Economic Feasibility Study of E-Waste Recycling Facility in Egypt

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On a global scale, the high consumption of electric and electronic equipment (EEE) leads to mounting volumes of e-waste. The e-waste problem in Egypt is not very well assessed, so a feasibility study for an e-waste dismantling facility in Cairo is introduced in this research. This feasibility study aims to provide a guide to set up an economically viable e-waste recycling business by calculating the main costs and revenues of the recycling system taking into account the environmental standards. The profit and loss predictions showed that the facility would gain revenues of USD 708,659 after a 5-year of operation.

Keywords: Egypt, E-waste, E-Waste streams, Feasibility study, Recycling facility, WEEE.

1. Introduction

Nowadays the technological advancements led to high use of electric and electronic equipment (EEE) which caused those devices a lifetime reduction especially the IT ones because of the fast changes in the abilities and features, therefore expediting the process of creation and accumulation of e-waste. E-waste is a term used for such type of items of EEE and its parts that have been discarded by its owner as waste without the intent of re-use. It is also referred to as WEEE (Waste Electrical and Electronic Equipment), electronic waste or e-scrap in different regions. E-waste includes any household or business products with circuitry or electrical components with power or battery supply [1]. According to the United Nations (UN), the WEEE can be classified into six categories as follows:

- Temperature exchange equipment such as refrigerators and air conditioners.
- Screens, monitors for instance televisions, monitors, laptops, notebooks, and tablets.
- Lamps.
- Large equipment; like washing machines, clothes dryers, dishwashing machines, electric stoves, large printing machines, copying equipment and photovoltaic panels.
- Small equipment which includes vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, electrical and electronic toys, small electrical and electronic tools, small medical devices, small monitoring and control instruments).
- Small Information Technology (IT) and telecommunication equipment. For example; mobile phones, Global Positioning System (GPS), pocket calculators, routers, personal computers, printers, telephones).

Furthermore, according to the volume, the waste in each category is classified into; economic value, effect on the environment and public health if they are not properly recycled.

Balde, C. P. et al. estimated that the total amount of e-waste generated globally in 2014 was 41.8 million metric tons (Mt). It is forecasted to increase to 50 Mt of e-waste in 2018. This e-waste is comprised of 1.0 Mt of lamps, 6.3 Mt of screens, 3.0 Mt of small IT, 12.8 Mt of small equipment, 11.8 Mt of large equipment and 7.0 Mt of temperature exchange equipment. With such colossus amounts of waste, recycling of e-waste became indispensable.

The economic, environmental, public health and data security are considered the driving forces behind recycling e-waste. Electronic devices contain up to 60 different elements, many of which are valuable, such as precious and special metals, and some of which are hazardous [2].

In 2014, Egypt recorded the highest e-waste generation in Africa with absolute quantity (0.37 Mt) in relative quantity of 4.3 Kilogram/Inhabitant (kg/inh.) [1]. The current e-waste recycling system which is dominated by informal activities has negative socio-economic and environmental impacts [3] such as:

- Child labor
- Individual disposal of all e-waste types in public spaces, or with municipal waste that are later destined to open uncontrolled dumpsites.
- Burning of e-waste which releases toxic gases.

The present study discusses an e-waste treatment facility in Egypt estimated by the following schemes:

- The financial balance for e-waste dismantling calculated within the feasibility study should be extended to a five-year business plan including profit and loss forecast calculation. Estimated revenues and costs should be based on realistic assumptions

concerning input of e-waste from different streams, process calculation and downstream options.
- The complete business plan should give interested entrepreneurs the ability to introduce the idea for getting a loan or investors to get the required investments and the initial requirements for the operation phase.
- According to the profit and loss calculation, the written business plan should provide information concerning space requirements, and required number of employees, equipment, etc.
- Furthermore, this business plan should be designed for future schemed projects by utilizing the key figures of time, prices and costs and adapting regional framework conditions.

The rest of the paper is arranged as follows. Section 2 covers the used methodology. Section 3 briefly introduces the current situation and the e-waste mass flow in Egypt. The main assumptions for the feasibility study will be covered in Section 4. In section 5, different sources of costs and revenues will be covered. The profit and cost forecast are shown in section 6. Conclusions are drawn in section 7.

