commercial vehicles.

7. Both the households and the commercial sector look for best monetary and exchange value of their old product. Therefore, any E-waste management system should factor in the salvage value of the waste product. The best monetary and exchange value of the old product can be determined by understanding the E-waste composition and its recyclability described below.

3.2 E-waste Composition and Recyclability

The composition of E-waste is specific for each appliance. In order to handle this complexity, the parts/materials found in E-waste have been divided into six categories.

- iron and steel, used for casings and frames;
- non-ferrous metals, especially copper used in cables, and aluminum;
- glass used for screens, windows;
- plastic used as casing, in cables and for circuit boards;
- others (rubber, wood, ceramic etc.).

Table 3.2 provides an overview of the composition of the four types of appliances selected for the present project. Table 3.3 and table 3.4 describe the recyclability of a PC and a TV.

Table 3.2: Average weight and composition of selected appliances

Appliances	Average weight (kg)	Iron (Fe) % weight	Non Fe-metal % weight	Glass % weight	Plastic % weight	Electronic components % weight	Others % weight
Refrigerators and freezers	48	64.4	6	1.4	13		15.1
Washing Machine	40	59.8	4.6	2.6	1.5		31.5
Personal computer	25	53.3	8.4	15	23.3	17.3	0.7
Air Conditioners	45	55	24		11	3	7
TV sets	35	5.3	5.4	62	22.9	0.9	3.5
Mobile Telephones	0.160	8	20	10.6	59.6		1.8

Table 3.3: Recyclability of a PC

Elements	Content (% of total weight)	Content (Kg)	Recycling efficiency (%)	Recoverable weight of element (kg)
Plastics	23	6.25	20%	1.25069408
Lead	6	1.71	5%	0.08566368
Aluminum	14	3.85	80%	3.08389248
Germanium	0.0016	0.00	0%	0
Gallium	0.0013	0.00	0%	0
Iron	20	5.57	80%	4.45453312
Tin	1	0.27	70%	0.19188512
Copper	7	1.88	90%	1.69614576
Barium	0.0315	0.01	0%	0
Nickel	0.8503	0.23	0%	0
Zinc	2	0.60	60%	0.35979072
Tanialum	0.0157	0.00	0%	0
Indium	0.0016	0.00	60%	0.00026112
Vanadium	0.0002	0.00	0%	0
Terbium	0	0.00	0%	0
Beryllium	0.0157	0.00	0%	0
Gold	0.0016	0.00	99%	0.000430848
Europium	0.0002	0.00	0%	0
Tritium	0.0157	0.00	0%	0
Ruthenium	0.0016	0.00	80%	0.00034816
Cobalt	0.0157	0.00	85%	0.00362984

Elements	Content (% of total weight)	Content (Kg)	Recycling efficiency (%)	Recoverable weight of element (kg)
Palladium	0.0003	0.00	95%	0.00007752
Manganese	0.0315	0.01	0%	0
Silver	0.0189	0.01	98%	0.005037984
Antinomy	0.0094	0.00	0%	0
Bismuth	0.0063	0.00	0%	0
Chromium	0.0063	0.00	0%	0
Cadmium	0.0094	0.00	0%	0
Selenium	0.0016	0.00	70%	0.00030464
Niobium	0.0002	0.00	0%	0
Yttrium	0.0002	0.00	0%	0
Rhodium	0	0.00	50%	0
Mercury	0.0022	0.00	0%	0
Arsenic	0.0013	0.00	0%	0
Silica	24.8803	6.77	0%	0
Total				

Table 3.4: Value of output evaluated after dismantling of single TV

Elements	%	ppm	Recoverable Weight of element (Kg)
Aluminium	1.2		0.4344
Copper	3.4		1.2308
Lead	0.2		0.0724
Zinc	0.3		0.1086
Nickel	0.038		0.013756
Iron	12		4.344
Plastic	26		9.412
Glass	53		19.186
Silver		20	0.000724
Gold		10	0.000362
Total			

The analysis of tables 3.2, 3.3 and 3.4 indicate that recyclability of E-waste is driven by electric component, copper and precious metal recovery. Therefore, E-waste collection, transportation and treatment are different from conventional solid waste collection, transportation and treatment system due to its composition and recyclability.

3.3 Components of E-waste Management System

There are three major components of E-waste management systems. These are:

4. E-waste collection, sorting and transportation system

5. E-waste treatment system

6. E-waste disposal system.

All the three components for PPM have been described below.

3.3.1 E-waste Collection Infrastructure in PPM

At the moment, there is no extended producer responsibility (EPR) regulation in Cambodia, which will ensure product take back by the producer. Hence, the collection and transportation channel driven through producers does not appear to be viable in the absence of EPR regulation.

As per the consumer behavior, E-waste collection channels in PPM is through municipal collection sites or drop off at dustbins. The only viable mechanism as per consumer behavior under the existing regulatory mechanism appears to be to capture E-waste at the point of generation. Since the majority of E-waste is generated in the commercial sector e.g. corporates/ business/ BPOs etc., and both the households and commercial sector prefers the best value of their waste, it is recommended that the E-waste collection facilities should be at two places to start with.

1. Retailers
2. Commercial sector e.g. corporates/ business/ BPOs etc.

Salient features of this collection mechanism are given below.

7. There is a need for separate collection facilities for ICT and white goods.

8. Location of collection facilities need to be near E-waste collection hubs. This need is projected on account of following reasons.

    - Ensure minimal movement of products
    - Efficient collection mechanism
    - Minimize manual handling
    - Avoid unsorted municipal waste

9. Each of the retailer's/ market association/ group can identify a place/ area as E-waste collection point. This place can serve as a place where retailers/ consumers can get value of their old product. The authorized E-waste recycler can collect from retailer's collection facilities and transport E-waste to their recycling facility.

10. E-waste from households can be routed through already existing municipal waste collection mechanism. Each of the localities can identify a place/ area as E-waste collection point in their premises. This place can serve as a place where retailers/

consumers can get value of their old product. There is a need to initiate public awareness campaign to collect E-waste at authorized collection facility and only give to authorized recycler for treatment and disposal.

11. There is a need for authorizing E-waste recyclers/ dismantlers in PPM. This will assist to divert E-waste from commercial sector e.g. corporates/ business/ BPOs using existing mechanism to authorized recycler.

12. Books of E-waste account should be maintained at all the three types of collection facilities and match with authorized recycler's books. In case of mismatch, penalty provisions can be invoked on either party using appropriate legal instrument. It is recommended that the value of the penalty should be the difference between the value offered by the informal sector and the value offered by the authorized recycler. This mechanism will discourage leakage of E-waste into informal sector.

13. The research literature cites that the efficiency of E-waste collection system ranges from approximately 60% to even less than 30% even in the most efficient system functioning under EPR in EU. This indicates that leakages exist even in the most efficient system. In this context it should be noted that any penal provision highlighted in item 4 above should be invoked only as a deterrent to prevent leakage.

The fundamental basis to design conventional E-waste collection and transportation infrastructure requires assessment of the lowest and highest volume of E-waste to be collected during the planned period. This is carried out based on E-waste capture rate. E-waste capture rate can be assessed by implementing a pilot project for E-waste collection and transportation, which has been conceptualized in third E-waste report.

3.3.2 Proposed Treatment Technology

The proposed technology has been described based on first and second level of treatment given below. These levels have been proposed considering two levels of treatment occurring in PPM. Out of the two levels, the major part of treatment is occurring at first level only, while the second level is occurring to a minimal extent. However, E-waste inventory estimate encourages recommending second level treatment after 2019. Some elements of third level treatment already occurring in Cambodia are also described to assess the viability of third level treatment.

First Level E-waste Treatment

Input: E-waste items like TV, refrigerator/ washing machine and Personal Computers (PC)

Unit Operations: Following three unit operations occur at first level of treatment

1. Removal of all liquids and Gases
2. Dismantling (manual)
3. Segregation

All the three unit operations are dry processes, which do not require use of water. The first step is to decontaminate E-waste and render it non-hazardous. This involves removal of all types of liquids and gases (if any) under negative pressure, and their recovery and storage. Further, all other hazardous E-waste residues are dismantled and segregated. These segregated hazardous E-waste fractions are then sent for third level treatment.

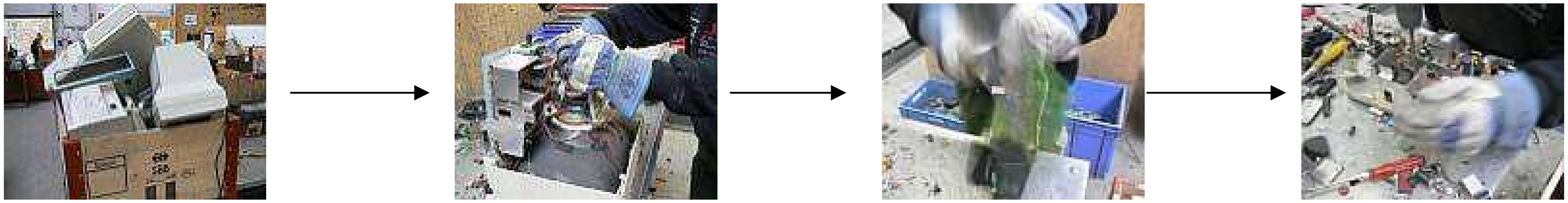
Output:

1. Segregated hazardous wastes like CFC, Mercury (Hg) Switches, CRT, batteries and capacitors
2. Decontaminated E-waste consisting of segregated non-hazardous E-waste like plastic, circuit board and cables

Various steps in the manual dismantling process at a E-waste dismantling facility are depicted in figure 3.1.

<u>Second Level E-waste Treatment</u>

The proposed second WEEE/E-waste treatment technology has been described in terms of process overview, unit operations and equipments to be used. The conceptual process flow diagram to be used is given in figure 3.2 and figure 3.3.



