FINANCIAL FEASIBILITY OF E-WASTE RECYCLING IN GEORGIA

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List of Abbreviations

AC	Air Conditioner
ARF	Advance Recycling Fee
EEE	Electrical and Electronic Equipment
EPR	Extended Producer Responsibility
HFC	Halo-Fluorocarbon
PCB	Printed Circuit Board
PRO	Producer Responsibility Organisation
WEEE/e-waste	Waste Electrical and Electronic Equipment
USD	United States Dollar

1 Introduction

The establishment of a modern waste management system is one of the priority goals for the Government of Georgia. To achieve this, a new Waste Management Code and a number of secondary legislations have been adopted. In addition, the National Waste Management Strategy (2016-2030) and the National Waste Management Action Plan (2016-2020) were approved in April 2016. The implementation of these documents, which are in line with the EU-Georgia Association Agreement (AA) and best international practices, requires intensive work and an iterative consultation process from all stakeholders.

The Waste Management Code (2015) introduces Extended Producer Responsibility (EPR) as an overarching policy approach which will become obligatory for producers (i.e. manufacturers and importers) operating in Georgia from December 2019 onwards. EPR is an internationally applied principle according to which producers are held responsible for the professional treatment and disposal of generated wastes. This helps to improve recycling rates and reduce landfilling of toxic and precious materials. Implementation modalities of EPR can vary considerably across different national contexts. Various studies indicate that the intrinsic value contained in waste from electrical and electronic equipment (WEEE or e-waste) represents a significant opportunity (Itronics Inc. 2018). In the case of Georgia, however, it remains unclear if e-waste recycling could generate economical and sustainable value and to what extent domestic recycling capacities for e-waste should be developed.

Against this background, the overall objective of this study is to examine a fictitious Georgian recycling facility in order to determine if domestic e-waste recycling can be economically viable. More specifically, the study seeks to a) identify the major limitations and cost drivers which may inhibit cost effective recycling of e-waste; b) provide a first estimation for the magnitude of an Advance Recycling Fee (ARF) which could help to increase domestic recycling capacities and c) outline a potentially appropriate technology scenario for e-waste recycling in Georgia.

This study is structured as follows:

Chapter 2 presents the methodology applied to assess the financial feasibility of e-waste recycling based on a break-even analysis and delineates the scope as well as major assumptions employed.

In chapter 3, detailed information regarding the key characteristics of three different scenarios is provided.

In chapter 4, the results for break-even analyses of three different scenarios are presented.

The paper concludes with Chapter 5 by discussing the implications of the analysis with respect to the three objectives mentioned above.

2 Methodology

2.1 Breakeven Analysis

The analysis presented in this paper is rested upon a break-even analysis of three different recycling scenarios. Break-even analyses are commonly employed in business management in order to determine what levels of sales need to be achieved so as to make neither profit nor loss (Investopedia 2018a). Within the context of this study, it can be understood as a supply-side analysis which provides an indication regarding the minimum amount of e-waste which needs to be purchased, processed and sold in order to maintain economically viable e-waste recycling. In mathematical terms, a break-even analysis can be expressed as follows:

$$Fixed\ Costs \big/ (Unit\ Price - Variable\ Costs) = Breakeven\ Point$$

Fixed costs describe those costs which are incurred on a regular basis and show little fluctuations from period to period as they are generally independent from the amount of units processed. Examples of fixed costs include monthly expenses for loans, rent for facilities, and electricity for lighting, amongst others. Moreover, monthly salaries which are paid to employees irrespective of the number products processed, such as administrative staff, are counted as fixed costs.

The united price describes the revenues generated from selling recycled fractions. Within the scope of this study, the unit price is expressed as USD per kg.

Unlike fixed costs, variable costs are dependent on production output, i.e. the amount of e-waste dismantled or recycled. Key parameters of variable costs include purchasing costs for the items as well as labour involved in dismantling of products. Variable costs are expressed as USD per kg of processed e-waste (Investopedia 2018b).

2.2 Key Assumptions and Scope

2.2.1 Categories and Material Availability

In order to maintain coherence with other project activities, the analysis focuses on nine categories of e-waste as referred to by the baseline report of GEO (2017). These categories were selected as they represent the major share of domestic e-waste for which relevant information was available. For more information, please refer to the above mentioned report. For 2017, it is estimated that some 15,700 tonnes of e-waste were generated in Georgia across all nine categories. In the context of this analysis, this represents the total amount of available for recycling. A detailed break-down of waste generated across all nine categories is presented in Figure 1 below.