2. Methodology

The instant business plan is composed of two main parts:
- A strategic analysis based on the inventories [3]-[5] and the feasibility study [6]-[8].
- A calculation of a profit and loss forecast based on assumed mass flows and expected revenues and costs

For the business plan, a calculation tool that is developed within the Solving the E-waste Problem (StEP) network (Task-Force 4 Recycling) in cooperation with Center of Excellence Electronics & Environment Subsidiary iPoint-Systems (KERP), The Dismantling- and Recycling-Center (D.R.Z) and Swiss Federal Laboratories for Materials Science and Technology (EMPA), has been further developed into an Excel-based business plan calculation tool.

With the business plan calculation tool, it is possible to calculate the financial performance for the first five years of operation based on the production of wide range of appliance groups. Furthermore, local relevant cost factors like average salaries, purchase prices, fuel prices, etc., are included. Based on the general data provided and considering the chosen modeling parameters (dismantling depth and dismantling efficiency), the tool calculates the following results:
- Required staff, investments and equipment;
- Required working hours;
- Expected revenues and operational costs;
- An entire profit and loss forecast;
- Required additional income stream (e.g. through an Extended Producer Responsibility (EPR) financing mechanism, recycling fees, etc.).

By utilizing the business plan calculation tool, different profit and loss scenarios for the planned facility in Cairo have been calculated by modifying certain framework conditions.

3. Egypt's E-waste Current situation and Mass Flow

According to the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS), Egypt hosts a population of 92.5 million [9]. More than 43% of the population dwell in urban cities [3]. The population growth recorded in 2015 is approximately 2.4%. With this growth the use of the electrical and electronic devices becomes an essential part of the lifestyle of the society.

Adoption of ICT in Egypt is raised to 97.79 million mobile phone service subscribers registered by Dec 2016, growing at an annual rate of 4.02%, while internet users have reached 30 million as shown in Table 1 [10].

Other indicators show the high penetration of other electrical appliances as well. Nearly all (98.8%) Egyptians have a working television in their home, while 37.9% of Egyptians have a radio [11]. Furthermore, the local production of 782,000 air conditioners is recorded in a single year, mostly destined to the local market. In 2014 Egypt imported US$12.1bn machines. The Telephones and mobile sets represent 7.2% of the amount of total imported machines with US$865mn import value while the amount of computer imported was $331mn, which was 3.1 % of total imported amounts this category [12]. Detailed statistics about amounts is mention in [5]. The present study focuses mainly on Personal Computers (PCs), Cathode Ray Tube (CRT) monitors, Liquid Crystal Display (LCD) monitors, telephones and mobile phones, as they fall under the scope of the Green Information and Communications Technology (ICT) Strategy. Nevertheless, most considerations for initiating a recycling system can be extended to other appliances.

E-waste creators are grouped into households, the private sector including large, small and medium enterprises, and the governmental sector. In general, all consumers followed a behavior of generation and stockpiling; WEEE is purchased, used, and then stockpiled. The stockpile duration ranges from 1 to 2 years depending on which group the consumers belong to.

Most of households prefer to sell their demoded EEE to second-hand dealers followed by scrap dealers while the remaining household does dispose with municipal waste. Private sector enterprise behavior in disposing of their outdated EEE varies by level. Large enterprises carry public auction periodically but not on a regular basis, it is carried out to avoid accumulating of disposed equipment while ensuring they keep up with the most up-to-date new equipment in use. Large enterprises especially the ones in IT sector disposes the electronic waste with formal WEEE recyclers, as WEEE recyclers can provide a certificate of safe electronic waste disposal, which require to be presented to governmental environmental and tax inspectors. Small and Medium Enterprises (SMEs) generally sell their electronic waste by auction or dispose

of it with other waste streams. Governmental sector disposes of their electronic waste in public auction. Generally, the fate of this electronic equipment when it reaches the end of its useful life is unknown [5].

There is no formal legislation to manage and enforce WEEE management in Egypt. Electronic waste is majorly dealt with by the informal sector. After extracting the recyclable streams, it is generally either burned or thrown into landfills/dump sites in slums such as Manshiet Nasser, Mokattam or Dewei'a. Over time, harmful emissions start to affect the people who are living near those landfills. In the absence of formal and serious national programs for WEEE management, along with the shrinkage cost of buying new technologies especially mobile phones and personal computers, and the surge in perceptive obsolescence according to the modern technologies acquainted in the market, it is anticipated that more WEEE will be disposed in such dumpsites/landfills and unknown destiny.