Step 1 **Step 2** **Step 3** **Step 4**

Figure 3.1: Manual Decontamination/ Dismantling Process

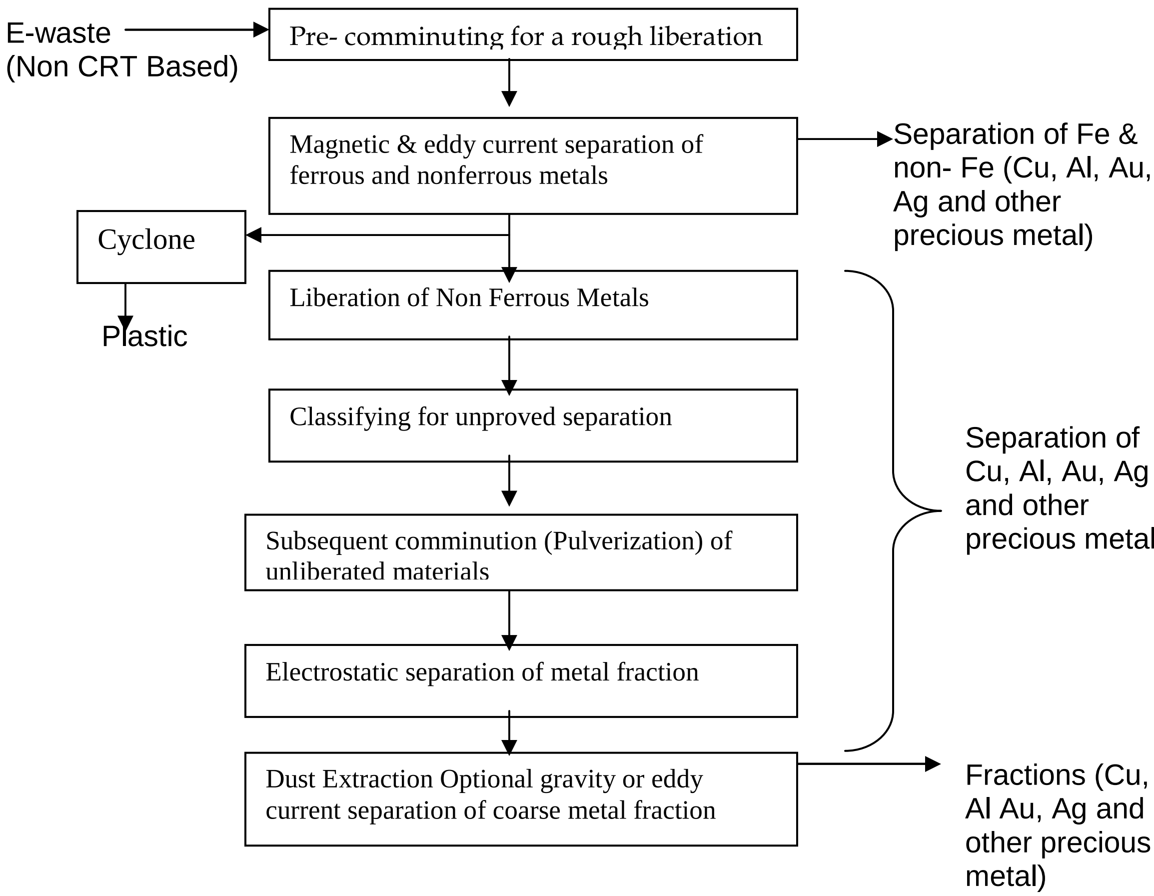
Step 1: Collected E-waste entering the disassembly line in the dismantling facility

Step 2: Manual dismantling of monitor (removal of plastic back cover and disposal into a plastic bin)

Step 3: Decontamination by manually removing the hazardous items and their collection in bins

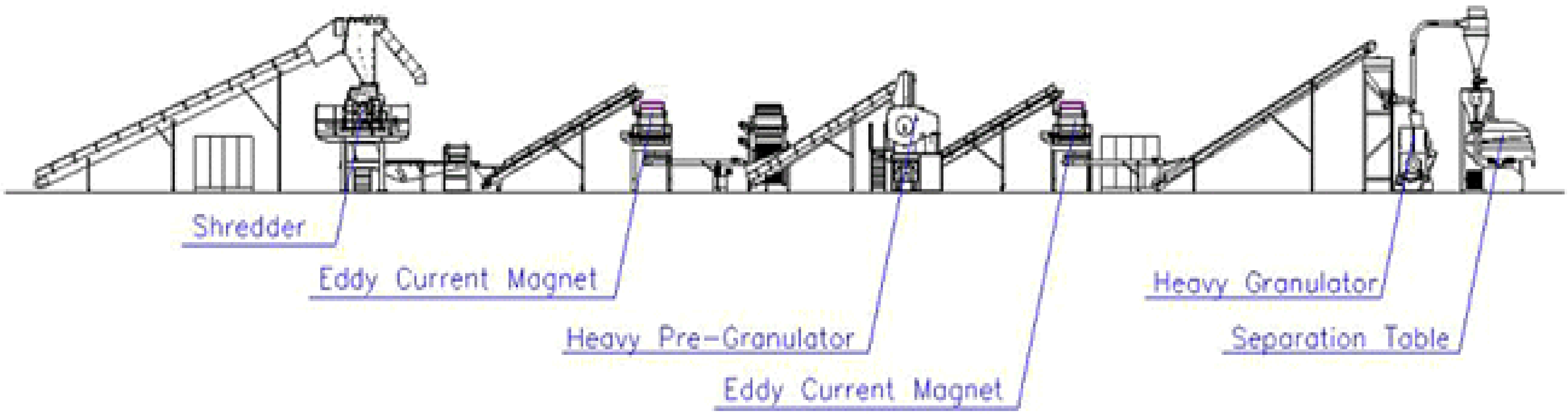
Step 4: Complete dismantling and segregation of E-waste fractions

Source: E-waste Management Manual, Volume II, UNEP DTIE/ITC



Source: E-waste Management Manual, Volume II, UNEP DTIE/ITC

Figure 3.2: Process flow of Non CRT based E-waste treatment



Source: E-waste Management Manual, Volume II, UNEP DTIE/ITC

Figure 3.3: Unit Operations

S. No.	Unit Operations	Pictures
1.	**Shredder** For size reduction into a size enabling the majority of the ferrous material to be separated from the non-ferrous/insulation and plastic fraction	
2.	**Eddy Current Separator 1** For separation of the heavy mixed metal fraction.	
3.	**Heavy Pre-Granulator** For size reduction of the material prior to separation in the Eddy Current Separator 2.	

S. No.	Unit Operations	Pictures
4.	**Eddy Current Separator 2** For separation of the light mixed metal fraction	
5.	**Heavy Granulator** For final size reduction of the material	
6.	**Separation Table** For final separation of the remaining fraction into a plastic (organic) fraction and a mixed metal fraction.	

Source: E-waste Management Manual, Volume II, UNEP DTIE/ITC

The salient features of Non CRT E-waste treatment technology and process are given below and shown in figure 3.3.

1. The process will use ICT and brown goods equipment like PCs, cellphones, televisions and other electronic items and will not use white goods like refrigerators, washing machine or air conditioners.

2. The process is focused on removal of three basic components.

    I. Plastic
    II. CRT/ Glass
    III. Metals/ Non metals

3. There will be different lines for E-waste and CRT treatment.

4. The proposed technology for sorting, treatment, including recycling and disposal of E-waste is fully based on dry process using mechanical operations.

5. The process uses a combination of three unit operations (figure 3.3) for Non-CRT based E-waste treatment. These operations include

   I. Pre-comminuting/ comminuting
   II. Magnetic/ electrostatic separation
   III. Eddy current separation

The pre-comminuting stage includes separation of Plastic, CRT and remaining non CRT based E-waste. Equipments like hammer mill and shear shredder will be used at comminuting stage to cut and pulverize E-waste and prepare it as a feedstock to magnetic and eddy current separation. A heavy-duty hammer mill grinds the material to achieve separation of inert materials and metals. After separation of metals from inert material, metal fraction consisting of Ferrous and Non-Ferrous metals are subjected to magnetic current separation. After separation of Ferrous containing fraction, Non-ferrous fraction is classified into different non-metal fractions, electrostatic separation and pulverization. The ground material is then screened and de dusted subsequently followed by separation of valuable metal fraction using electrostatic, gravimetric separation and eddy current separation technologies to recover fractions of Copper (Cu), Aluminum (Al), residual fractions containing Gold (Au), Silver (Au) and other precious metals. This results in recovery of clean metallic concentrates, which are sold for further refining to smelters.

6. Process water, oil or any liquid additive will not be used in both non-CRT and CRT based E-waste treatment.

7. No incineration will be used in the process for both CRT and Non CRT based E-waste treatment.

The salient features of CRT based E-waste treatment technology and process is given below.

1. CRT is dismantled manually by removing metal casing around it.

2. The dismantled CRT enters the chamber through a conveyor.

3. CRT is held firmly in the chamber using a vacuum pad.

4. A NiChrome wire or ribbon is wrapped round a CRT and electrically heated for at least 30 seconds to causes a thermal differential across the thickness of the glass. The area is then cooled (e.g. with a water-soaked sponge) to create thermal stress which results in a crack. When this is lightly tapped, the screen separates from the funnel section.

5. The cut CRT enters the brush cabinet, where the funnel glass is mechanically cleaned by brushes.

6. The coating is sucked through vacuum and stored separately for disposal.

7. Two types of glass ex. Screen glass and funnel glass are separated and sorted out automatically.

8. The CRT can handle partially broken funnel ensuring that the operator can process just about anything that comes through the door.

9. The system utilizes the latest technology in recycling and utilises advanced PLC hardware and software to maximise throughput with the minimum of downtime.

<u>Third Level E-waste Treatment</u>

The input, output and unit operations at 3rd level treatment are described in table 3.5. The table also describes its status in PPM/ Cambodia.

Table 3.5: Input/ Output and unit operations for 3rd level treatment of E-waste

Input/ WEEE Residues	Unit Operation/ Disposal/ Recycling Technique	Output	Technology status in Cambodia	Remarks
Sorted Plastic	Recycling	Plastic Product	√	Limited recycling because of different types of plastic used in electrical and electronic products.
Plastic Mixture	Energy Recovery/ Incineration	Energy Recovery	X	
Plastic Mixture with FR	Incineration	Energy Recovery	X	
CRT	Breaking/ Recycling	Glass Cullet	X	
Lead Smelting	Secondary Lead Smelter	Lead	X	
Ferrous metal scrap	Secondary steel/ iron recycling	Iron	X	
Non Ferrous metal Scrap	Secondary copper and aluminum smelting	Copper/ Aluminum	X	
Precious Metals	Au/ Ag separation	Gold/ Silver	Limited Technology	E-waste stream containing precious metals are expected to join other streams containing gold for its extraction beyond municipal limits of PPM.
Batteries (Lead Acid/ NiMHand LiION)	Lead recovery and smelting Remelting and separation	Lead	X	
CFC	Recovery/ Reuse and Incineration	CFC/ Energy recovery	X	
Oil	Recovery/ Reuse and Incineration	Oil recovery/ energy	X	
Capacitors	Incineration	Energy recovery	X	
Mercury	Separation and Distillation	Mercury	X	

Note: √ - yes and X -No

The conclusions drawn from table 3.5 are given below.