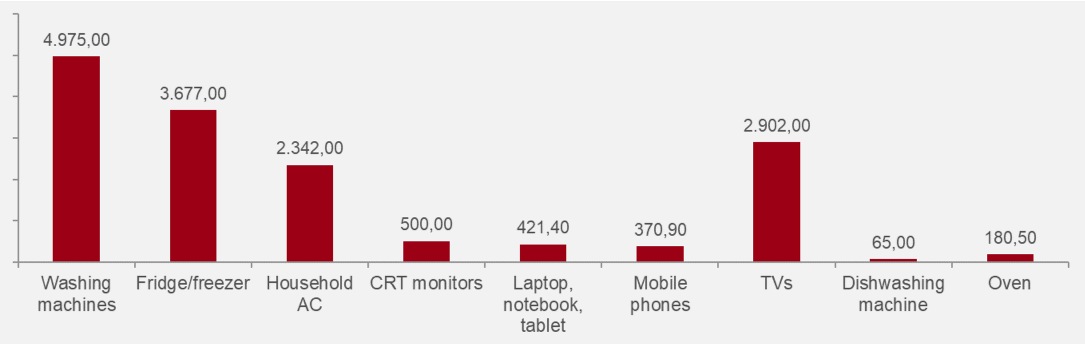

Figure 1: E-waste generated in Georgia (tonnes, 2017, GEO 2017)

2.2.2 Costs and Revenues

The introduction of EPR is generally associated with a number of costs along the waste management value chain which arise from implementing and maintaining a functioning scheme (i.e. system costs for monitoring and enforcement, administrative fees for impact assessments, activities for awareness raising etc.) as well as building and operating waste infrastructure, and conducting collection and recycling activities (i.e. technical costs). This is illustrated in Figure 2 below.

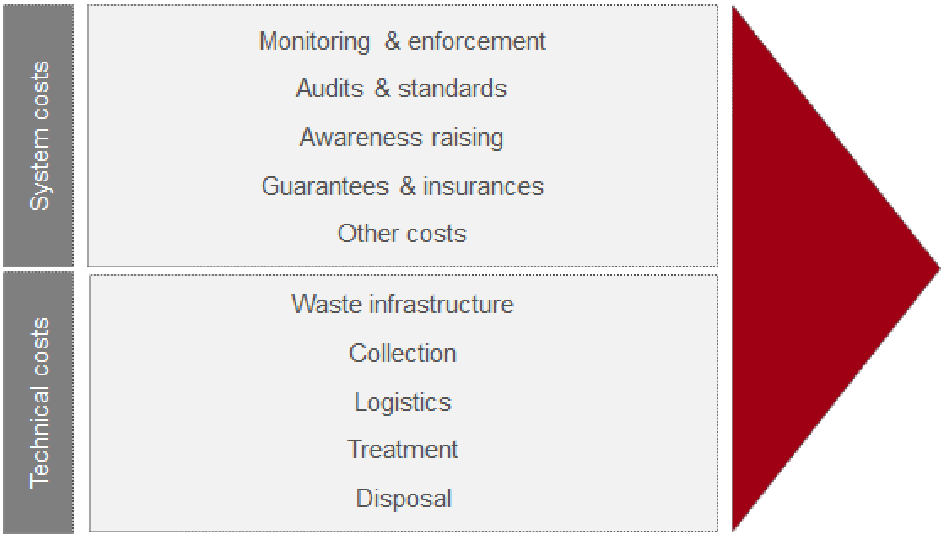

Figure 2: Costs of waste management which can be covered by EPR schemes

Since the study at hand aims to analyse the financial feasibility of e-waste recycling, calculations entirely omit system costs associated to the introduction of EPR and focus on technical costs only. Moreover, due to the limited scope of the analysis and lack of available data, technical costs cannot be covered in an exhaustive manner. For instance, expenses for taxation and interest from loans have been omitted. Costs and revenues covered by this analysis are displayed in Table 8 in Annex I. Estimations are based on local market research, international market prices (e.g. London Metal Exchange for specific raw materials) and interviews with international recyclers.

2.2.3 Weight and Material Composition

As part of the local market research, the weight of items within the nine categories was estimated as displayed in Table 1 below. In order to determine unit prices and ultimately calculate the price per kg or recycled item, a list of material composition was developed. Estimations were based on an extensive desktop review of commonly available materials, including publications by StEP and eco3e (United Nations University/ Step Initiative 2018; Eco^{3e} 2016). To verify collected data, interviews with international recyclers were conducted. A detailed break-down of the composition of all nine e-waste fractions is displayed in Table 9 in Annex II.

Table 1: Estimated weight of different types of e-waste

Item	Weight
Washing machines	75.00 kg
Fridge/freezer	32.00 kg
Household AC	42.64 kg
CRT monitors	6.00 kg
Laptop, notebook, tablet	2.80 kg
Mobile phones	0.17 kg
TVs	14.42 kg
Dishwashing machine	40.00 kg
Oven	50.00 kg

2.2.4 Labour

In order to find a workable solution for the amount of labour involved in all recycling processes, the project team assumed that e-waste categories are manually dismantled up to a point at which further separation into pure materials would not be possible without mechanical shredding. This correlates to the highest dismantling depth in the above mentioned StEP (2013) assessment tool. Dismantling times are intimately linked to the complexity of the dismantled products and can thus vary considerably. Estimations for dismantling times per category are displayed in Table 2 below.

