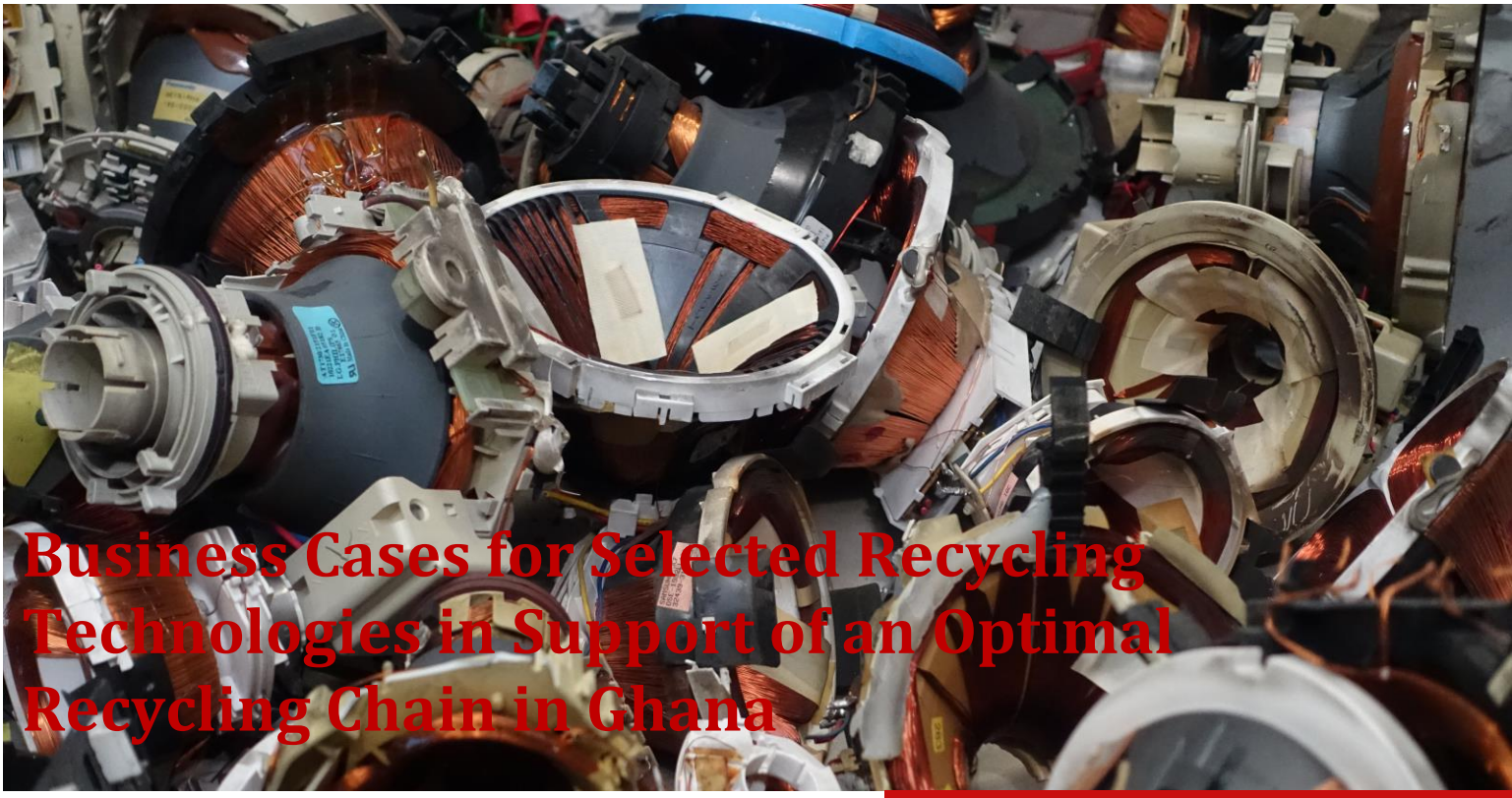


Business Cases for Selected Recycling Technologies in Support of an Optimal Recycling Chain in Ghana

GIZ e-Waste Programme Ghana
LOT 2: Recycling chains, business models, and capacity development

November 2019

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

MESTI

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH
Registered offices
Bonn and Eschborn

GIZ Country Office Accra
7 Volta Street | Airport Residential Area
P.O. Box KIA 9698
Accra | Ghana
F +233 302 760 448
E giz-ghana@giz.de
I www.giz.de/ghana
I www.giz.de

Programme/project description:
Environmentally Sound Disposal and Recycling of E-waste in Ghana (E-Waste Programme)
Airport Residential Area
Accra – Ghana
Head of Programme: Markus Spitzbart
https://www.giz.de/en/worldwide/63039.html

Authors:
Manuele Capelli
Mathias Schluep (World Resources Forum), Switzerland

Editor:
Manuele Capelli
Mathias Schluep (World Resources Forum), Switzerland

Design/layout, etc.:
Manuele Capelli
Mathias Schluep, Switzerland

Photo credits/sources:
Main text: Source given next to image
Cover Page: GIZ/ E-Waste Programme

On behalf of
German Federal Ministry for Economic Cooperation and Development (BMZ)
Division 203 West Africa II
Contact person at the ministry: Dr. Friederike Fuhlrott
Bonn

GIZ is responsible for the content of this publication.