1. Table 3.5 identifies the gaps in existing 3rd level treatment in PPM, which are mainly related to technologies and its application to E-waste residues.

2. E-waste fractions for base metals like Cu, Fe, Al are already being exported from PPM for metal smelting.

3. Recyclable plastic fractions are being recycled in PPM to a limited extent.

4. Treatment technology for precious metal recovery, which drives the E-waste recycling, is expected to exist in a limited manner in Cambodia. However, its scale is expected to be low.

It may be noted that even in the best of E-waste collection scenario with 90% coll-ection efficiency, Cambodia will not be able to generate adequate quantity of E-waste till 2030 to sustain an integrated metal recovery facility, which will require about 300,000 tons per annum of input raw material. In such scenario, hydrometallurgical/ electrolysis appears to be the viable third level option for precious metal recovery in Cambodia beyond 2030.

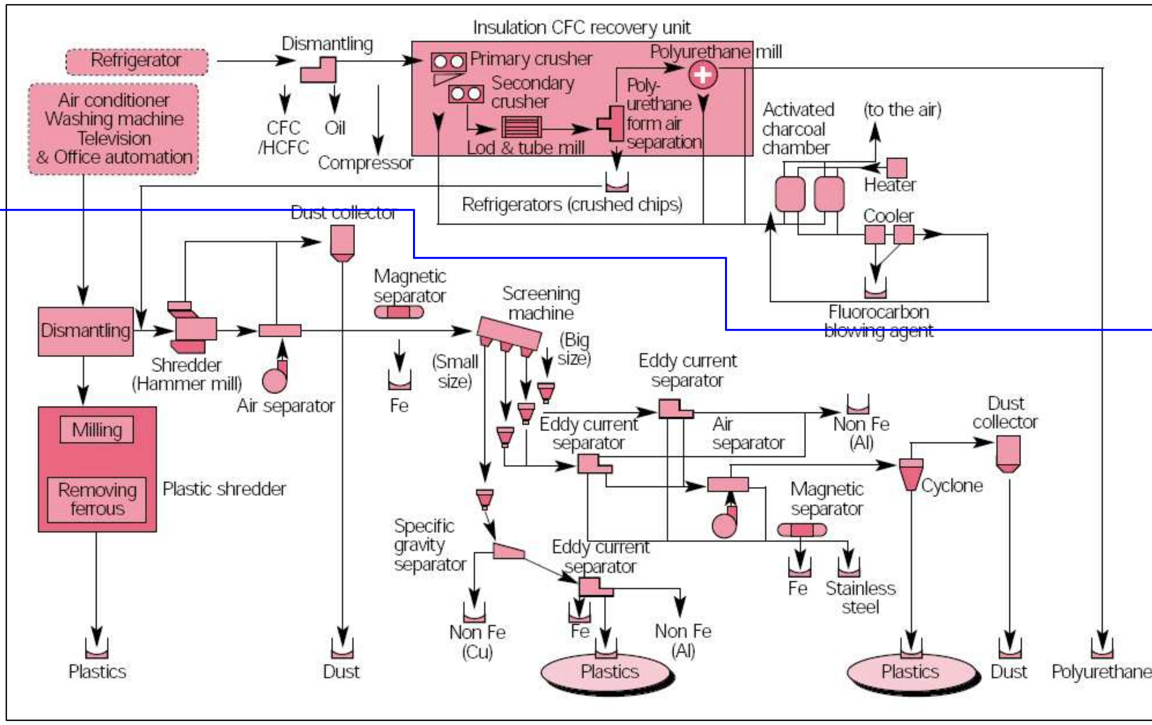
3.4 Best Available Technology

Best available technologies (BAT) have been described by highlighting the existing E-waste treatment process in Switzerland, Japan and Europe. The process flow diagram of the E-waste treatment technology used by a Japanese E-waste treatment plant is given in figure 3.4, while salient features of technology used by E-waste treatment plant in Switzerland is given below.

1. The process combines manual and machine procedures.

2. The E-waste is at first cut, crushed and finally sorted into discreet product streams. These streams consist of scrap iron, non-ferrous metal fractions, PC and TV casing components (consisting of wood and plastics), granulates of mixed plastics, cathode ray tubes, printed circuit boards, copper cables, components containing organic pollutants such as batteries and condensers, and fine particulates (dust).

3. The machine processes include breaking of / crushing the equipment in a hammer mill. Further, the crushed material is separated according to density, granulate size and magnetic properties, and multiple pulverizations by milling using magnetic and eddy current separation systems.



Source: E-waste Management Manual, Volume II, UNEP DTIE/ITC

Figure 3.4: Flow sheet of a Japanese E-waste recycling plant

The analysis of the best available technology shows that the process uses a combination of magnetic and electric conductivity based separation. The research publications sites that magnetic separators, in particular, low-intensity drum separators are widely used for the recovery of ferromagnetic metals from non-ferrous metals and other non-magnetic wastes. Over the past decade, there have been many advances in the design and operation of high-intensity magnetic separators, mainly as a result of the introduction of rare earth alloy permanent magnets capable of providing very high field strengths and gradients. Literature sites that magnetic separation leads to recovery of about 80% of ferrous metal from E-waste.

Electric conductivity-based separation separates materials of different electric conductivity (or resistivity) mainly different fractions of non-ferrous metals from E-waste. Eddy current separation technique has been used based on electrical conductivity for non ferrous metal separation from E-waste. Its operability is based on the use of rare earth permanent magnets. When a conductive particle is exposed to an alternating magnetic field, eddy currents will be induced in that object, generating a magnetic field to oppose the magnetic field. The interactions between the magnetic field and the induced eddy currents lead to the appearance of electrodynamic actions upon conductive non-ferrous particles and are responsible for the separation process. Currently, eddy current separators are almost exclusively used for waste reclamation where they are particularly suited to handling the relatively coarse sized feeds of size > 5 mm. However, recent developments show that eddy current separation process has been designed to separate small particles. It has been reported that eddy current separation leads to more than 75% recovery of non-ferrous metals from the E-waste. However, most of the recycling plants operating with BAT claim to recover 95% of the precious metal content from E-waste.

Salient Features of CRT splitting technology

1. CRT is manually removed from plastic/ wooden casing.
2. Picture tube is split and the funnel section is then lifted off the screen section and the internal metal mask can be lifted to facilitate internal phosphor coating.
3. Internal phosphor coating is removed by using an abrasive wire brush and a strong vacuum system to clean the inside and recover the coating. The extracted air is cleaned through an air filter system to collect the phosphor dust.

Different types of splitting technology used are given below.

- NiChrome hot wire cutting

  A NiChrome wire or ribbon is wrapped round a CRT and electrically heated for onds at least 30 seconds to causes a thermal differential across the thickness of the glass. The area is then cooled (e.g. with a water-soaked sponge) to create thermal stress which results in a crack. When this is lightly tapped, the screen separates from the funnel section.

- Thermal shock

  The CRT tube is subjected to localized heat followed by cold air. This creates stress at the frit line where the leaded funnel glass is joined to the unleaded panel glass and the tube comes apart.

- Laser cutting

  A laser beam is focused inside and this heats up the glass. It is immediately followed by a cold water spray that cools the surface of the glass and causes it to crack along the cut line.

- Diamond wire method

  In this method, a wire with a very small diameter, which is embedded with industrial diamonds is used to cut the glass as the CRT is passed through the cutting plane.

- Diamond saw separation

  Diamond saw separation uses either wet or dry process. Wet saw separation involves rotating the CRT in an enclosure while one or more saw blades cut through the CRT around its entire circumference. Coolant is sprayed on to the surface of the saw blades as they cut. This is to control temperature and prevent warping.

- Waterjet separation

  This technology uses a high-pressure spray of water containing abrasive, directed at the surface to be cut. The water is focused through a single or double nozzle-spraying configuration set at a specific distance.

3.5 Comparison of BAT with proposed technology and technology risks

The comparison of BAT with proposed technology shows that similar technology consisting of milling, magnetic and eddy current separation will be used. However, hydrometallurgical process may be be used for precious metal recovery after 2030 due to constraint of availability of raw material. The risks associated with technology have been described in terms of following factors.

1. Type of raw material/ input to E-waste recycling system
2. Scale of operation
3. Expected yield/ output
4. Experience of technology supplier
5. Environmental Issues

Risk profiling giving the intensities of these factors in the context of technology and country has been highlighted in the following risk matrix.

Technology Risk Matrix

Factors/ Intensity	High	Medium	Low
Type of raw material/ input to E-waste recycling system	√		
Scale of operation	√		
Expected yield/ output		√	
Environmental Issues			√

The intensities have been fixed as per following analysis.

1. The efficiency of recycling system in terms of output is dependent on quantity and quality of Input raw material/ E-waste. E-waste generational potential has already been assessed in inventory report. However, availability or quantity of raw material for recycling is dependent on efficiency of E-waste collection system. The quality of raw material is dependent on the type and obsolescence rate of the E-waste item. The expected obsolescence rate of PCs, TVs and refrigerators, which will form the bulk of input raw material has been assessed to be between 2 to 15 years. The operating facilities using BAT are recycling E-waste having similar obsolescence rates. But the real challenge is the arrival of intact E-waste (with all the items in place) at the recycling facility. Further, chances of leakages to informal sector are very high. Therefore the risk associated with this factor has been identified as high.

2. One of the risks associated with technology is the scale of operations, which has been estimated to be of medium level. In general all the technology suppliers supply non-ferrous metal separators, which are equipped with conditions as given below:

   - Infinitely variable adjustment of all function parameters
   - Stable steel framework for the accommodation of all separator components
   - Separate electronics cabinet with monitoring of all important parameters
   - Access to the magnet wheel adjustment via large doors
   - Large material function funnel for the filling of the vibration feeder

- Variable partition plate for the allocation of the non-metallic parts and the non-ferrous metal
- Discharge of the ferrous fraction via chute
- Cover of the separation area with large hood

The scale of operations of third level treatment/ hydrometallurgical operations is dependent on the availability of E-waste fractions consisting of precious metals e.g. printed circuit board.