Table 2: Dismantling times for e-waste categories

Category	Dismantling time/unit (minutes)
Washing machine	20
Fridge/freezer	20
Household AC	26
CRT monitors	8
Laptop, notebook, tablet	30
Mobile phones	8

TVs	20
Dishwashing machine	15
Oven	15

With regards to framework conditions of labour involved, it was assumed that a regular working day would have eight hours/day and a full-time worker would work for five days a week. This correlates to 40 hours a week and 160 hours a month. Further, it was assumed that no shift work would be performed and both technical (floor-level) and managerial (executive) staff would be required to run the facility.

2.2.5 Processing

With regards to processing of e-waste within the facility, a key assumption is that recycling fridges/freezers and air conditioners (ACs) would require a degasser (stage 1) which needs to be purchased when setting up the facility. Through this, extraction of halo-fluorocarbon (HFCs) would be made possible which could be sold via international carbon markets. Other types of processing equipment include a cable stripper and a cable shredder. Using this processing equipment would yield additional revenues by extracting copper and plastics. Upfront investments for processing equipment were integrated into the break-even analysis as additional fixed costs in the form of monthly repayments for bank loans (assuming a simple pay-back time). For more information regarding the investment costs and technical specifications of processing equipment, please refer to Table 10 in Annex III.

With regards to the point of sale and further processing of recycled e-waste fractions, it was assumed that certain domestic processing capacities are present in Georgia (mainly referring to smelters and local scrap dealers). However, various components (e.g. PCBs or HFCs) are too complex to be fully recycled within the country or require further treatment before being disposed of. In the break-even analysis, this is reflected by additional variable costs for shipment to Europe (Rotterdam).

2.2.6 Logistics

With regards to the location and logistics, it was assumed that the recycling facility would be located in a 50 km radius outside of Tbilisi as illustrated by figure 3. Vehicles for transport (including trucks for local and long-range cargo and containers for shipments overseas) were assumed to be rented. In addition, shipment of various fractions (see previous section) was assumed to follow a route from Tbilisi via Poti to Rotterdam.

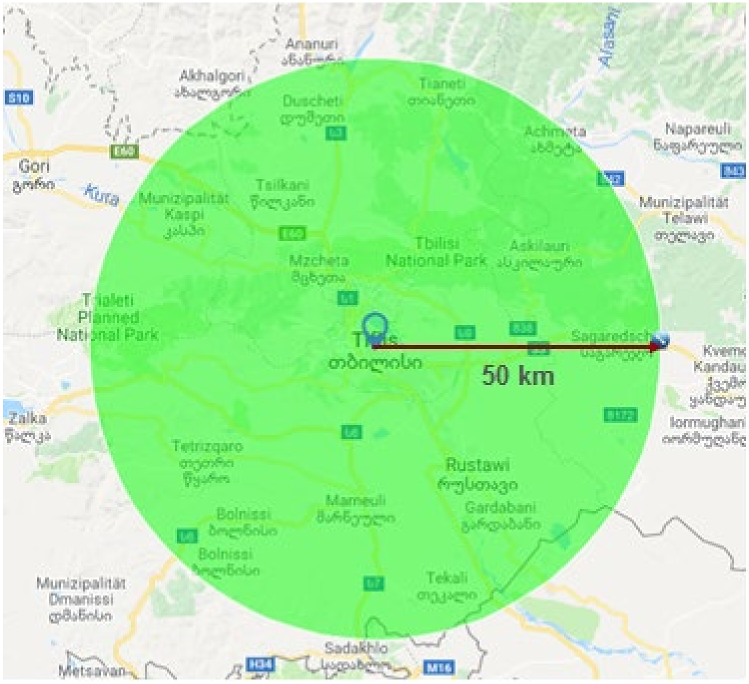

Figure 3: Radius of location of recycling facility (adapted from Google Maps)

3 Scenario Building

A break-even analysis of three different scenarios was conducted in order to determine to what extent recycling of e-waste in Georgia could be economically viable. For all three scenarios it was assumed that 90% of materials would be purchased via scrap dealers and small repair shops, while 10% would be obtained from e-auctions.[1] The shares of e-waste categories processed in each scenario are displayed in Table 3 below.