Accra, November 2019

Table of Contents

Executive Summary

This report covers the financial assessment of the different E-waste categories with data specific to **Ghana**, to provide a basis for the financial viability of e-waste recycling technology options for Ghana. Due to the lack of quantitative data, some figures in this report are based on estimations and must be used with precaution and seen as a realistic range of values instead of absolute values.
The four covered categories of e-waste by this report are: **Lighting equipment**, **CRT and FPD monitors**, **cables** and **used lead acid batteries (ULABs)**.
For each category the value of waste material is estimated, recycling technologies identified, investment and running costs calculated and a profit/loss projection established.
The end-product of the recycling of **Lighting equipment** is crushed glass, with an estimated value of **197 USD/ton**. For a fully operating 200kg/h glass recycling machine (LP400) a **gate fee** of approx.. **362 USD/ton** (232 USD/ton for OPEX) is needed to ensure financial stability. This is necessary due to the high cost of an industrial lamp recycling machine which is required to remove the hazardous fractions contained in many lamps ("Swedish Dry Processing Technology").

For **CRT** and **FPD monitors**, a break-even point can be achieved in theory but is unlikely to be reached due to the low volumes available for processing. With a moderate scenario of two tons per day (equals 730 tons/year), a gate fee of **176 USD** per ton is needed to cover all costs (62.7 USD for OPEX).

Cable recycling is **financially sustainable** if a volume of **100 – 150 tons/year** is available to be processed. This assumes that a price for scrap cables of 1000 USD/ton has to be paid. This break-even point is much lower compared to the other categories due to the high value of copper and assumed to be possible to achieve, removing the need of a gate fee for cable recycling. Optimal quantity for the specifications of the facility used in the assessment is 504 tons/year.

Similarly, **used lead acid battery (ULABs)** recycling can be done with a net positive balance, given enough available feedstock and a potential profit of 657 USD/ton of raw material. This report estimates a break-even point achieved at **860 tons/year** of primary material covering all costs per year, and at **614 tons/year** to cover OPEX. If the break-even point is achieved, no gate fee is necessary.

AT A GLANCE:

Categories	Estimated amount available in Ghana [tons/year]	volumes needed for full operation (given specifications used in this report) [tons/year]	Break-even point (tons/year)	estimated feedstock amount available [ton]	gate fee for expected amount (USD/ton)	Estimated gate fee range [USD/ton]
Lighting	1500	500 (LP200)	never	500	362	80 - 400
CRT/FPD	5850	3568	1825	730	176	100 - 250
Cables	no data	504	116 - 154	> 154	none	none

ULABs	10'000 - 15'000	1260	614 - 860	> 860	none	none

1. Lighting equipment

1.1. Introduction

1.1.1. Input fractions

Lighting equipment refers to all devices used as luminaries. Table 1 shows the most common types of lamps and their respective market share. The market share is based on an estimation in South Africa, the exact market shares of the different types for Ghana is unknown but thought to be similar.
Lamps often contain hazardous fractions which need adequate recycling procedures to minimize health and environmental damages.
For a large-scale recycling facility, the preferred technology is the "Swedish dry processing method" [2] which involves mechanical crushing of the lamps and extraction of hazardous fractions. As a result, the end-product is crushed glass which can be sold to downstream producers for further beneficiation.

TABLE 1: SHARE OF AVAILABLE LIGHTING WASTE, NOTICEABLY FLUORESCENT TUBES MAKE UP THE LARGEST SECTION WITH 50%. THE AVERAGE VALUE OF A TON OF CRUSHED LAMPS IS 197.53 USD, WITH AN ESTIMATED VARIANCE OF 30%.

Type	Value per ton [USD]	Market share	Value/market share ton [USD]
Fluorescent tubes	150.6	50%	75.3
CFL's	186.2	8%	14.89
CFL-i's	223.3	20%	44.66
HID's	140.7	5%	7.035
LED's (lamps & tubes)	321.4	12%	38.57
Int. LED fittings	341.4	5%	17.07
Total avg. value per Ton		*100%*	**197.53**

According to the e-Waste Monitor report of 2017, there is a total of 39'000 tons e-waste generated in Ghana. Generally, lamps and other lighting equipment make up around 4% of total e-Waste, which would result in **1500 tons** of lighting waste available in Ghana per year [1].

1.1.2. Recycling technology

There exist two suitable versions of the "Swedish Dry Processing Recycling Machine" for the volumes estimated for Ghana as seen in table 2.

TABLE 2: OVERVIEW OF SPECIFICS OF THE TWO RECYCLING MACHINES

Type	Capacity per hour [kg]	Hours in operation per day	Capacity per year (with 2520 yearly hours) [kg/year]

LP200	200	10	5.04E+05
LP400	400	10	1.01E+06

Referring to the estimated 1500 tons/year, operating the LP200 at 100% capacity would require a collection rate of **~33%**. Correspondingly, operating a LP400 machine would require a collection rate of 66%.

1.2. Financial assessment

1.2.1. Capital expenditures (CAPEX)

Depending on the available volume, it needs to be decided which of the two machines is suited better. Table 3 shows the different initial expenditures for the two options.