3. The efficacy/ profitability of the recycling system are dependent on the expected yields/ output of the recycling system. The expected yields/ output from the recycling system is dependent on the optimization of separation parameters. These parameters are given below.

    - Particle size
    - Particle shape
    - Feeding rate/ RPM
    - Optimum operations

Figure 3.5 shows the non- ferrous metal distribution (which forms the backbone of financial viability of recycling system) as a function of size range for PC scrap. It can be seen that aluminum is mainly distributed in the coarse fractions (+6.7 mm), but other metals are mainly distributed in the fine fractions (−5 mm).

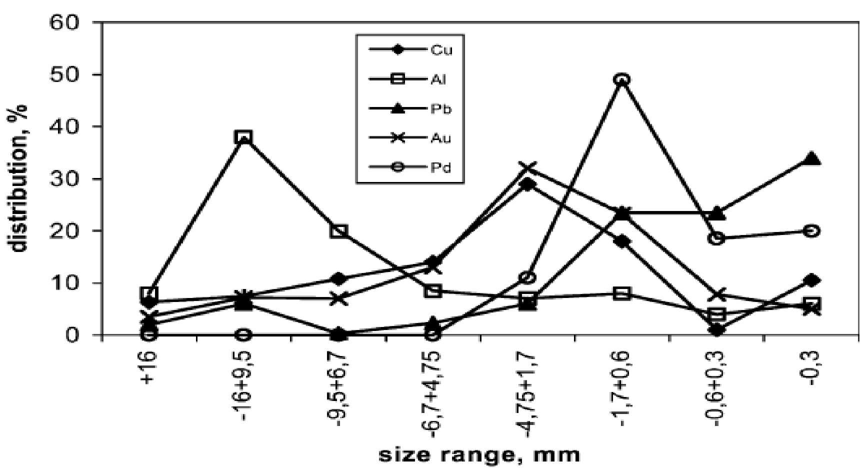


Figure 3.5: Non- ferrous metal distribution Vs. size range for PC scrap

Size properties are essential for choosing an effective separation technique.

Optimization of operations from technology perspective is dependent on a number of factors in Cambodian context. These are dependent on the following sub-factors.

- Climatic conditions for operations (rain, dust and temperature)
- Maintenance period and expected outages
- Availability of spare parts at recycling facility
- Fluctuation of power supply

- Training and capacity building of operating staff

The overall risks associated with these sub-factors have been identified to be of medium intensities since such facilities are operating in developing countries.

4. Environmental risks associated with this technology are expected to be low as it is a process operating under controlled conditions. Occasionally dust emissions are expected at localized places in the process, which can be easily mitigated.

Technology risks matrix highlight the availability and quality of raw material as risk of high intensity, while scale of operation and expected yields and output as risk of medium intensity.

3.6 Conclusions

E-waste collection and transportation system forms the backbone of any treatment and disposal system. In the existing E-waste management system, the link after generation stage is very crucial since "leakage of E-waste" into informal sector/ exports starts from here. E-waste management will be driven by its composition, recyclability and its collection efficiency in PPM. Two types of E-waste collection mechanism at household, and commercial/ corporate levels have been proposed considering all the consumers prefer to get the best value of their old products. Collection mechanism of recyclers will drive the E-waste collection and transportation system to minimize its leakage. It is recommended to use 1st and 2nd level of treatment technology for E-waste treatment in PPM in a phased manner. The major risks anticipated is the availability and quality of raw material, scale of operation and expected yield on account of efficiency of E-waste collection system. The detailed specifications of the E-waste management system are described in chapter 4.

CHAPTER 4: E-WASTE MANAGEMENT SYSTEM SPECIFICATIONS

4.0 Introduction

This chapter describes the E-waste management system specifications of the technology proposed and its financial viability. In this chapter, at first, specifications of E-waste collection and transportation system has been described followed by specification of 1st and 2nd level of E-waste treatment. These specifications are based on the technical specifications, which are used globally and the cost estimates from international plant and equipment suppliers.

4.1 Tentative Specifications for E-waste collection system

The volume of E-waste item to be collected and transported till 2020 based on E-waste inventory estimates in Phnom Penh is given in table 4.1. This is based on 50% availability of E-waste for recycling.

Table 4.1: Volume and start date for E-waste collection and transportation

E-waste Item	Minimum Volume (m^3)	Maximum Volume (m^3)
Television	4490	32923
Personal Computer	5140	6925
Mobile phone	9	46
Refrigerator	2918	9573
Air Conditioner	1458	5976
Washing Machine	1557	2618

Depending upon the type of E-waste, different types of bins/ cages will be used as shown in figure 4.1. The collected E-waste in container will be lifted manually, through fork lifts, placed into small trucks/ container carriers and transported from the collection facility to E-waste treatment facility.

Figure 4.1: E-waste Container/ Bins/ Carriers

As per the international best practices, the type and specification of collection bins/ cages/ containers to be used for collection of each E-waste item are given in table 4.2.

Table 4.2: Type and specification of collection bins/ cages/ containers

S. No.	WEEE/E-waste item	Bin/ Cage/ Container	Volume (m^3)	Picture
1.	Television	Wire Mesh Stillage (stackable)	2	
2.	Personal Computer, Laptop			
3.	Washing Machine	Container	33	
4.	Refrigerator			

S. No.	WEEE/E-waste item	Bin/ Cage/ Container	Volume (m^3)	Picture
5.	Air Conditioner			
6.	Mobile Phone	Plastic Gaylord container with lid (stackable)	0.624	

The number of collection bins/cages/container required is dependent on following criteria.

1. Volume of each collection bin/ cage/ container
2. Collection frequency
3. E-waste inventory of each item generated in a particular year
4. Layout and land use of serviced area
5. Inventory maintained at recycling facility

E-waste collection frequency is dependent on E-waste inventory and inventory maintained at recycling facility. The forklifts and trucks to lift containers are required for safe transport of E-waste from collection locations to recycling facility. As discussed in chapter 3, the responsibility of E-waste collection will be that of the either recycler or collection agency. Further, the collection centers at commercial/ corporate/ business centers can use the above specifications of the bins to collect and store E-waste. These collection facilities are recommended to meet the minimum specifications as summarized in section 4.3. As the volume of the E-waste starts increasing, collection facilities will be required at retailer and household level. The design criteria will be dependent on the area requirement in order to capture E-waste from a respective catchment. Again inventory from the catchment will determine the bin requirement and the area required for storing bins and collection frequency of the bins will determine the basis for area of collection facility.

4.2 Tentative Specifications for E-waste Treatment System

E-waste treatment facility will consist of 1st and 2nd level E-waste treatment. After 1st and 2nd level E-waste treatment, E-waste fractions will be sold/ exported to 3rd level recyclers for precious metals recovery. The installed capacity of the 1st and 2nd level plant has been conceptualized to be about 9 tons per day during 2009 to 32 tons per day during 2019 considering 50 % collection efficiency. This is based on 220 operating days with one general shift of 8 hours a day as shown in table 4.3.

Table 4.3: Inventory of ICT items in PPM in tons

Year	TV	PC	MP	Total	Tons/ day
2008	1461	2670	30	**4171**	**9**
2009	1904	2731	43	**4678**	**10**
2010	2420	2796	53	**5269**	**12**
2011	3009	2762	61	**5833**	**13**
2012	3672	3015	66	**6753**	**15**
2013	3826	3075	76	**6977**	**15**
2014	5050	3138	87	**8275**	**18**
2015	6274	3202	100	**9577**	**21**
2016	7542	3267	116	**10924**	**24**
2017	8819	3397	124	**12340**	**28**
2018	9718	3498	136	**13352**	**30**
2019	10714	3597	149	**14459**	**32**

The tentative layout of the recycling facility is shown in figure 4.2. The tentative total area requirement is about 4 acres or about 15,600 sq meters as per international best practices and design criteria of plant and equipment supplier. Out of this total area, processing area is about 25%, area for administration 5%, area for storing raw material to be about 30% and for finished product to be about 15% and open area is about 25 %. Therefore, the break up of total area requirement is given below.

1. Total Land Requirement – 15600 m^2
2. Processing Area - 4000 m^2 with 3000 m^2 for 1st and 2nd level
3. Raw material inventory area – 4500 m^2
4. Product inventory – 2750 m^2
5. Administration area – 780 m^2

The height of the processing, storage and administrative area is limited up to 10 meters.

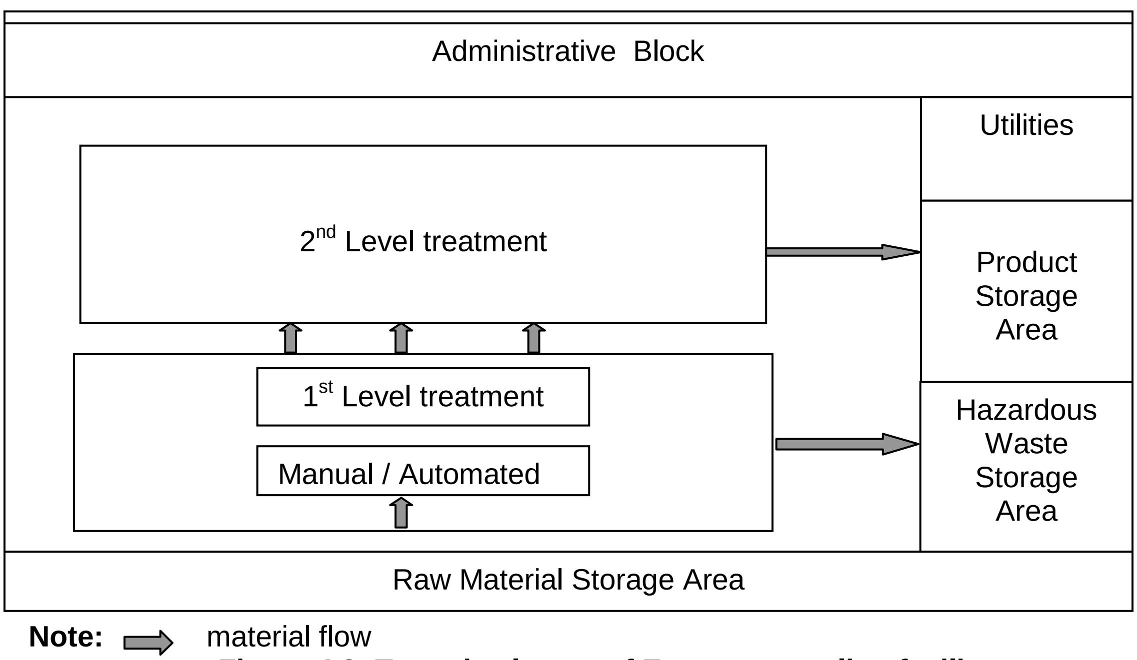


Figure 4.2: Tentative layout of E-waste recycling facility

First level treatment could be either manual or semi-automatic using conveyor system. Second level treatment will follow the same scheme as shown in chapter 3. The specification of shredder in the 1st and 2nd level treatment determines the equipment specifications. Tentative shredder specifications are given below.