Table 3: Share of categories processed in three scenarios

Type	Scenario 1	Scenario 2	Scenario 3
Washing machines	30%	30	10%
Fridge/freezer	-	-	10%
Household AC	-	-	10%
CRT monitors	15%	15%	15%
Laptop, notebook, tablet	15%	15%	15%
Mobile phones	10%	10%	10%
TVs	20%	20%	20%
Dishwashing machine	5%	5%	5%
Oven	5%	5%	5%

The following sections will an overview regarding the key characteristics of each scenario. Taking into account local conditions in Georgia, it should be highlighted that high-tech scenarios such as highly integrated smelters for processing of PCBs which require investments of multi-million USD were excluded ex-ante. The specs of different scenarios were verified by conducting interviews with international e-waste recyclers. An overview of different specs (as reflected by the fixed costs) of all three scenarios is presented in Table 11 in Annex IV.

3.1 Scenario 1: Manual

Scenario 1 assumes a small recycling facility which only employs manual labour in order to disassemble collected e-waste fractions. The size of the facility is estimated at 200 m² with one production manager (management staff) and a minimum of 6.5 factory workers (floor-level staff). Further, it is assumed that an average of four trips to Tbilisi city centre are undertaken in order to collect readily available e-waste. Due to the absence of mechanical processing technologies, fridges/freezers and ACs cannot be

[1] The only exceptions are mobile phones and laptops/notebooks for which it was assumed that 100% of materials would be purchased from local repair shops. This decision was made as prices for mobile phones obtained from e-auctions are considerably higher than from small repair shops and would prohibit economically viable recycling altogether.

recycled. Thus, upfront investments of 1,000 USD for purchasing manual tools and simple equipment (screwdrivers, workbenches etc.) would be required.

3.2 Scenario 2: Low-Tech

Scenario 2 assumes a mid-sized recycling facility which employs mainly manual labour in order to disassemble collected e-waste fractions but is also equipped with a used cable stripper. The size of the facility is estimated at 500 m² and run by one production manager (management staff) and a minimum of 12 factory workers (floor-level staff). To collect e-waste, it is assumed that about six trips to Tbilisi are undertaken. Due to the absence of degassing technologies, fridges/freezers and ACs cannot be recycled. Upfront investments of 7,000 USD for purchasing manual tools and a used cable stripper would be required.

3.3 Scenario 3: Advanced

Scenario 3 assumes a larger recycling facility which employs manual labour in order to disassemble e-waste fractions but is also equipped with new processing equipment, i.e. a cable shredder and a stage-1-degasser. The size of the facility is estimated at 1500 m² and run by two production managers (management staff) and a minimum of 20 factory workers (floor-level staff). Further it is assumed that an average of eight trips to the city centre for E- waste collection is undertaken. Due to the availability of degassing technologies, fridges/freezers and ACs are also recycled and extracted refrigerant gases (HFCs) are sold via international carbon markets. Upfront investments of 408,000 USD for purchasing manual tools, a new cable shredder and a new stage-1-degasser would be required.

4 Results

4.1 Scenario 1: Manual

Results for scenario 1 indicate that 9,039.88 kg of e-waste would need to be collected, processed and sold every month in order to break even. With regards to the different e-waste fractions, it is noteworthy that about 8.3% of all dishwashers monthly available for recycling in Georgia would have to be collected. Although this appears rather unlikely, this can be explained by the rather small quantities of dishwashers available and may be offset by collecting other materials for recycling.

Table 4: Break-even analysis for scenario 1.

	Scenario 1			
Breakeven Point [KG/month]	**KG 9.039,88**			
Categories	Processed [%]	KG [per month]	Units [per month]	Share of WEEE available [%]
Washing machines	30	2711,96	36,16	0,65
Fridge/freezer	0	0,00	-	-
Household AC	0	0,00	-	-
CRT monitors	15	1355,98	226,00	3,25
Laptop, notebook, tablet	15	1355,98	484,28	3,86
Mobile phones	10	903,99	5317,58	2,92
TVs	20	1807,98	125,38	0,75
Dishwashing machine	5	451,99	11,30	8,34
Oven	5	451,99	9,04	3,00

4.2 Scenario 2: Low-Tech

With respect to scenario 2, results suggest that 17,180.74 kg would need to be processed in order to start making profits. Notably, the break-even point is almost twice as high as compared to scenario 1. This can be attributed to higher fixed costs which require additional processing in order for the enterprise to become profitable. Looking at the amount of e-waste available for recycling in Georgia, it appears rather unlikely that one single facility would be able to process more than 15% of all dishwashers available in the country. The significant volumes of washing machines and TVs on the market, however, may help to offset the lack of other categories.