According to the report [5] and interview with one of the stakeholders in the Ministry of Environment [13], there are two types of collectors who serve the informal sector. The First type is "Merchants": they collect electronic waste in bulk, they basically depend on the auctions carried out by the governmental and private sector auctions. There are no settled dates for the auctions; they take place whenever there are adequate quantities of WEEE. Merchants exhibit their products in their owned spaces and trade it with other stakeholders. they usually do not apply any processes on the collected WEEE, they are just dealers who buy and sell WEEE, most of the time they trade it to WEEE dismantlers or recyclers. The second type is "Sar'eha (literally mean scavengers) or Robabekia men": they are an organized group of workers. The two words collectively refer to drifters who roam around buying depleted items from people. Meanwhile, they are peddlers who sell wares to waste buyers who bargain specific waste items. By end of each working day, the Sar'eha/Robabekia workers drop off all the parts and quantities that they collected to specific "drop off" points/ shops, each "drop off" point/shop has between 10-15 Sar'eha/Robabekia workers to deal with. The person in charge of this drop off points/shops reimburses them financially depending on the type and quantity of collected items.

The informal dismantlers are the workers who deal with dismantling and segregating the WEEE parts for other dealers to use for exporting or as a feedstock for other processes/industries. They also perform primary recycling of different commodities such as plastics. Moreover, they segregate WEEE parts that are functioning for EEE repair and maintenance ships. They collect from merchants or "drop off" points as previously explained. WEEE recyclers collect from dismantlers the segregated parts such as plastic cases, electric boards, glasses, etc. to export some streams (e.g. Printed Circuit boards (PCB)) and recycle other streams (e.g. glass) as a feedstock for other industries, some WEEE recyclers directly collect the raw WEEE stock from collectors without the need to go through dismantlers.

The informal recycling system suffers from many issues such as child labor and improper dismantling practices such as hammer smash of CRT displays front glass.

In the following part the amounts, mass flow and the growth rate of the devices under the scope of this study will be covered depending on references [3]-[5], and interviews with stakeholders from the Ministry of Environment [13] and industry [15].

The average lifetime of a mobile phone, telephone set, desktop computer, laptop and PC monitor (CRT and LCD) is 2, 10, 10, 10 and 10 years respectively. In addition, the majority of consumers behave average storage of 2 years before disposal of the EEE.

Table 2 shows the mass flow of EEE/WEEE based on 2015 installed base of tracers. The governmental sector and enterprise's obsolete electronic equipment are mostly disposed in auctions. The largest electronic waste generated is by enterprises (amounting ≈58% of total electronic waste), followed by households (amounting ≈23% of total electronic waste) and governmental sector (amounting ≈19% of total electronic waste). The mass flow is 66,203.8 tons/year. The largest amount of mass flow is generated by the enterprises, followed by households then governmental sector. Post dismantling of tracers, extracted commodities as plastics, iron, etc. are processed and reinstalled in the market as feedstock for other industries. Currently, only around 1,584.0 tons/year of electronic waste is being collected from the total generated electronic waste mass flow, which only represents 2.4% of the total generated waste. For the selected tracers, the stock of equipment/inh. and stock of equipment/household is around 8.3 kg and 34.69 kg respectively. Meanwhile, the waste mass /year/inh. is around 0.72 kg.

Indicator	Unit	Dec. 2015	Nov. 2016	Dec. 2016	Monthly Growth Rate (%)	Annual Growth Rate (%)
Mobile Subscription	Million Subscription	94	97	98	-	4
Mobile Penetration *	%	107.41	109.45	109.73	1.91	2.32
Internet Users	Million Users	-	-	33.70	-	-
Internet Penetration *	%	-	-	41.20	-	-

Table 1 Mobile Subscription and Penetration Indicators [10].