5. Input – 3 to 4 tons per hour
6. size of output < 4 - 5 mm
7. Driven by motor in the range of 300 to 400 kw
8. Hopper of around 1.5 m by 1 m

The entire system can be automated using conveyor system of about 0.75 meter width. Depending on the collection efficiency and availability of the input raw material, the facility can start with one shredder of half the capacity followed by the second.

Manual E-waste dismantling/ treatment plant

The specifications of 1t/hr manual E-waste dismantling/ treatment plant from an Asian supplier is given in table 4.3.

Table 4.3: Specification of manual E-waste dismantling plant

Name of Equipment	**Specifications**	**Tentative Cost (US$) 2009 base price**
Pre-Breaker Crusher	Input: Small House hold appliance Output: 6 x 4 cm.	127,000
Hammer Mill	Input: 6 x 4 cm. Output: 3-4 mm	127,000
Post hammer mill E-waste complete assembly line (magnetic separator/ eddy current separator/ cyclones)	Input: 3-4 mm Output: Depending on screen fitted	5,40,000

These prices do not include the custom duty.

Semi-Automatic E-waste dismantling/ treatment plant

The specifications of 3-4 t/hr semi automatic plant from a European supplier are given in table 4.4.

Table 4.4: Specifications of semi-automatic E-waste dismantling/ treatment plant

Name of Equipment		Specifications	Tentative Cast
Whole plant (compact turnkey solution)	Heavy duty chain mill	**Input:** Non disassembled electronic and electrical waste like small household appliances photo copiers, computers (without CRT) **Output:** Highly concentrated metal fractions and non metal fractions. **Metal:** 2mm to 12 cm **Plastic:** 1-2 mm	US$ 1.9 million
	Magnetic Separator		
	Eddy current separator		
	Cyclones		
	Gravity / Eddy current separator		

These prices do not include the custom duty.

Automatic E-waste dismantling/ treatment plant

The specifications of 3 t/hr automatic E-waste automatic plant from Europe are given in table 4.5.

Table 4.5: Specifications of automatic E-waste dismantling/ treatment plant

Item No.	Quantity (no.)	Designation	Kw
1.	1	Inlet conveyor	4
2.	1	Shredder S1000	252
3.	1	Vibratory Conveyor	3.15
4.	1	Electro Magnet	4
5.	1	Outlet Conveyor	1
6.	1	Inlet Conveyor including drum magnet	2.2
7.	1	Eddy current magnet	7.10
8.	1	Conveyor	2.2
9.	1	Tumble Back Feeder	4.0
10.	1	Rasper MPR 120	132.0
11.	1	Service Platform	
12.	1	Vibrating Discharge Conveyor	1.5
13.	1	Overband Magnet DM 1450	0.55
14.	1	Inlet Conveyor including drum magnet	2.2
15.	1	Eddy current magnet	5.5
16.	1	Conveyor	0.75
17.	1	Inlet Conveyor	2.2
18.	1	Silo SMV	0.40
19.	1	Heavy Granulator HG 169	110
20.	1	Pneumatic Material Transport	23.5
21.	1	Pneumatic Material Transport	23.5

Item No.	Quantity (no.)	Designation	Kw
22.	1	Silo SMV	0.40
23.	1	Separation Table C22	12.10
24.	1	Middling Return, Flexible Screw Conveyor	1.10
25.	1	Classifier PC 12 with flexible screw auger	1.85
26.	1	Electric power and control board	
27.	1	Electric power and control board	
28.	1	Filter system for shredder line	21.5
29.	1	Cyclone	
30.	1	Ventilator	
31.	1	Filter system for granulation line	46.5
32.	1	Cyclone	
33.	1	Ventilator	

The tentative cost of the plant is about € 2.1 million excusive of import/ customs duty. The E-waste plant availability scenarios along with manufacturers and tentative costs are summarized in table 4.6 and table 4.7.

Table 4.6: E-waste plant capacity and manufacturers

E-waste plant	Capacity		
	5000 TPA	7500 TPA	15000 TPA
Manual	Asian supplier from Singapore	Asian supplier from Singapore	Asian supplier
Semi Automatic	X	Plant from European Supplier 1	European supplier 1
Automatic	X	Plant supplier from European supplier 2	European supplier 2

Table 4.7: Cost Estimates (ex works)

E-waste plant	Cost (US$) (Exworks exclusive of customs duty)		
	5000 TPA	7500 TPA	15000 TPA
Manual	7,90,000	1,043,000	1,230,000
Semi Automatic	X	1,937,000	1,937,000
Automatic	X	3,129,000	3,129,000

4.3 Common Specifications for Utilities at Collection Centers and Processing Facilities

E-waste storage areas/ Hazardous waste storage areas/ Product storage areas should follow following basic design principles.

1. Sites for storage (including temporary storage) of E-waste prior to their treatment should have impermeable surface for appropriate areas with the provision of spillage collection facilities and where appropriate, decanters and cleanser-degreasers.

2. Sites for storage (including temporary storage) of E-waste prior to their treatment should have weatherproof covering for appropriate areas.

3. Some spare parts (e.g. motors and compressors) will contain oil and/or other fluids. Such part must be appropriately segregated, end stored in containers that are secured such that oil and other fluids cannot escape from them These containers must be stored on an area with an area with an Impermeable surface and a sealed drainage system.

4. Storage for other components and residues: Other components and residues arising from the treatment of E-waste will need to be contained following their removal for disposal or recovery. Where they contain hazardous substances they should be stored an impermeable surface and in appropriate containers or bays with weatherproof covering. Containers should be clearly labeled to identify their contents and must be secure so that liquids, including rain water, cannot enter them. Components should be segregated having regard to their eventual destinations and the compatibility of the component types. All batteries should be handled and stored having regard to the potential fire risk associated with them.

5. Waste Oil should be either reused or incinerated in common hazardous waste incineration facilities.

6. CFCs should be either reused or incinerated in common hazardous waste incineration facilities.

7. Capacitors containing PCB's shall be incinerated in common hazardous waste Incineration facilities.

8. Based on volume of E-waste items, the number of bin/ container/ cage/ Gaylord container, their size and their numbers should be calculated.

9. Ensure safe transport of the E-waste without any spillage.

10. Sites for handling of E-waste have balances to measure the weight of the segregated waste. The objective is to ensure that a record of weights can be maintained of E-waste entering a facility end components and materials leaving each site (together with their destinations). The nature of the weighing equipment should be appropriate for the type and quantity of E-waste being processed.

11. Facility shall maintain record of destruction of electronic waste collected from generator.

4.5 Conclusions

The specifications for proposed E-waste treatment system vary from 5,000 tons per annum to 7,500 tons per annum. There is huge variation in the prices of the treatment system starting from US$ 790,000 to US$ 3.129 million depending on type of technology. The specifications of E-waste treatment facility will depend on the E-waste collection efficiency in PPM. The range of specifications depends on the collection efficiency of 50% of the projected inventory. Therefore, there is a need to determine the E-waste collection efficiency in PPM through pilot study. The financial viability of the proposed specifications is described in chapter 5.

CHAPTER 5: E-WASTE MANAGEMENT FEASIBILITY STUDY

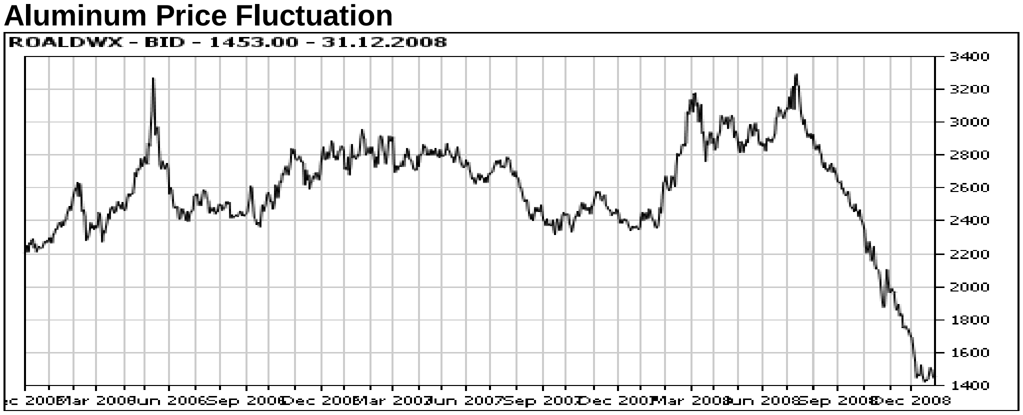
5.0 Introduction

This chapter describes the risks on account of price fluctuations, risk profiling and financial analysis based on amount recoverable, cost estimates, selling price of the recovered items, scenario analysis and rate of return. Rate of return has been estimated based on internal rate of return and net present value.