Table 5: Break-even analysis for scenario 2

	Scenario 2			
Breakeven Point [KG/month]	KG 17.180,74			
Categories	Share [%]	KG [per month]	Units [per month]	Share of WEEE available [%]
Washing machines	30	5154,22	68,72	1,24
Fridge/freezer	0	0,00	-	-
Household AC	0	0,00	-	-
CRT monitors	15	2577,11	429,52	6,19
Laptop, notebook, tablet	15	2577,11	920,40	7,34
Mobile phones	10	1718,07	10106,32	5,56
TVs	20	3436,15	238,29	1,42
Dishwashing machine	5	859,04	21,48	15,86
Oven	5	859,04	17,18	5,71

4.3 Scenario 3: Advanced

Results of the break-even analysis in scenario 3 indicate that some 28,202.83 kg of e-waste needs to be processed in sold in order to maintain cost-neutral operations. Notably, the break-even point is almost three times as high as in scenario 1, mainly owed to higher fixed costs induced by additional processing equipment (new stage-1-degasser and cable shredder). Therefore, the set-up of the facility also allows for processing of fridges/freezers and ACs.

When examining the results of this scenario, it becomes apparent that large quantities of various e-waste types would be required to break even, namely about 10.15% of CRT monitors and 12.05% of laptops/notebooks which are available for recycling in Georgia. In addition, 9.12% of mobile phones and 9.37% ovens available for recycling in Georgia would have to be collected and processed in order to have sufficient amounts of materials. Lastly, an astonishing 26.03% of all dishwashers would need to be recycled.

Table 6: Break-even analysis for scenario 3

	Scenario 3			
Breakeven Point [KG/month]	**KG 28.202,83**			
Categories	Share [%]	KG [per month]	Units [per month]	Share of WEEE available [%]
Washing machines	10	2820,28	37,60	0,68
Fridge/freezer	10	2820,28	88,13	0,92
Household AC	10	2820,28	66,14	1,45
CRT monitors	15	4230,42	705,07	10,15
Laptop, notebook, tablet	15	4230,42	1510,87	12,05
Mobile phones	10	2820,28	16589,90	9,12
TVs	20	5640,57	391,16	2,33
Dishwashing machine	5	1410,14	35,25	26,03
Oven	5	1410,14	28,20	9,37

5 Conclusions

5.1 Major Limitations and Cost Drivers

By running different scenario analyses, it becomes apparent that the purchasing price of input materials is one of the major cost drivers which may inhibit cost-effective recycling of materials. Assuming that all e-waste is purchased via e-auctions (where prices are considerably higher than at repair shops), there would be too little e-waste available on the market to break even in any of the three scenarios. As for scenario 3, it appears unlikely that the facility would be able to obtain enough material. Therefore, material availability represents the main bottleneck to establishing a large-scale, economically viable e-waste recycling facility in Georgia.

Another major cost driver is the logistics associated with local transport and export of complex or hazardous fractions. Therefore, the location of the recycling plant is crucial to maintain viable operations; key parameters include the vicinity to the harbour and the number of trips made for collection of materials. Here, it appears that there may be potential trade-offs as most e-waste will be available in and around Tbilisi which is less ideally positioned for exporting materials due to its remote location from Poti harbour.

The type and composition of recycled e-waste represents another significant cost driver. While some materials have negative values due to toxic components which require further treatment, mobile phones, laptops/notebooks and household ACs contain the largest amount of valuable materials (see Figure 4).Yet, merely recycling such “cash-cows” is undesirable from an environmental point of view as it neglects a wide range of hazardous materials which require treatment before being disposed of. One possibility to aid recycling of all e-waste fractions is the introduction of an ARF for historical products and new EEE put on the market.

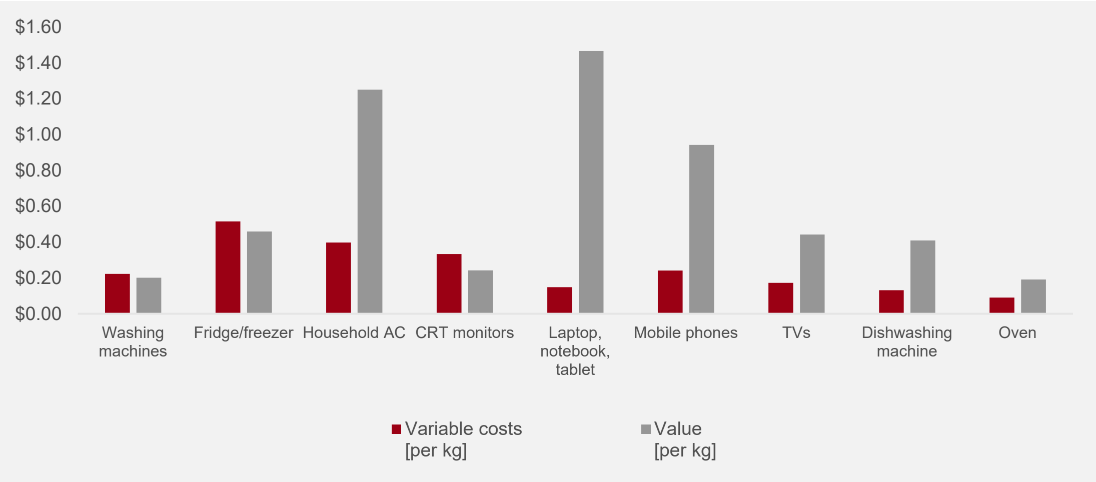

Figure 4: Cost- benefit analysis for the various categories of E-waste

Lastly, the use of processing technologies could be identified as a major cost driver. While processing equipment can help to generate additional revenues by extracting copper or HFCs, it can also induce significant fixed costs, making recycling only profitable at higher rates of material throughput.