Table 2 Mass Flow Chart.[5]

	Tracer	Stock		WEEE Mass Flow
		[tons]	[%]	[tons/year]
Households	Mobile	9,402	5	2,351
	Telephone	6,240	3	520
	Desktop PC	82,916	42	6,910
	Laptop PC	13,543	7	1,354
	CRT Monitor	69,675	35	5,806
	LCD Monitor	16,139	8	1,345
	Subtotal	197,914	100	18,286
Enterprises	Telephone	24,242	4	2,020
	Desktop PC	262,577	48	21,881
	Laptop PC	84,905	16	8,491
	CRT Monitor	74,795	14	6,233
	LCD Monitor	99,726	18	8,311
	Subtotal	546,244	100	46,936
Governmental Sector	Telephone	959	8	80
	Desktop PC	5,581	48	465
	Laptop PC	846	7	85
	CRT Monitor	2,384	21	199
	LCD Monitor	1,855	16	155
	Subtotal	11,624	100	983
All Actors	Mobile	9,402	1	2,351
	Telephone	31,441	4	2,620
	Desktop PC	351,073	47	29,256
	Laptop PC	99	13	9,929
	CRT Monitor	146,854	19	12,238
	LCD Monitor	117,720	16	9,810
	Total	656,589	100	66,204

4. Assumed Framework Conditions

To produce a realistic and accurate profit and loss calculation, framework conditions should be placed. These conditions are also important for the procurement phase to check that the project is being developed in accordance with the original framework conditions. If a change is necessary, it is also used to manage the change. Accordingly, the following settings have been assumed as achievable framework conditions for the business plan calculation:

- The period of operation is 5 years. The main reasons beyond choosing this number are as follows: Lack of sufficient data on the future penetration rates of the selected tracer; The country's economy as the central bank may allow the Egyptian pound to fall further into depreciation, which could place additional upward pressure on the price of electronic imports, consequently affecting the annual sales; Difficulty in forecasting the change in the number of enterprises and public-sector structures; New technologies development and penetration.
- The overall input has been estimated to start at 2500 t/a in the first year, then slowly increase by 3.14% every year up to 2829.1 t/a after 5 years of operation.
- The assumptions concerning the composition of collected e-waste during the first 5 years are listed in Table 3. The expected input divided per appliance group can be seen in Figure 1.
- The prices that have to be paid to the suppliers of e-waste (i.e. informal collectors, households, companies, authorities) are summarized in Table 4.
- The Facility will serve the greater Cairo area. It will be localized in 6th October industrial zone which characterized by several advantages such as cheap rent prices, fully facilitated, close to downtown, which reduces the transportation costs, and it is accessible from different roads that connect the industrial zone to different harbors like Alexandria port, Suez port and Port Said port. In addition to, being near to large consumers, like the universities and Smart Village which contains many high-tech office buildings, that increase the amounts of the e-waste that flow to the recycling facility.
- The Facility will be installed as a public-private partnership. The estate and building for plant operation are provided by the government. The plant layout will be adapted according to the conditions of the provided building. No construction costs are necessary. It was further assumed that the estate and building can be rented for about 2 USD/m² per year.
- The facility has its own trucks.
- The dismantling level in the facility is assumed in-depth dismantling where appliances are dismantled up to a point at which further separation into pure materials is impossible without mechanical shredding.
- CRT glass will be disposed in Egypt in an environmentally-sound manner.

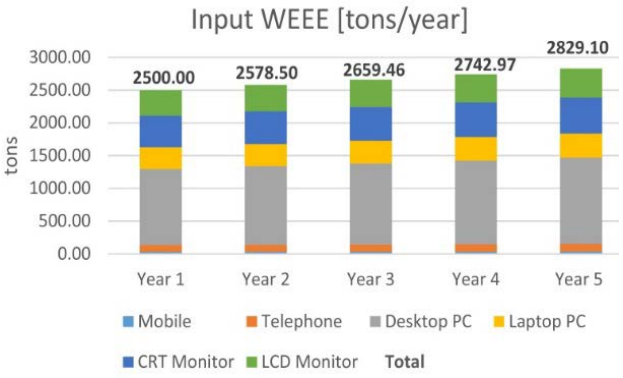

Figure 1 Input of WEEE [tons/year].

Table 3 Expected input composition of collected e-waste.