5.1 Price Risks

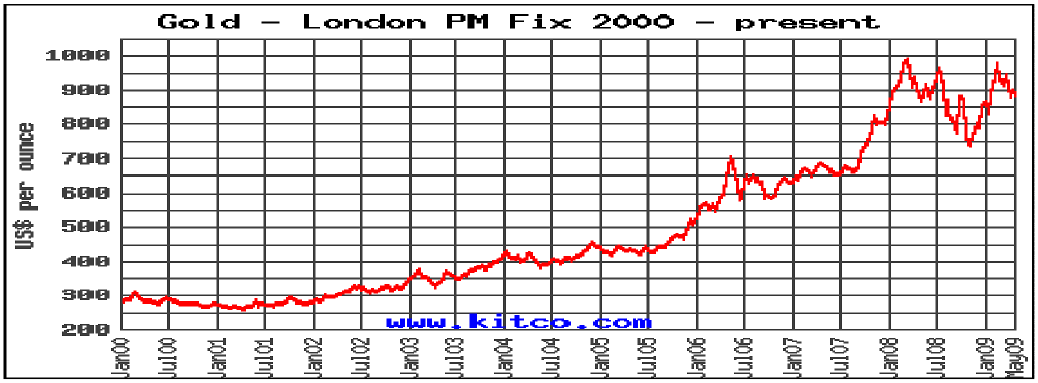
Price risks are associated with price variations in global metal markets and commodity exchanges e.g. London Metal Exchange, London Bullion Market etc. These prices are linked to global demand, supply and other economic factors. The metal markets in South East Asia are also linked to these markets. Since E-waste has recoverable quantities of precious metals, base metals and plastics, it is linked to metal market both as metal scrap and finished product. Their prices also follow the same trend and are subject to price volatility as global metal market. The different metal price volatility is shown in figure 5.1.

Aluminum Price Fluctuation

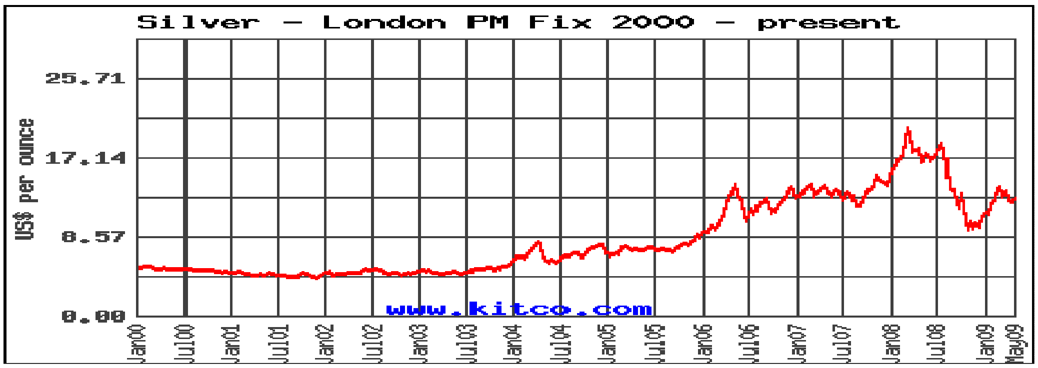


Copper Price Fluctuation

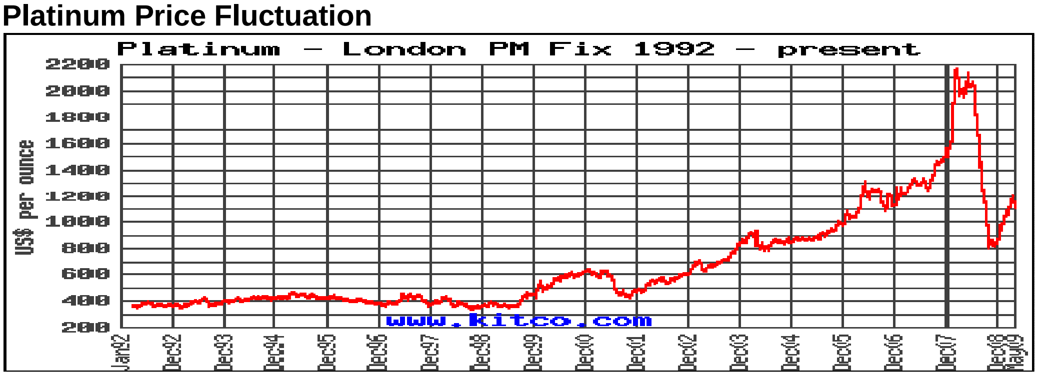
Gold Price Fluctuation



Silver Price Fluctuation



Platinum Price Fluctuation



Palladium Price Fluctuation

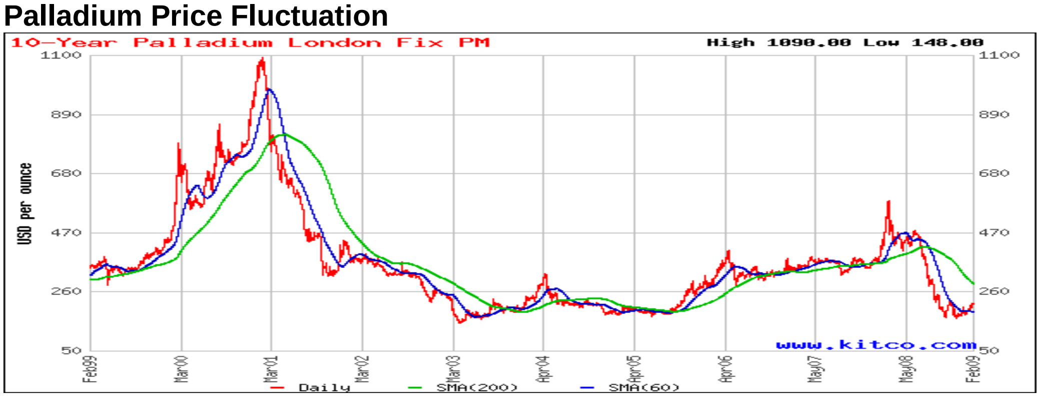


Figure 5.1: Metal price fluctuation in global market

The analysis of the above graphs indicates that metal market peaks and bottoms out in a ten year period. However, the prices of majority of precious metals are on the rise within this period. E-waste purchase price has ranged from US$ 1/kg to US$ 4/kg during this period. Therefore, trend analysis indicates that E-waste market is expected to follow the same trend as that of precious metals and can be categorized as risk of medium intensity.

5.2 Recoverable Quantities

The financial analysis has been carried out based on recoverable quantities of elements of value from PC and TV, which have been calculated below. The amount of different elements present in a PC and TV and their recovery is given in table 5.1 and table 5.2.

Table 5.1: Recoverable quantity of elements in a PC

Elements	Content (% of total weight)	Content (Kg)	80% Recoverable weight of element (kg)
Plastics	22.990700	6.253470	5.00277632
Lead	6.298800	1.713274	1.37061888
Aluminum	14.172300	3.854866	3.08389248
Germanium	0.001600	0.000435	0.00034816
Gallium	0.001300	0.000354	0.00028288
Iron	20.471200	5.568166	4.45453312
Tin	1.007800	0.274122	0.21929728
Copper	6.928700	1.884606	1.50768512
Barium	0.031500	0.008568	0.0068544
Nickel	0.850300	0.231282	0.18502528
Zinc	2.204600	0.599651	0.47972096
Tanialum	0.015700	0.004270	0.00341632
Indium	0.001600	0.000435	0.00034816
Vanadium	0.000200	0.000054	0.00004352
Terbium	0.000000	0.000000	0
Beryllium	0.015700	0.004270	0.00341632
Gold	0.001600	0.000435	0.00034816
Europium	0.000200	0.000054	0.00004352
Tritium	0.015700	0.004270	0.00341632
Ruthenium	0.001600	0.000435	0.00034816
Cobalt	0.015700	0.004270	0.00341632
Palladium	0.000300	0.000082	0.00006528
Manganese	0.031500	0.008568	0.0068544
Silver	0.018900	0.005141	0.00411264
Antinomy	0.009400	0.002557	0.00204544
Bismuth	0.006300	0.001714	0.00137088
Chromium	0.006300	0.001714	0.00137088
Cadmium	0.009400	0.002557	0.00204544
Selenium	0.001600	0.000435	0.00034816
Niobium	0.000200	0.000054	0.00004352
Yttrium	0.000200	0.000054	0.00004352
Rhodium	0.000000	0.000000	0

Elements	Content (% of total weight)	Content (Kg)	80% Recoverable weight of element (kg)
Mercury	0.002200	0.000598	0.00047872
Arsenic	0.001300	0.000354	0.00028288
Silica	24.880300	6.767442	5.41395328
Total	**99.994700**	**27.198558**	21.75884672

Table 5.2: Recoverable quantity of elements in a TV

Elements	%	ppm	Recoverable Weight of element (Kg)	80% Recovery (kg)
Aluminium	1.2		0.4344	0.34752
Copper	3.4		1.2308	0.98464
Lead	0.2		0.0724	0.05792
Zinc	0.3		0.1086	0.08688
Nickel	0.038		0.013756	0.0110048
Iron	12		4.344	3.4752
Plastic	26		9.412	7.5296
Glass	53		19.186	15.3488
Silver		20	0.000724	0.0005792
Gold		10	0.000362	0.0002896

As per literature survey, the two tables describe recoverable weight of elements from a PC and a TV. Since technology supplier claim 95% recovery of the precious and base metals at the first and second level treatment and above 90% at the third level treatment, about 85% recovery of metals of economic value can be assumed for financial analysis. However, 5% loss in recovery has been assumed on account of variation in quality of available raw material. Therefore, it has been assumed that the E-waste facility will be able to recover a minimum of 80% of these elements by using the proposed technology.

5.3 Cost Estimates

The proposed project will consists of a plant with 1st and 2nd level treatment. An estimate of costs has been prepared based on capital cost and operating cost as described below under two scenarios. It has been assumed that the project will be financed partly by debt and partly by equity. Land cost and its development cost has been considered as one time cost. The project cost has been estimated to be about US$ 7.7041 million. The breakup of capital and operating cost estimate is given in table 5.3, table 5.4 and table 5.5. Construction of the project and installation of equipment will be completed in two years. Construction costs will be disbursed in the ratio of 70 percent and 30 percent during two years.