5.2 Magnitude of Advance Recycling Fee

Based on the analysis conducted, some preliminary conclusions regarding the magnitude of a potential ARF can be drawn. In order to do so, it is worthwhile to take a closer look at the contribution margin of the analysed types of e-waste. In the context of this analysis, the contribution margin essentially describes how a specific category of e-waste contributes to the recycling facility profit. In mathematical terms, it can be described as follows:

$$Unit\ Price - Variable\ Costs = Contribution\ Margin$$

The contribution margin differs widely among different e-waste categories due to the varying amounts of precious metals which can be extracted. By multiplying the contribution margin per kg of each e-waste category, we end up with the contribution margin per item. For a detailed presentation of contribution margins across all categories, please refer to Table 7below.

Table 7: Variable costs, unit price and contribution margin (per kg/item)

Category	Variable costs [per kg]	Unit price [per kg]	Contribution margin [per kg]	Contribution margin [per item]
Washing machines	$0.22	$0.20	-$0.02	-$1.65
Fridge/freezer	$0.51	$0.46	-$0.06	-$1.80
Household AC	$0.40	$1.25	$0.85	$36.34
CRT monitors	$0.33	$0.24	-$0.09	-$0.55
Laptop, notebook, tablet	$0.15	$1.47	$1.32	$3.69
Mobile phones	$0.24	$0.94	$0.70	$0.12
TVs	$0.17	$0.44	$0.27	$3.89
Dishwashing machine	$0.13	$0.41	$0.28	$11.10
Oven	$0.09	$0.19	$0.10	$5.04

As indicated in the two right-most columns, some categories have a negative contribution margin, implying that recycling induces costs rather than generating profit. This can be attributed to comparatively long dismantling times paired with low or even negative value of certain components (such as CRT glass in CRT monitors). To ensure that recycling of these components is at least cost-neutral, additional monetary resources would have to be provided. The negative contribution margins per item can thus be used as a proxy for an ARF.[2]

Since most categories of e-waste can be recycled at a profit, recycling of products with a negative contribution margin could potentially be cross-financed by recycling e-waste categories of higher value. However, the incentive for collecting items of negative material value is low and profit-driven recyclers would avoid it at all cost. Hence, introduction of an ARF appears worthwhile in order to ensure that sufficient monetary resources are available.

Based on international experience, the magnitude of ARF can be very low, at times only 1% or 2% of the original sales price of new EEE put on the market. Laptops, notebooks and tablets are subject to a surcharge of 2-6 USD in Switzerland (depending of the size of the product), 0.06 USD in Belgium and 0.93 USD in Alberta, Canada. The fees on TVs are connected to the size of the product and vary from 2-28 USD in Switzerland, 6 USD in Belgium and 3-7.8 USD in Canada (Swico Recycling 2018; Recupel 2017; Alberta Recycling 2017). Examples for ARFs for different categories can be seen in Table 12 in Annex V.

Since the analysis was based on a limited number of variables which are directly linked to the technical costs of recycling, the exact magnitude of an ARF cannot be quantified. In order to come to a cost effective solution, initiating a dialogue between various stakeholders appears necessary. For instance, a monopolistic non-profit Producer Responsibility Organisation (PRO) chaired by producers could act as a common centre of intelligence and achieve very high collection and recycling rates at minimum cost.

5.3 Most Appropriate Recycling Scenario

The break-even analysis of three recycling scenarios suggests that advanced facilities (scenario 3) with higher fixed costs are less suitable for Georgia due to limited availability of e-waste in the country. In order to break even, such a facility would have recycle about 10% of selected e-waste fractions in Georgia and even more than 25% of dishwashing machines available for recycling.

On the other hand, the break-even analysis of a manual recycling facility (scenario 1) yields most realistic results, followed by low-tech facility (scenario 2). For both scenarios, significantly lower amounts of e-waste are required in order to start generating profits. However, specialising on selected fractions (e.g. washing machines) appears necessary in all three scenarios to ensure that enough material is available.