TABLE 3: CAPITAL EXPENDITURES (CAPEX) FOR THE TWO MACHINE OPTIONS, IDENTICAL EXCEPT OF MACHINE PRICE

Item	LP200	LP400
LP200, 200kg/h Recycling machine	**400,000**	
LP400, 400kg/h Recycling machine		**500,000**
Air Compressor	10,000	10,000
Forklift 2,5 ton - no diesel	20,000	20,000
Ventilation System	2,000	2,000
Storage system	5,000	5,000
Scales	1,000	1,000
Pallet jacks and drum handlers	200	200
Machine recyclables Containers	1,200	1,200
Machine feedstock containers	2,400	2,400
210 ltr. Drums (feed and recyclables)	600	600
Bulk bags / other large capacity storage containers	500	500
Operations Vehicle 1-ton vehicle	35,000	35,000
Office Equipment, Furniture, IT, etc…	8,000	8,000
Waste Compliance Software	25,000	25,000
Total CAPEX	**510,900**	**610,900**

The bulk of investment is the cost of the recycling machines, however the LP400 has a proportionally lower cost per ton compared to the LP200. If volumes available allows it, LP400 would be preferred due to cost efficiency (see also later sections).

1.2.2. Operational expenditures

Likewise, the operating costs for the two options are depicted by table 4. The LP200 is a bit shorter and thus less space is needed.

TABLE 4: OPERATIONAL EXPENDITURES (OPEX) FOR THE TWO MACHINE OPTIONS, IDENTICAL EXCEPT FOR FACILITY SIZE, ELECTRICITY COST AND FUTURE PROVISIONS FOR CAPEX REPLACEMENT

Item	Annual Cost with LP200 [USD]	Annual Cost with LP400 [USD]
Facility		
Facility, min 640sqm inside warehouse area	46,080	
Facility, min 800sqm inside warehouse area		57,600
Facility costs (water, electricity, etc.) machine Kwh/month approx. 3500kwh	10,000	12,000
Minimum Staff		
Waste Control Officer / Ops Manager	6,000	6,000
Machine Operators	3,600	3,600
Operator Assistant	1,840	1,840
Forklift Driver / Stockist	1,840	1,840
Administrator / Scale Operator	3,000	3,000
Accounts Administrator	4,810	4,810
Sales	7,500	7,500
General/Financial Manager	9,620	9,620
Office		
Subscriptions, annual renewals	1,440	1,440
Consumables	360	360
Operations		
PPE	6,000	6,000
Fuel	2,400	2,400
Vehicle/Forklift Maintenance	12,000	12,000
Machine Spare/Wear parts (pro-rated)	100,000	150,000
Financials		
Future Provisions for Capital Expenditures (CAPEX) replacement; depreciation over 60 (Machine) and 12 months (Containers)	102,180	145,940
Total OPEX (without depreciation/future provision)	**216,490**	**280,010**

Figures such as wages, rent and facility costs are Ghana specific, see annex 5.1 for a more detailed explanation on these values.

1.2.3. Profit/loss statement

Out of the data given in tables 1 – 4, the profit/loss can be calculated as shown in table 5.

TABLE 5: DEPICTION OF TOTAL COSTS AND REVENUE IN USD

Type	Total Investment costs	yearly repayment[1]	Operating costs	Total costs per year (without fut. Provisions)	Value generated (Revenue)	Yearly Balance with Loan
LP200	510,900	65,906	216,490	**282,396**	99,555	**-182,841**
LP400	610,900	78,806	280,010	**358,816**	199,109	**-159,706**

1.3. Discussion

One can see that costs far exceed the revenues generated. This is on one hand side due to the necessity of a sophisticated and therefore costly recycling technology to thoroughly remove the hazardous fractions (mercury) from the glass and, on the other hand side, the relative low value of the recovered materials. To make lamp recycling viable, a specific fee per ton needs to be provided ("gate fee"). The necessary gate fee to make lamp recycling viable in Ghana is computed in table 6.

TABLE 6: DEPICTION OF TOTAL COSTS AND REVENUE OF THE LIGHTING RECYCLING FACILITY IN USD

Type	Gate fee for all costs CAPEX & OPEX [USD]	Gate fee for OPEX only [USD]
LP200 @ full capacity (500 tons/year)	362.78	232.01
LP400 @ full capacity (1000 tons/year)	158.44	80.26

If initial investments are funded otherwise and the gate fee is only needed to cover operational costs (OPEX), the value of the fee is almost halved. These values highly depend on the accuracy of the estimated value/ton (here 197 $/ton), which is difficult to assess and could vary up to a factor of 50%. Therefore, the calculation must be taken more as a reference point, in which range costs and revenues are likely to be and not as an absolute value.

Furthermore, to operate the recycling machines at full capacity (and thus maximum efficiency), high collection rates (see 1.1.2) are needed which currently cannot be achieved realistically in Ghana.

[1] Assumption of a 10-year repayment plan for Capital Expenditures (CAPEX), with an interest rate of 29% (see also annex 5.1)

2. CRT-FPD monitors

2.1. Introduction

2.1.1. Input fractions

This section considers the different screen technologies "Cathode Ray Tubes (CRT)" and "Flat Panel Displays (FPD)". Table 7 shows the most common types of monitors and their respective market share. The market share is based on an estimation in South Africa, the exact market shares of the different types for Ghana are unknown but expected to be similar.