Table 5.3: Project Cost Estimates (US$ millions)

SUMMARY OF PROJECT COST			
	Total	**Year-1**	**Year-2**
Land	3,120,000	3,120,000	-
Development cost	124,800	124,800	
Construction Cost	2,015,002	1,410,501	604,501
Equipments (Manual)	1,043,000	625,800	417,200
Customs Duty (35%)	365,050	219,030	146,020
Interest During Construction (IDC)	1,036,308	693,017	210,190
Project Cost	**7,704,160**	**6,193,148**	**1,377,910**

Table 5.4: Assumption for Operating Costs and Estimates

Purchase cost	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**
Computers	750000.0000	1350000.0000	1650000.0000	2250000.0000	2250000.0000	2250000.0000
Televisions	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Electricity cost	15000.0000	27000.0000	33000.0000	45000.0000	45000.0000	45000.0000
Collection Cost of Materials	6187.5000	11137.5000	13612.5000	18562.5000	18562.5000	18562.5000
Salary	163200.0000	254400.0000	304800.0000	386400.0000	416400.0000	416400.0000
Maintenance cost	173447.3026	272138.4193	276070.0516	278659.8494	279907.8128	279813.9418
Other Misc exp (% of Total Rev)	56016.7162	100830.0892	123236.7757	168050.1486	168050.1486	168050.1486
Depreciation	87240.1736	134183.4445	134183.4445	134183.4445	134183.4445	134183.4445
Interest	(321,428)	674,937	810,864	630,672	450,480	270,288

Table 5.5: Other Assumptions

Rate per square meter	200	US$/ sq mtrs
Cost of land	3,120,000	US$
constructed area %	50%	
constructed area	7,800	sq mtrs
constructed area	83,958	sq ft
Development cost per sq mtrs	8	US$ per Sq mtrs
Development cost	124,800	US$
Construction cost	24	$ per sq ft
Construction cost	2,015,002	US$
Interest rate	18%	
Debt Equity Ratio		
Debt	2	
Equity	1	
Total	**3**	
No of working days	300	
Weight per computer	27	kg
Purchase cost per kg Computers	0.4	$/ Kg
Other Misc exp (% of Total Rev)	3%	
Maintenance cost % of Net Block	8%	
Increase in Maintenance exp p.a	0.50%	
P/E OF Infrastructure sector	10	
Collection cost of materials	**0.0033**	**$ per kg**

Loan and equity contributions will be disbursed in two years while loan repayment period is five years. A rate of interest of 18% has been assumed for financial analysis. It will start from the beginning of third year and will be repaid at the end of seventh year. Capacity of the E-waste recycling plant has been assumed to be 7,500 tons per annum. It is assumed that plant will start with 25% capacity utilization during first year, which will reach 80 % after fifth year. It is assumed that total input raw material will be 100% PCs only. Maintenance costs have been assumed to change starting from 8 % to 13% of net block. Net block has been computed by estimating fixed assets schedule where 0% depreciation on land, 3.34% depreciation rate on building and other assets and 4.75% depreciation rate on equipment has been assumed on straight line basis.

5.4 Financial Viability

Financial viability has been assessed in terms of internal rate of return (IRR), net present value (NPV) and payback period. Further, sensitivity analysis has been carried out to assess the impact of various factors on the financial viability of the project.

S. No.	Indicator	Results
	Business as Usual Scenario	
1.	Project IRR	15%
2.	NPV after 10 years (Int:18%)	4319641
3.	Payback Period	About 6 Years
	Sensitivity to Customs Duty	
4.	Project IRR	Increases by 2%
5.	Payback Period	About 6 Years
	Sensitivity to Land (free)	
6.	Project IRR	Increases by 32 %
7.	Payback Period	About 3 Years
	Sensitivity without interest costs	
8.	Project IRR	Increases by 10 %
9.	Payback Period	About 5 Years

Financial indicators e.g. IRR shows viability of the project. NPV is positive and decreases with high cost of capital. But the financial indicators are not strong enough to attract private investment because IRR value is much lower than 25% and payback period is 5 years. The project is most sensitive to land prices followed by interest rates, and customs duty. This analysis also indicates that if lower quantities of PC are dismantled then financial viability goes down significantly, which means that for waste white goods treatment and disposal, the combination of incentives should be higher. Financial viability is also sensitive to price fluctuations i.e. prices with respect to both input raw material as well as output. Since these prices are linked to metal prices, it is expected that both the prices will follow the same trend.

5.5 Conclusions

Financial analysis indicates that project financial viability is higher if greater percentage of PCs dismantled in comparison to TV. It is a clear indicator of recycler's preference of recycling PC over TV. A comparative analysis of financial analysis indicators shows that viability improves with the improved capacity utilization. Capacity utilization depends upon the availability of the raw material. In order to make the project more viable a set of incentives like lower interest rate or duty exemption or subsidy on land may be planned.

CHAPTER 6: CONCLUSIONS & RECOMMENDATIONS

6.0 Introduction

The objective of the proposed project is to formulate, design and implement an integrated E-waste management pilot project in PPM. Inventory studies show that E-waste generation potential ranges from 6792 metric tons in 2008 to 22,443 metric tons in 2019. Further, the results of extensive field work highlighted that the E-waste trade value chain consists of stakeholders, who use twelve processes during E-waste management. These processes are carried out in an environmentally unsound manner, which need to be addressed both at national and city level. Therefore, there is a need for environmentally sound management of these processes while planning for future interventions within municipal boundary of PPM. In this context, an effort has been made to study E-waste recycling/ other recycling infrastructure (formal/informal) and its capacity, study of E-waste toxic footprint by inventorizing E-waste recycling sites in informal sector and study of the feasibility of the level of treatment of E-waste in formal sector in PPM. The major conclusions drawn from this report are described below.

6.1 Major Conclusions/ Recommendations

Major conclusions have been described below under each head.

<u>E-waste Management in PPM</u>

At the moment, retailer's/ producer's take back system and producer's/ retailer's transportation system is non existent in PPM. Further, there is no exclusive municipal collection and transportation system for E-waste in PPM. There is a limited usage of existing municipal solid waste collection and transportation system for E-waste in PPM while dismantler's in informal sector have their collection and transportation system.

There are two types of E-waste collection system in PPM. Type 1 involves the intervention of waste picker and type 2, involves the intervention of dismantler. Other features of both types of collection and transportation system are described below.

7. These collection systems indicate the difference in scale of E-waste collection and transportation within the same geographical boundaries.

8. Both the mechanism collect and transport mixed type of E-waste and its fractions.

9. No separate collection and transportation mechanism exist for individual E-waste item.

10. Both the mechanism use significant manual handling of E-waste.

11. No occupational health and safety practices are visible during E-waste collection and transportation.

12. E-waste collection and transportation system appear to be market driven without regulatory controls.

Tracer tracking indicates that there is no company/enterprise in formal sector in PPM that collects/purchases E-waste from households and offices in Cambodia. Cambodia has no modern technology to carry out repair/ dismantling /refurbishing. The outcome of the survey carried out by the project team showed that most E-waste residues generated from repairing and/or dismantling shops are disposed in dustbin and later at urban dumpsite by domestic waste collection service. Some areas where waste-collection trucks are not available, such kind E-wastes are disposed improperly at sites close to/behind the repairing/dismantling shops, and are finally burnt. Therefore, the location of this footprint can be correlated to the location of major hubs of formal and informal sectors on the major streets in PPM in areas like Chamkamorn and Toul Kok, which serve as two major hubs for TV and PCs repair/ refurbishment and dismantling. Chamkamorn, Toulkok and Meanchay also serve as major repairing/ refurbishing centre for washing machine.

It can be concluded that current E-waste collection, transportation, treatment and disposal in PPM is inadequate both in terms of capacity and environmentally sound management. The expansion of E-waste treatment is expected to significantly increase the E-waste toxic footprint within PPM. Since the existing toxic footprint covers areas, which are commercial along the main streets of PPM, its expansion is likely to further impact air, water and soil conditions in its area of influence. Therefore, there is a need for environmentally sound management of E-waste in order to reduce its volume as well as its toxic footprint.

<u>E-waste Management System & Technology Evaluation</u>

The major conclusions, which will drive the development (planning / design / implementation) of environmentally sound E-waste management system in PPM, are given below.

8. ICT will continue to drive the E-waste management system including E-waste recycling in the country.

9. E-waste collection and transportation mechanism in PPM is diverse in nature ranging from hand driven cart to light commercial vehicles.

10. Both the households and the commercial sector look for best monetary and exchange value of their old product. Therefore, any E-waste management system should factor in the salvage value of the waste product. The best monetary and exchange value of the old product can be determined by understanding the E-waste composition and its recyclability described below.

11. Recyclability of E-waste is driven by electric component, copper and precious metal recovery. Therefore, E-waste collection, transportation and treatment are different from conventional solid waste collection, transportation and treatment system due to its composition and recyclability.

As per the consumer behavior, E-waste collection channels in PPM is through municipal collection sites or drop off at dustbins. The only viable mechanism as per consumer behavior under the existing regulatory mechanism appears to be to capture E-waste at the point of generation. Since the majority of E-waste is generated in the commercial sector e.g. corporates/ business/ BPOs etc., and both the households and commercial sector prefers the best value of their waste, it is recommended that the E-waste collection facilities should be at retailers and at commercial sector e.g. corporates/ business/ BPOs etc. Salient features of this collection mechanism are given below.

14. There is a need for separate collection facilities for ICT and white goods.

15. Location of collection facilities need to be near E-waste collection hubs. This need is projected on account of following reasons.

    - Ensure minimal movement of products
    - Efficient collection mechanism
    - Minimize manual handling
    - Avoid unsorted municipal waste

16. Each of the retailer's/ market association/ group can identify a place/ area as E-waste collection point. This place can serve as a place where retailers/ consumers can get value of their old product. The authorized E-waste recycler can collect from retailer's collection facilities and transport E-waste to their recycling facility.

17. E-waste from households can be routed through already existing municipal waste collection mechanism. Each of the localities can identify a place/ area as E-waste collection point in their premises. This place can serve as a place where retailers/ consumers can get value of their old product. There is a need to initiate public awareness campaign to collect E-waste at authorized collection facility and only give to authorized recycler for treatment and disposal.

18. There is a need for authorizing E-waste recyclers/ dismantlers in PPM. This will assist to divert E-waste from commercial sector e.g. corporates/ business/ BPOs using existing mechanism to authorized recycler.

19. Books of E-waste account should be maintained at all the three types of collection facilities and match with authorized recycler's books. In case of mismatch, penalty provisions can be invoked on either party using appropriate legal instrument. It is recommended that the value of the penalty should be the difference between the value offered by the informal sector and the value offered by the authorized recycler. This mechanism will discourage leakage of E-waste into informal sector.

20. The research literature cites that the efficiency of E-waste collection system ranges from approximately 60% to even less than 30% even in the most efficient system functioning under EPR in EU. This indicates that leakages exist even in the most efficient system. In this context it should be noted that any penal provision highlighted in item 4 above should be invoked only as a deterrent to prevent leakage.