It appears beneficial to the economic viability for all scenarios to choose a location which provide easy access to large amounts of e-waste (possibly Tbilisi) but also minimise the distance to the harbour in order to ensure that logistical costs for exported materials are minimised.

[2] It is important to remark, however, that this proxy only covers a number of technical costs and entirely omits system costs of EPR schemes which can be associated to awareness raising activities or monitoring & enforcement.

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ANNEX I

Table 8: Fixed costs, unit price and variable costs

Fixed costs	
Item	**Price/unit**
Rent for facility	0.90 USD/m²
Labour	830.00 USD/month
Electricity	0.07 USD/kWh
Transport	4.00 USD/km
Tools	25.00 USD/unit per month
Cable Stripper *(optional)*	154.15 USD/ unit per month
Cable Shredder *(optional)*	555.00 USD/ unit per month
Small degasser *(optional)*	3,468.60 USD/ unit per month
Unit price	
Item	**Price/unit**
Washing machines	15.07 USD
Fridge or combined fridge/freezer	14.68 USD
Household AC	53.29 USD
CRT monitors	1.45 USD
Laptop, notebook, tablet	4.11 USD
Mobile phones	0.16 USD
TVs	6.38 USD
Dishwashing machine	16.38 USD
Oven	9.45 USD
Variable costs	
Item	**Price/unit**
Washing machines	16.82 USD
Fridge or combined fridge/freezer	16.48 USD
Household AC	16.95 USD
CRT monitors	2.00 USD
Laptop, notebook, tablet	0.42 USD
Mobile phones	0.04 USD

TVs	2.49 USD
Dishwashing machine	5.28 USD
Oven	4.50 USD

ANNEX II

Table 9: Break- down of material composition of E-waste categories

Fractions	Washing machines		Fridge/ Freezers		Household AC		CRT monitors		Laptop, notebook, tablet		Mobile phones		TVs		Dishwashing machine		Oven	
	%	kg	%	kg	%	kg	%	kg	%	kg	%	kg	%	Kg	%	kg	%	kg
Aluminium	5.00%	3.75 kg	5.31%	1.70 kg	9.00%	3.84 kg	1.40%	.08 kg	5.40%	.15 kg	3.40%	.006 kg	5.50%	.79 kg	0.80%	.32 kg	1.90%	.95 kg
Iron/steel	38.00%	28.50 kg	52.27%	16.73 kg	46.00%	19.61 kg	11.50%	.69 kg	4.80%	.13 kg	1.70%	.003 kg	45.00%	6.49 kg	45.20%	18.08 kg	81.30%	40.65 kg
Copper	1.38%	1.04 kg	3.06%	.98 kg	18.00%	7.68 kg	1.50%	.09 kg	0.10%	.00 kg	0.10%	.000 kg	0.00%	.00 kg	1.50%	.60 kg	0.20%	.10 kg
Bronze/ Brass	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.30%	.01 kg	0.10%	.000 kg	0.00%	.00 kg	0.20%	.08 kg	0.50%	.25 kg
Stainless steel	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	1.00%	.03 kg	0.20%	.000 kg	0.00%	.00 kg	23.20%	9.28 kg	0.70%	.35 kg
Plastics	22.00%	16.50 kg	15.40%	4.93 kg	18.00%	7.68 kg	19.50%	1.17 kg	27.60%	.77 kg	27.50%	.047 kg	24.20%	3.49 kg	14.10%	5.64 kg	1.10%	.55 kg
Wood	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	2.10%	.84 kg	0.00%	.00 kg
Cable without plugs	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	2.50%	.15 kg	7.00%	.20 kg	4.80%	.008 kg	1.60%	.23 kg	1.50%	.60 kg	1.30%	.65 kg
Processors	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.70%	.02 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Power supply	0.57%	.43 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
PCB Grade I	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	14.00%	.39 kg	10.30%	.018 kg	5.50%	.79 kg	0.00%	.00 kg	0.00%	.00 kg
PCB Grade II	0.00%	.00 kg	0.00%	.00 kg	3.00%	1.28 kg	2.00%	.12 kg	0.20%	.01 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
PCB Grade III	3.00%	2.25 kg	0.00%	.00 kg	0.00%	.00 kg	3.00%	.18 kg	0.00%	.00 kg	6.40%	.011 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Motors/inductors/ transformers	0.70%	.53 kg	0.00%	.00 kg	0.00%	.00 kg	5.00%	.30 kg	1.20%	.03 kg	15.60%	.027 kg	1.70%	.25 kg	0.00%	.00 kg	0.00%	.00 kg
Deflection coil	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	4.50%	.27 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Mixed Scrap	2.00%	1.50 kg	6.66%	2.13 kg	0.00%	.00 kg	0.60%	.04 kg	15.80%	.44 kg	2.10%	.004 kg	3.40%	.49 kg	0.00%	.00 kg	0.00%	.00 kg
Glass	2.00%	1.50 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.000 kg	3.60%	.52 kg	0.00%	.00 kg	0.00%	.00 kg
Residual waste	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.60%	.02 kg	0.00%	.000 kg	2.20%	.32 kg	9.50%	3.80 kg	13.00%	6.50 kg
Batteries	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	15.60%	.43 kg	25.10%	.043 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Capacitors	0.35%	.26 kg	0.00%	.00 kg	0.00%	.00 kg	0.40%	.02 kg	0.00%	.00 kg	0.00%	.000 kg	0.20%	.03 kg	0.00%	.00 kg	0.00%	.00 kg
LCD-displays	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	5.60%	.15 kg	2.70%	.005 kg	6.20%	.89 kg	0.00%	.00 kg	0.00%	.00 kg
Fluorescent Tubes	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.10%	.00 kg	0.00%	.000 kg	0.90%	.13 kg	0.00%	.00 kg	0.00%	.00 kg
CRT glass	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	47.85%	2.87 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Phosphor powder	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.25%	.02 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Refrigerant gas	0.00%	.00 kg	4.70%	1.50 kg	6.00%	2.56 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Concrete	25.00%	18.75 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	1.90%	.76 kg	0.00%	.00 kg
Polyurethane foam	0.00%	.00 kg	12.60%	4.03 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.000 kg	0.00%	.00 kg	0.00%	.00 kg	0.00%	.00 kg
Total	**100.00%**	**75.00 kg**	**100.00%**	**32.00 kg**	**100.00%**	**42.64 kg**	**100.00%**	**6.00 kg**	**100.00%**	**2.79 kg**	**100.00%**	**.170 kg**	**100.00%**	**14.42 kg**	**100.00%**	**40.00 kg**	**100.00%**	**50.00 kg**