TABLE 7: SHARE OF AVAILABLE MONITOR WASTE, NOTICEABLY LCD FPP MAKE UP THE LARGEST SECTION WITH 50%. THE AVERAGE VALUE OF A TON OF MATERIALS RECOVERED FROM MONITORS IS 116.01 USD

Type	Market Share	Value per ton [USD]	Value/market share ton [USD]
CRT	10.00%	91.86	9.19
LCD FP	50.00%	112.84	56.42
LED FP	30.00%	112.84	33.85
Plasma FP	5.00%	208.39	10.42
OLED FP	5.00%	122.71	6.14
Weighted total	*100.00%*		**116.01**

According to the e-Waste Monitor report of 2017, there is a total of 39'000 tons E-waste generated in Ghana. Generally, monitors make up around 15% of total e-Waste, which would result in **5850 tons** of monitor waste available in Ghana per year [1].

2.1.2. Recycling technology

A recycling facility that covers all types of monitors must have recycling machines that can deal with both CRT and FPD screen technologies. For CRT a **"Hot band"** is used, where the CRT monitor is put through to separate the hazardous fractions from the front glass. After this, it can be further dismantled manually. For the FPD a **"Flat Panel Processor (FPP)"** is required, which makes precise cuts to prepare the FPD for further dismantling, which is also done manually [2].

TABLE 8: CAPACITY OF A FACILITY WITH ONE CRT HOTBAND AND ONE FPP

Machines	Capacity per hour (kg)	Hours in operation per day	Capacity per year (with 2520 yearly hours) (kg)
CRT Hot Band and FPP	1415	10	**3.57E+06**

2.2. Financial assessment

2.2.1. Capital expenditures

Table 9 shows the initial expenditure that can be expected.

TABLE 9: CAPITAL EXPENDITURES (CAPEX) FOR A RECYCLING FACILITY IN GHANA EQUIPPED WITH A CRT HOT BAND AND FPP IN USD

Item	Amount	Cost each [USD]	Cost total [USD]
CRT Hot Band	1	100,000	100,000
FPP with discs	1	440,000	440,000
Air Compressor Large Reservoir for air tools	1	25,000	25,000
Forklift 1,5 ton - no diesel	1	10,000	10,000
Ventilation System	1	2,000	2,000
Scales	1	500	500
Pallet jacks and drum handlers	1	100	100
Machine recyclables Containers	5	120	600
Machine feedstock containers	5	120	600
210 ltr. Drums (recyclables)	10	30	300
Bulk bags/large capacity storage containers	20	10	200
Operations Vehicle 1-ton vehicle	1	35,000	35,000
Office Equipment, Furniture, IT, etc.	2	1,000	2,000
Waste Compliance Software	1	25,000	25,000
Total CAPEX			**641,300**

The largest investments are the CRT Hot Band and the Flat Panel Processor, accounting for over 80% of all capital investment.

2.2.2. Operational expenditures

Likewise, the operating costs are depicted by table 10.

TABLE 10: OPERATIONAL EXPENDITURES (OPEX) FOR A CRT AND FPP RECYCLING FACILITY IN GHANA

Line Item	Monthly [USD]	Annual [USD]
Facility		
Facility min 500 sqm inside warehouse ($72 per sqm)	3,000	36,000
Facility costs (water, electricity, etc.) machine Kwh/month approx. 3500kwh	500	6,000
Minimum Staff		
Waste Control Officer / Ops Manager	600	7,200
Dismantlers x 8 @ 150 USD each	1,200	14,400
Forklift Driver / Stockist	150	1,800
Administrator / Scale Operator	400	4,800
Accounts Administrator	400	4,800
Sales	400	4,800
General/Financial Manager	800	9,600
Office		
Subscriptions, annual renewals	120	1,440
Consumables	30	360
Operations		
PPE	200	2,400
Fuel	100	1,200
Vehicle/Forklift Maintenance	1,000	12,000
Machine Spare/Wear parts (for cutting discs)	2,000	24,000
Financials		
Future Provisions for Capital Expenditures (CAPEX) replacement; depreciation over 60 and 12-month	10,801	129,620
Total OPEX (without Future Provisions)	**10,900**	**130,800**

Figures such as wages, rent and facility costs are Ghana specific, see annex for a more detailed explanation on these values.