		Mobile	Telephone	Desktop PC	Laptop PC	CRT Monitor	LCD Monitor	Total
Weight (Kg)		0	1	10	3	17	5	**36**
Percentage (%)		1	4	47	13	19	16	**100**
Year 1	Tons	30	105	1,163	328	485	390	**2,500**
	Unit	100,000	108,247	122,368	116,964	28,529	78,000	**554,110**
Year 2	Tons	31	108	1,199	338	500	402	**2,579**
	Unit	103,140	111,646	126,211	120,637	29,425	80,449	**571,509**
Year 3	Tons	32	112	1,237	348	516	415	**2,659**
	Unit	106,379	115,152	130,174	124,425	30,349	82,975	**589,454**
Year 4	Tons	33	115	1,275	359	532	428	**2,743**
	Unit	109,719	118,768	134,261	128,332	31,302	85,581	**607,963**
Year 5	Tons	34	119	1,316	371	549	441	**2,829**
	Unit	113,164	122,497	138,477	132,362	32,285	88,268	**627,053**

Table 4 Assumed purchase prices for the different input Items.

WEEE Stream	Price from [8] USD/Unit	Price from [8] USD/ton	Prices Now USD/Unit	Prices Now USD/ton
Mobile	0.96	3200	2.25	7500
Telephone	0.5	515.4639175	1	1030.927835
Desktop PC	5.6	589.4736842	12	1263.157895
Laptop PC	3	1071.428571	6	2142.857143
CRT Monitor	2.22	130.5882353	3	176.4705882
LCD Monitor	1.2	240	2	400

5. Investments, Equipment and Costs

5.1 Human Resources

The dimensioning of the facility concerning human resources is based on the data listed in Table 5. In general, it is assumed that one general manager will be needed to manage the company. Concerning department managers, it is assumed that one department manager can coordinate up to 25 workers. It is assumed that 10% of all workers are skilled workers and 10% of all required human resources are administrative staff. According to this information and additional assumptions, the average working hours per employee was estimated to be almost 2,750 hours per year. Together with managing and administrative staff, the facility will need a staff of 86 to 97 persons during the initial five years of operation (Table 6). Salaries listed in Table 7 have to be paid to different staff levels. Workers and administrative staff get between USD 155 and USD 180 per month, the salaries for department manager and sales manager can be assumed to be USD 220 per month and USD 500 for the general manager. Based on the selected staff composition (Table 7) between USD 177,282 and USD 199,899 per year are the expenses for staff costs during the first five years of operation.

Table 5 Assumed basic data concerning staff composition and working hours.

Employees	Quantity	Calculation bases
General Manager	1	
Department manager	1	per 25 dismantling workers
Sales manager	0	
Skilled workers	10%	of all wokers
Unskilled workers	90%	of all wokers
Administrative Staff	10%	of total staff
Security	0	
Drivers	1	Included in skilled workers
Co-Drivers	1	Included in unskilled workers
Non-wage Labor Costs	5%	
Salaries/a	12	
Working hours per week	10	
working days per week	6	
Average sick leave per worker	5%	
Official Holidays per year	10	
Holiday Entitlement per year	2 weeks	
Working days per year	275	
Annual working hours	2750	

Table 6 Selected staff composition.

Employees	Year 1	Year 2	Year 3	Year 4	Year 5
General Manager	1	1	1	1	1
Department Manager	3	4	4	4	4
Skilled Workers	8	8	8	9	9
Unskilled workers	66	68	70	72	74
Administrative Staff	8	8	8	9	9
Total	**86**	**89**	**91**	**95**	**97**

Table 7 Staff costs [USD/year].

Employees	Salary [USD/month]	Staff costs per year				
		Year 1 [USD/year]	Year 2[USD/year]	Year 3[USD/year]	Year 4[USD/year]	Year 5[USD/year]
General Manager	-500	-6300	-6300	-6300	-6300	-6300
Department manager	-220	-8316	-11088	-11088	-11088	-11088
Skilled workers	-180	-18144	-18144	-18144	-20412	-20412
Unskilled workers	-155	-128898	-132804	-136710	-140616	-144522
Administrative Staff	-155	-15624	-15624	-15624	-17577	-17577
Total		-177282	-183960	-187866	-195993	-199899

5.2 Infrastructure and Equipment

5.2.1 Space

Table 8 gives an overview of the required spaces for the whole dismantling facility. These spaces have been calculated based on the results concerning staff composition (Table 6) and the specific space requirements that will be mentioned in the following subsection. Costs of 25 USD/m² per year have been considered to be charged on the total indoor area of 11905 m². The considerations result in rental costs of USD 297,625 per year.

Table 8 Required space for the dismantling facility.