ANNEX III

Table 10: Investment costs and technical specifications of processing equipment

Equipment	Average price [USD]	Payback time [yrs]	Payback time [month]	Monthly costs [USD]	Power Usage [kW]	Power Usage per month [kWh]
Tools	1,000.00 USD	3	36	25.00 USD	0	0
Cable striper (used)	6,166.00 USD	3	36	154.00 USD	8	1,280.00
Cable shredder (new)	37,000.00 USD	5	60	555.00 USD	6.5	1,040.00
Small degasser (stage 1) (new)	369,984.00 USD	8	96	3,469.00 USD	8.5	1,360.00

ANNEX IV

Table 11: Scenario- specific fixed costs (monthly)

		Scenario 1		Scenario 2		Scenario 3	
	Cost	Amount needed	Total	Amount needed	Total	Amount needed	Total
Fixed Costs (monthly)			**2,895.00 USD**		**4,592.35 USD**		**12,364.60 USD**
Rent	0.90 USD/ m²	200 m²	180.00 USD	500 m²	450.00 USD	1500 m²	1,350.00 USD
Labour (fixed staff)	830.00 USD/ employee	1 employee	830.00 USD	1 employee	830.00 USD	2 employees	1,660.00 USD
Electricity	0.07 USD/ kWh	4000 kWh	260.00 USD	10.000 kWh	650.00 USD	30.000 kWh	1,950.00 USD
Electricity for Equipment	0.07 USD/ kWh	0	0.00 USD	1.280 kWh	83.20 USD	2.400 kWh	156.00 USD
Transport	4.00 USD/ km	400 km	1,600.00 USD	600 km	2,400.00 USD	800 km	3,200.00 USD
Tools	25.00 USD/ tool	1	25.00 USD	1	25.00 USD	1	25.00 USD
Cable stripper (used)	154.15 USD/ tool	0	0.00 USD	1	154.15 USD	0	0.00 USD
Cable shredder (new)	555.00 USD/ tool	0	0.00 USD	0	0.00 USD	1	555.00 USD
Small degasser (stage 1) fridge/freezer (new)	3,468.60 USD/ tool	0	0.00 USD	0	0.00 USD	1	3,468.60 USD

ANNEX V

Table 12: ARFs in Switzerland, Belgium and Canada per catergory

Category	Switzerland[3]	Belgium[4]	Alberta, Canada[5]
Washing machines	n/a	0.61 USD	n/a
Fridge/ Freezer	n/a	12.20 USD	n/a
Household AC	n/a	n/a	n/a
CRT monitors	n/a	0.61 USD	n/a
Laptop, notebook, tablet	2-6 USD	0.06 USD	0.93 USD
Mobile phones	0.40 USD	0.06 USD	n/a
TVs	2-28 USD	6.10 USD	3-7.8 USD
Dishwashing machine	n/a	0.61 USD	n/a
Oven	n/a	0.61 USD	n/a

[3] Swico Recycling 2018
[4] Recupel 2017
[5] Alberta Recycling 2017