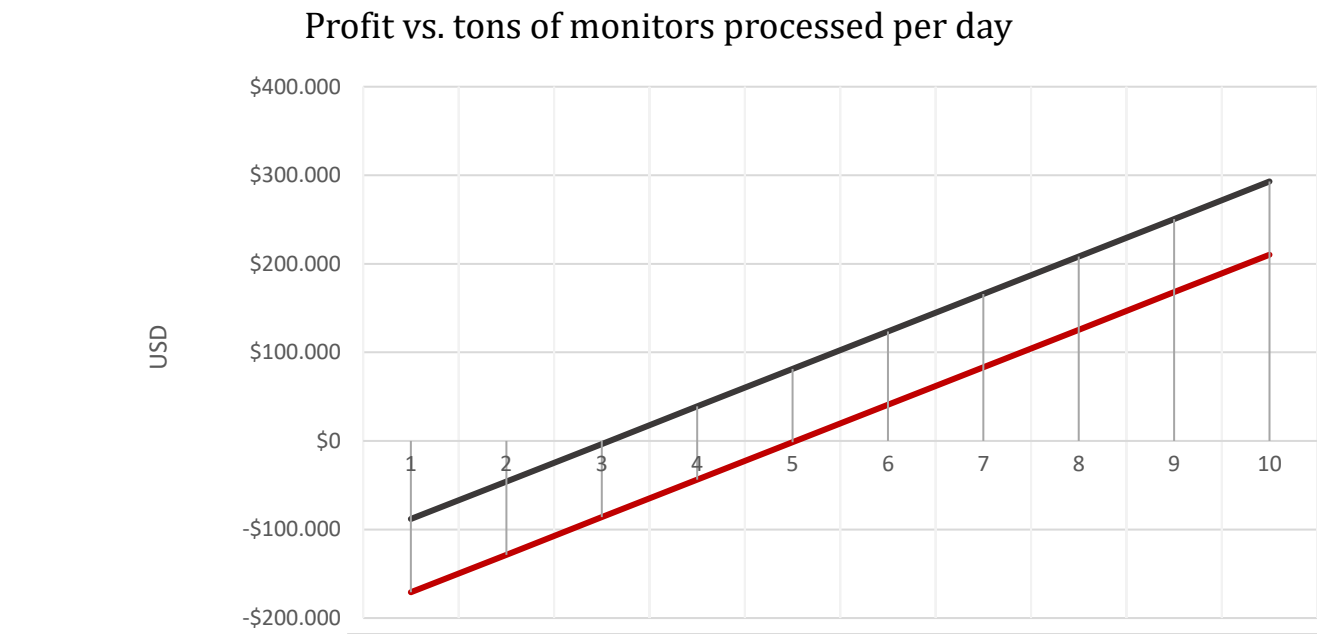
2.2.3. Profit/loss statement

Out of the data given in tables 7 – 10, the profit/loss can be calculated as shown in table 11.

TABLE 11: DEPICTION OF TOTAL COSTS

Total Investment costs [USD]	yearly repayment[2] [USD]	Operating costs [USD]	Total costs per year (without fut. Provisions) [USD]
641,300	82,727	130,800	**213,528**

Total revenue is highly dependent on availability of feedstock for the recycling machines. As figure 1 shows, the break-even point for Ghana is just above 5 tons per day (=1825 tons/year) if all costs need to be covered. If Initial investment (CAPEX) is otherwise funded, and only operational costs need to be covered, the break-even point is at 3 tons per day (1095 tons/year). Assuming two tons per day (equals 730 tons/year), a gate fee of **176 USD** per ton is needed to cover all costs (**62.7 USD** for OPEX).



	1	2	3	4	5	6	7	8	9	10
Balance covering all costs	-$170.824	-$128.480	-$86.137	-$43.793	-$1.449	$40.894	$83.238	$125.582	$167.925	$210.269
Balance covering only OPEX	-$88.096	-$45.753	-$3.409	$38.935	$81.278	$123.622	$165.966	$208.309	$250.653	$292.997

Figure 1: Balance projection for a CRT-FPD facility depending on daily capacity of feedstock

[2] Assumption of a 10-year repayment plan for Capital expenditures (CAPEX), with an interest rate of 29% (see also annex 5.1)

2.3. Discussion

The optimal volume for a facility with the specifications as presented in section 2.2 is 14 tons per day, which is roughly equivalent to one fully loaded truck each day. Realistically, substantially less volumes would be expected in Ghana (< 3 tons per day), due to number of Monitors being reused and stripped for parts and other informal entities in the market (numbers based on expert estimations). Hence it has to be expected that a CRT-FPD recycling facility in Ghana is not financially stable without a gate fee, as for the break-even point higher volumes are needed.
In addition, as of estimation by the global e-waste monitor, the trend towards thinner screens with reduced material resources leads to a further decline of the value/ton for monitors, further diminishing financial stability of a recycling facility solely focusing on monitors [1].

As there is a significant uncertainty in the exact value of the figures used for the calculation, the presented financial assessment must be evaluated carefully, and more seen as a guideline instead of an exact statement of revenue and costs.

3. Cables

3.1. Introduction

3.1.1. Input fractions

This section considers the different types of cables as described in "Downstream Technology Option for e-waste recycling" [2]. Table 12 shows the most important categories of cables and their respective market share. The market share is based on an estimation from South Africa. The exact market shares of the different types for Ghana is unknown but thought to be similar.

TABLE 12: SHARE OF AVAILABLE CABLE WASTE, NOTICEABLY THE AVERAGE VALUE OF A TON OF MATERIALS RECOVERED FROM CABLES IS 3416 USD. DUE TO THE HIGH COPPER CONTENT, CABLE WASTE IS MUCH MORE VALUABLE THAN THE OTHER TYPES OF E-WASTE AS DESCRIBED IN THE OTHER CHAPTERS

Type	Value per ton	Market share	Value/market share ton [USD]
Insulated Copper Cable	3,736.00	65.00%	2,428.40
Steel Sheathed Cable	2,566.00	20.00%	513.20
Communications Cable	3,160.00	15.00%	474.00
Weighted total		*100.00%*	**3,415.60**

According to the e-Waste Monitor report of 2017, there is a total of 39'000 tons of E-waste generated in Ghana [1]. However, as cables are not a separate category and can also come from other sources it is difficult to estimate what the available quantity per year in Ghana is (see figure 2).