The proposed E-waste treatment technology has been described based on first and second level of treatment. These levels have been proposed considering two levels of treatment occurring in PPM. Out of the two levels, the major part of treatment is occurring at first level only, while the second level is occurring to a minimal extent. However, E-waste inventory estimate encourages recommending second level treatment after 2019.

It may be noted that even in the best of E-waste collection scenario with 90% collection efficiency, Cambodia will not be able to generate adequate quantity of E-waste till 2030 to sustain an integrated metal recovery facility, which will require about 300,000 tons per annum of input raw material. In such scenario, hydrometallurgical/ electrolysis appears to be the viable third level option for precious metal recovery in Cambodia beyond 2030. The major risks anticipated is the availability and quality of raw material, scale of operation and expected yield on account of efficiency of E-waste collection system.

<u>E-waste Management System Specifications</u>

The volume of E-waste item to be collected and transported till 2020 based on E-waste inventory estimates in Phnom Penh ranges from 4490 m^3 to 32923 m^3 for washing machine, 5140 m^3 to 6925 m^3 for personal computers, 9m^3 to 46m^3 for mobile phones, 2918 m^3 to 9573 m^3 for refrigerator, 1458 m^3 to 5976 m^3 for Air Conditioners and 1557 m^3 to 2618 m^3 for washing machine. This is based on 50% availability of E-waste for recycling. Depending upon the type of E-waste, different types of bins/ cages have been identified and recommended. The collected E-waste in container will be lifted manually, through fork lifts, placed into small trucks/ container carriers and transported from the collection facility to E-waste treatment facility. E-waste collection frequency is dependent on E-waste inventory and inventory maintained at recycling facility. The forklifts and trucks to lift containers are required for safe transport of E-waste from collection locations to recycling facility. It has been recommended that the responsibility of E-waste collection will be that of the either recycler or collection agency. Further, the collection centers at commercial/ corporate/ business centers can use the above specifications of the bins to collect and store E-waste. As the volume of the E-waste starts increasing, collection facilities will be required at retailer and household level. The design criteria will be dependent on the area requirement in order to capture E-waste from a respective catchment. Again inventory from the catchment will determine the bin requirement and the area required for storing bins and collection frequency of the bins will determine the basis for area of collection facility.

The specifications of E-waste treatment facility will depend on the E-waste collection efficiency in PPM. The specifications for proposed E-waste recycling facility vary from 5,000 tons per annum to 7,500 tons per annum based on 50% collection efficiency by 2019. The tentative total area requirement for catering to such type of facility has been estimated to be about 4 acres or about 15,600 sq meters as per international best practices and design criteria of plant and equipment supplier. Out of this total area, processing area is about 25%, area for administration 5%, area for storing raw material to be about 30% and for finished product to be about 15% and open area is about 25 %. First and second level treatment could be either manual or semi-automatic using conveyor system. The specification of shredder in the 1st and 2nd level treatment determines the equipment specifications. Tentative shredder specifications are given below.

9. Input – 3 to 4 tons per hour
10. size of output < 4 - 5 mm
11. Driven by motor in the range of 300 to 400 kw
12. Hopper of around 1.5 m by 1 m

Depending on the collection efficiency and availability of the input raw material, the facility can start with one shredder of half the capacity followed by the second. There is huge variation in the prices of the treatment system starting from US$ 789700 to US$ 3.1 million depending on type of technology.

E-waste Management Feasibility Study

E-waste market is expected to follow the same trend as that of global market for precious metals. Therefore, price risks related to E-waste fractions are associated with price variations in global metal markets and commodity exchanges e.g. London Metal Exchange, London Bullion Market etc. These prices are linked to global demand, supply and other economic factors. The metal markets in South East Asia are also linked to these markets. The analysis of the price graphs indicates that metal market peaks and bottoms out in a ten year period. E-waste purchase price in PPM has ranged from US$ 1/kg to US$ 4/kg during this period. Therefore, price risks can be categorized as risk of medium intensity.

A financial analysis for proposed 7500 tons per annum E-waste recycling facility in PPM has been carried out based on capital and operating cost estimates considering local land prices, labor costs, customs duty, equipment costs, electricity costs and current interest rates. It has been proposed that the capital costs will be in the form of debt and equity in a ratio of 70:30. The financial viability indicators e.g. IRR shows viability of the project. NPV is positive and decreases with high cost of capital. But the financial indicators are not strong enough to attract private investment because IRR value is much lower than 25% and payback period is 5 years. The project is most sensitive to land prices followed by interest rates, and customs duty. This analysis also indicates that if lower quantities of PC are dismantled then financial viability goes down significantly. It shows that for waste white goods treatment and disposal, the combination of incentives should be higher. Financial viability is also sensitive to price fluctuations i.e. prices with respect to both input raw material as well as output. A comparative analysis of financial analysis indicators shows that viability improves with the improved capacity utilization. Capacity utilization depends upon the availability of the raw material. In order to make the project more viable an efficient E-waste collection and transportation system and a set of incentives like lower interest rate or duty exemption or subsidy on land may be planned.

The fundamental basis to design conventional E-waste collection and transportation infrastructure and E-waste treatment facility requires assessment of the lowest and highest volume of E-waste to be collected during the planned period. This is carried out based on E-waste capture rate. E-waste capture rate can be assessed by implementing a pilot project for E-waste collection and transportation, which has been conceptualized in third E-waste report. Therefore, there is a need to determine the E-waste collection efficiency in PPM through pilot study.

E-waste Management for Phnom Penh,
Kingdom of Cambodia

Date: 8-10 April 2009
Place: Ministry of Environment, Cambodia (Phnom Penh)
Participants: Project Team and UNEP-DTIE-IETC

Training on E-waste Manual, Volume II
E-waste Management

First Day – 8 April 2009

9:00 – 10:00 De-briefing on Roles and Responsibilities

10:00 – 11:00 Outline of the Training on E-waste Manual, Volume II
- Mushtaq Ahmed Memon, UNEP-DTIE-IETC

11:00 – 13:00 First Session
- Perspective of E-waste / WEEE Management

13:00 – 14:00 Lunch

14:00 – 15:30 Second Session
- Current Practices of E-waste / WEEE Management
- National and Social Policies/Regulations/Laws/Institutions in Developed Countries

15:30 – 17:00 Third Session (with working coffee/tea)
- National and Social Policies/Regulations/Laws/Institutions in Developing Countries
- Initiatives of Different Agencies

Second Day – 9 April 2009

9:00 – 13:00 First Session
- Stages and Technologies for E-waste / WEEE Management
- Collection System

13:00 – 14:00 Lunch

14:00 – 17:00 Second Session (with working coffee/tea)
- Treatment system

Third Day – 10 April 2009

9:00 – 13:00 First Session

- Financing Mechanism of E-waste / WEEE Management
- Developed Countries Case

13:00 – 14:00 Lunch

14:00 – 15:30 Second Session

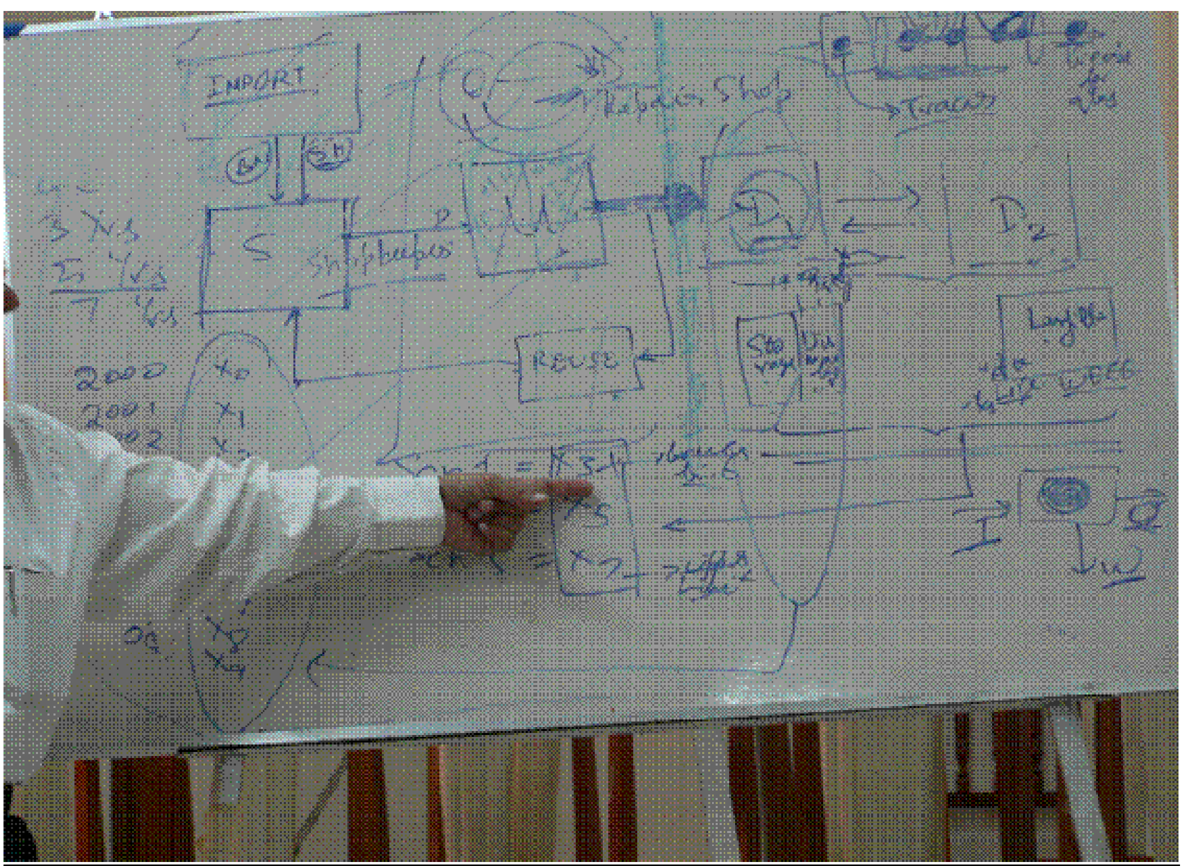
- Developing countries Case

15:30 – 17:00 Third Session (with working coffee/tea)

- Case Study

Appendix II

PHOTOGRAPHS


IMPORT
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