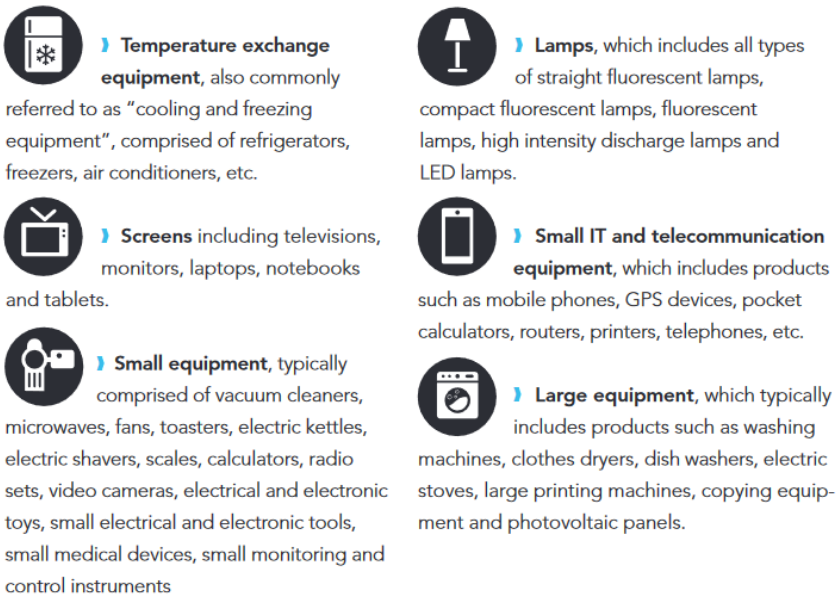


Figure 2: E-Waste categories as defined by the Global E-Waste Monitor. All categories include cables to some extent, adding uncertainty to the overall quantity of cable scrap available

3.1.2. Recycling technology

As described in the other GIZ report "Downstream Technology Option for E-waste recycling" there are two methods for an environmentally sound cable recycling [2]. Firstly, there is a small-scale manual stripping machine, where cables are fed into the cable stripper and the copper content is separated from the plastic insulation. Secondly, if a sufficient volume is available an industrial cable processing machine is used, which cuts the cables in small segments and then separates the insulation in a second step. This report assumes that enough material is available for the industrial solution, the processing machine considered here has a capacity of 200 kg/hour.

3.2. Financial assessment

The following sections present the cost of the initial investment necessary to build up a cable recycling facility as well as operational costs. It further makes an estimation of the profitability of such a facility and determines necessary break-even points for sustainable operation.

3.2.1. Capital expenditures

Depending on the available feedstock material, several manual cable stripping machines or an industrial large-scale solution might be preferred.
Cost of manual cable stripping machines range between 2,000 – 15,000 USD, whereas the cost of a large-scale solution lies around 600,000 USD.

TABLE 13: ESTIMATION OF CAPITAL EXPENDITURES (CAPEX) FOR A CABLE RECYCLING FACILITY IN GHANA

Item	Amount	Cost each [USD]	Cost total [USD]
Recycling machine 200kg/h	1	600,000	600,000
Air Compressor 1	1	10,000	10,000
Forklift 2,5 ton - no diesel	1	20,000	20,000
Ventilation System	1	2,000	2,000
Storage system	1	5,000	5,000
Scales	2	500	1,000
Pallet jacks and drum handlers	2	100	200
Machine recyclables Containers	10	120	1,200
Machine feedstock containers	20	120	2,400
210 ltr. Drums (recyclables)	20	30	600
Bulk bags/large capacity storage containers	50	10	500
Operations Vehicle 1 ton vehicle	1	35,000	35,000
Office Equipment, Furniture, IT, etc…	8	1,000	8,000
Waste Compliance Software	1	25,000	25,000

Total Capital Expenditures (CAPEX)	**710,900**

3.2.2. Operational expenditures

TABLE 14 ESTIMATION OF OPERATIONAL EXPENDITURES (OPEX) FOR A CABLE RECYCLING FACILITY IN GHANA

Line Item	Monthly [USD]	Annual [USD]
Facility		
Facility min 800 sqm inside warehouse ($72 per sqm)	4,800	57,600
Facility costs (water, electricity, etc.) machine Kwh/month approx. 3500kwh	900	10,800
Minimum Staff		
Waste Control Officer / Ops Manager	600	7,200
Machine Operator	400	4,800
Operator Assistant	150	1,800
Forklift Driver / Stockist	150	1,800
Administrator / Scale Operator	400	4,800
Accounts Administrator	400	4,800
Sales	400	4,800
General/Financial Manager	800	9,600
Office		
Subscriptions, annual renewals	120	1,440
Consumables	30	360
Operations		
PPE	500	6,000
Fuel	200	2,400
Vehicle/Forklift Maintenance	1,000	12,000
Machine Spare/Wear parts (for cutting discs)	12,500	150,000
Financials		
Future Provisions for Capital Expenditures (CAPEX) replacement;	12,161	145,940
depreciation over 60 and 12 month		
Total Operational Cost (without Future Provisions)	**23,350**	**280,200**

Figures such as wages, rent and facility costs are Ghana specific, see annex for a more detailed explanation on these values.

Due to the low wages in Ghana, the running costs for rent and other facility costs make up the bulk of all expenditures, as can be seen in table 14.

3.2.3. Profit/loss statement

TABLE 15: DEPICTION OF ALL COSTS OF A CABLE RECYCLING FACILITY IN USD/YEAR IN GHANA

Total Investment costs [USD]	yearly repayment[3] [USD]	Operating costs [USD]	Total costs per year (without fut. Provisions) [USD]
710,900	91,706	280,200	**371,906**

TABLE 16: POTENTIAL YEARLY PROFIT OF A CABLE RECYCLING OPERATION IN USD/YEAR, ASSUMING NO ADDITIONAL COST FOR SCRAP CABLES

Average value of raw material [see table 12] [USD/ton]	Yearly Amount (Estimation to match Recycling Machine capacity) [tons]	Total Revenue [USD]	Balance (with Loan) [USD]
3,415.60	504	**1,721,462**	**1,349,556**

It can be seen that, if the recycling machine can be operated at full capacity, a large yearly profit is possible (**504 tons/year**), assuming waste material is collected at no extra cost. Given the investment and operating costs as calculated in the previous sections, a break-even can be achieved at **109 ton/year** (and **82 ton/year** to cover just operational costs), again assuming that waste material is collected at no extra cost.

A more realistic assumption is that cables need to be purchased from collectors.
According to current trade prices found on the internet, scrap cables are traded at approximately 1000 USD/ton **[3]**. This is about a third of the value of processed material (as seen in table 12).
This reduces profitability of copper cable recycling and thus requires a higher volume to reach a break-even point.

If a purchasing cost of $1000/ton for raw material is assumed, break-even would be 154 ton/year (116 ton/year for operational costs only).

3.3. Discussion

Of all technologies considered in this report, copper cable recycling is the most lucrative due to the simplicity of recycling and the high value of copper. A break-even point can be achieved at a relatively low volume per year and a recycling facility focusing on copper cables is likely to be profitable given easy access to feedstock material. The profitability of copper recycling may also be able to carry the load of the other technology recycling options when integrated into a national facility dealing with various types of E-waste.

[3] Assumption of a 10-year repayment plan for Capital expenditures (CAPEX), with an interest rate of 29% (also see annex 5.1)

4. Used lead acid batteries (ULABs)

4.1. Introduction

4.1.1. Input fractions

This section considers recycling of used lead acid batteries (ULABs), as used in most motorized vehicles. Table 17 shows the value of a ton of lead acid battery waste based on the containing fractions. Overall, lead acid battery waste has a positive value.

TABLE 17: VALUE OF A TON OF ULABS BASED ON CONTAINING FRACTIONS IN USD/TON

Fractions of ULABs	Volume fraction	Value per ton [USD]	Value/Volume fraction per ton [USD]
Lead Chips	0.300	2000	600.00
Electrode Paste	0.430	2000	860.00
Sulphuric Acid	0.130	-100	-13.00
Polypropylene	0.065	240	15.60
Other Plastics	0.050	-80	-4.00
Ebonite	0.020	-40	-0.80
Others-Waste	0.005	-40	-0.20
	100.00%		**1457.60**

As ULABs are commonly found in motorized vehicles, they are often not considered as a category for e-waste. Nevertheless, a baseline assessment has been done under the Sustainable Recycling Industries (SRI) programme and the amount of ULABs was estimated at 36'700 tonnes per year in Ghana [4].

4.1.2. Recycling technology

The capacity of a smelter commonly used for ULABs recycling lies at approximately 500 kg/h of operation. Table 18 shows that the capacity per year would amount to **1260 tons**. Given the estimation of ULABs available, operation at full capacity should be achievable even with low collection rates.

TABLE 18: ASSUMED TYPICAL CAPACITY OF A ULAB FACILITY IN GHANA

Machines	Capacity per hour [kg]	Hours in operation per day [h]	Capacity per year (with 2520 yearly hours) [kg]
Smelting operation	500	10	**1.26E+06**

4.2. Financial assessment

When considering the development of a ULAB recycling facility one must account for the access to the waste (volume of waste available) and the availability and proximity of downstream partners for the fractions as well as other entities in the market that will compete for the same recyclable materials.
ULAB recycling features high overhead costs involved in running a compliant operation, due to health safety and environmental standards. These requirements are factored into the operational costs, though this will vary from country to country. Ghana has seen various lead smelters, but some of them having had to shut down due to compliance issues. Known to the authors is that there are currently two smelters running in Ghana, one under unclear compliance level, and the other one being a newly built and state of the art facility.

4.2.1. Capital expenditures

Table 19 shows the estimated initial expenditure needed for a ULAB recycling facility in Ghana.

TABLE 19: CAPITAL EXPENDITURES (CAPEX) FOR A ULAB RECYCLING FACILITY IN GHANA

Item	Amount	Cost each [USD]	Cost total [USD]
Smelting Operation with capacity of 500 kg/h	1	800,000	800,000
Basic Acid storage and separation	1	100,000	100,000
Flue gas separation plant	1	150,000	150,000
Air Compressor	1	25,000	25,000
Forklift 3,5 ton - no diesel	1	35,000	35,000
General Ventilation System	1	5,000	5,000
Storage System	1	25,000	25,000
Weigh bridges	1	10,000	10,000
Pallet jacks and drum handlers	2	100	200
Machine recyclables Containers	100	120	12,000
Machine feedstock containers	200	120	24,000
210 ltr. Drums (recyclables)	50	30	1,500
Bulk bags/large capacity storage containers	100	10	1,000
Operations Vehicle 1-ton vehicle	1	35,000	35,000
Office Equipment, Furniture, IT, etc…	8	1,000	8,000
Waste Compliance Software	1	25,000	25,000
	Total CAPEX		**1,256,700**

4.2.2. Operational expenditures

Likewise, the operating costs are depicted in table 20.

TABLE 20: OPERATIONAL EXPENDITURES (OPEX) FOR A ULAB RECYCLING FACILITY IN GHANA

Line Item	Monthly [USD]	Annual [USD]
Facility		
Facility min 2000 sqm inside warehouse ($72 per sqm/year)	12,000	144,000
Facility costs (water, electricity, etc.) machine Kwh/month approx. 3000kwh	900	10,800
Gas supply	2,500	30,000
Acid neutralization cost	1,000	12,000
Minimum Staff		
Waste Control Officer / Ops Manager	500	6,000
Machine Operators	300	3,600
Operator Assistant	150	1,800
Forklift Driver / Stockist	150	1,800
Administrator / Scale Operator	250	3,000
Accounts Administrator	400	4,800
Sales	625	7,500
General/Financial Manager	800	9,600
Office		
Subscriptions, annual renewals	120	1,440
Consumables	30	360
Operations		
PPE	200	2,400
Fuel	200	2,400
Vehicle/Forklift Maintenance	1,000	12,000
Machine Spare/Wear parts (for cutting discs)	12,500	150,000
Financials		
Future Provisions for Capital Expenditures (CAPEX) replacement; depreciation over 60 months	23,511	282,140
Total OPEX (without Future Provisions)	**33,625**	**403,500**

Figures such as wages, rent and facility costs are Ghana specific, see annex for a more detailed explanation on these values.

4.2.3. Profit/loss statement

Based on the data given in tables 17 – 20, the profit/loss can be calculated as shown in table 21.

TABLE 21: TOTAL COSTS ESTIMATED FOR A ULAB RECYCLING FACILITY IN GHANA, YEARLY REPAYMENT REFERS TO A 10 YEAR PLAN OF REGULAR PAYMENTS WITH INTEREST FOR THE LOAN NEEDED FOR INITIAL INVESTMENT COSTS (SEE FOOTNOTE)

Total Investment costs [USD]	yearly repayment[4] [USD]	Operating costs [USD]	Total costs per year (without fut. Provisions) [USD]
1,256,700	162,114	403,500	**565,614**

In addition to these costs it has to be anticipated that ULABs will have to be purchased from collectors, for which additional costs of 800 USD/ton are estimated. This reduces potential profit from 1457 USD/ton (see table 17) to **657 USD/ton**.

For the Ghana specific case, given the values above, a break-even is achieved at **860 tons/year** of primary material covering all costs per year (565,614 USD).
If only operating costs are considered (403,500 USD), a break-even is achieved at **614 tons/year**.

A facility with the specifications as estimated in this report (section 4.1.2 – 4.2.2) running at full capacity (1260 tons/year) would yield a yearly profit of **262,962 USD** (total costs) or **425,076 USD** (only operating costs).

4.3. Discussion

Utilising the above figures shows that ULAB recycling is a lucrative business on a large scale if sufficient feedstock is available. A fully utilised plant can operate cash positive if the correct feedstock is supplied.

[4] Assumption of a 10-year repayment plan for Capital Expenditures (CAPEX), with an interest rate of 29% (see also annex 5.1)

5. Bibliography

[1] Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna.

[2] Ottiger, F., Schluep, M.: Downstream Technology Option for e-waste recycling, 2019, WRF, GIZ Ghana

[3] Scrap cable prices, Scap-Metal-Readers http://scrapmetalreaders.co.uk/scrap-metal-prices/ accessed on 30.10.2019

[4] Atiemo, S. et al, 2016: Baseline Assessment on E-waste Management in Ghana. Sustainable Recycling Industries (SRI) programme. https://www.sustainable-recycling.org/sampson_2016_sri-ghana/

6. Annex

Values used for Ghana specific information

TABLE 22: FIGURES USED FOR CALCULATION OF GHANA SPECIFIC COSTS SUCH AS WAGES IN THE OPEX CALCULATION OF THE DIFFERENT TECHNOLOGIES

Ghana Specific figures	Value	Unit
Salary unskilled worker recycling plant	1,800	USD/year
Salary skilled worker recycling plant	4,800	USD/year
Salary plant manager recycling plant	9,600	USD/year
Avg. Electricity cost for medium voltage	15.0	USD/kWh
Cost of Sqm for industrial warehouse	72	USD/sqm/year
Interest for loans for Initial capital expenditures	29	%

Values of Ghana specific figures in Table 22 were provided by Dr. Sampson M. Atiemo, of the Mountain Research Institute (MRI) based in Accra, Ghana.

Certain values estimated by using report on **Reclite SA, South Africa** and adjusted for Ghana-specific values.

TABLE 23: SALARIES AS USED IN THE OPEX CALCULATIONS IN THE REPORT

Salaries as used in OPEX calculations	Salary/year [USD]
Waste Control Officer / Ops Manager	6,000
Machine Operators	3,600
Operator Assistant	1,800
Dismantler	1,800
Forklift Driver / Stockist	1,800
Administrator / Scale Operator	3,000
Accounts Administrator	4,800
Sales	7,500
General/Financial Manager	9,600

When comparing the values from table 22 and table 23, it can be seen that “Operator Assistant”, “Forklift Driver/Stockist” and “Dismantler” fall into the “unskilled worker” category. “Accounts administrator” refers to category “skilled worker” and “General/Financial Manager” to “plant manager”.
For the remaining jobs available, a proportional wage was estimated for a better separation based on wages at **Reclite SA**, a Recycling facility in South Africa. This includes wages for “Sales”, “Scale Operator”, and “Machine Operator”.