Required Infrastructure	[m2]
Open Area	2829
Administrative Department	210
Recreation and sanitary rooms	291
Dismantling Working Stations	5706
Weee-receiving area	20
Area for further treatment	20
Storage	2829
Hall total	9076
Real Estate	11905

5.2.2 Equipment

According to the assumptions concerning input and processing, the equipment listed in Table 9 is required to run the dismantling facility. Table 9 further contains specific acquisition costs for the required items [8] [14]. Average indicated lifespan is based on experiences in European dismantling facilities. The current business plan is based on equipment investment requirements of about USD 70,000. The highest investment amount for required equipment with a lifespan of more than one year is spent for the trucks and the CRT-treatment. Required expenses for equipment with a lifespan of less than one year vary between nearly USD 25,000 per year to USD 28,000 per year. Table 10 shows the annual required equipment quantity and costs.

Table 9 Specific space requirements and acquisition costs for infrastructure and equipment.

Items	Costs [USD/unit]	Life span	Required Space [m²]	Required Quantity	Calculation bases
WEEE-receiving and sorting area		25	20	1	total per facility
Administrative Working Place (PC, table, chair)	-500	15	15	1	per administrative staff member
Recreation and sanitary rooms		25	2.5		per total staff member
Dismantling Working station (table, chair)	-200	10	20	1	per dismantling worker
CRT-treatment unit	-10000	25	40	1	total per facility
Cable stripper	-3000	25	25	1	total per facility
Plastic Shredder	-10000	25	40	1	total per facility
Lift truck	-10000	20	6	0	per 1000 t/a input
Truck	-17000	20	20	1	per 1000 t/a input
Container (for transport)	-2000	25	20		total per facility
Working tools	-200	1		1	per dismantling worker
HSE (shoes, helm, gloves, etc.)	-120	1		1	per worker
Ventilator	-50	10		1	per total staff member
Collection box	-50	15		10	per 100 t/a input
Palette	-5	10		5	per 100 t/a input
Scale	-1200	20		1	per 2000 t/a input
Pallet truck (internal transport)	-150	20		2	per 1000 t/a input

Table 10: Calculation of costs for needed equipment per year [USD/a].

	Year 1		Year 2		Year 3		Year 4		Year 5	
Items	**Required Quantity**	**Cost [$]**	**Required Quantity**	**Cost [$]**	**Required Quantity**	**Cost [$]**	**Required Quantity**	**Cost [$]**	**Required Quantity**	**Cost [$]**
Administrative Working Place (PC, table, chair)	12	-6,000	1	-500	0	0	1	-500	0	0
Dismantling Working station (table, chair)	74	-14,800	2	-400	2	-400	3	-600	2	-400
CRT-treatment unit	1	-10,000	0	0	0	0	0	0	0	0
Cable stripper	0	0	0	0	0	0	0	0	0	0
Plastic Shredder	0	0	0	0	0	0	0	0	0	0
Truck	2	-20,000	0	0	0	0	0	0	0	0
Working tools	74	-14,800	76	-15,200	78	-15,600	81	-16,200	83	-16,600
HSE (shoes, helm, gloves, etc.)	86	-10,320	89	-10,680	91	-10,920	95	-11,400	97	-11,640
Ventilator	74	-3,700	2	-100	2	-100	3	-150	2	-100
Collection box	250	-12,500	8	-400	8	-400	8	-400	9	-450
Palette	125	-625	4	-20	4	-20	4	-20	4	-20
Scale	1	-1,200	0	0	0	0	0	0	0	0
Pallet truck (internal transport)	5	-750	0	0	0	0	0	0	0	0
Total		**-94,695**		**-27,300**		**-27,440**		**-29,270**		**-29,210**

5.3 Purchase Costs and Revenues

According to the assumed input quantities listed in Table 3 and the purchase prices for e-waste devices listed in Table 4, the following purchase costs have to be considered within the business plan (Table 11) [5] [15].

The calculation of expected revenues and disposal costs have been based on the assumptions listed in Table 13 [16]-[22]. The main share of revenues comes from the commercialization of fractions. According to the expected input sales, revenues will be almost USD 3,899,334 during the first year of operation, then grow up to almost USD 4,412,489 after five years of operation (Table 12). Printed circuit boards (PCBs) are the largest revenue source followed by Processors.

5.4 Depreciation

5.4.1 Depreciation of Infrastructure

As the estate and building are rented according to the business plan, it is assumed that no depreciation costs for the estate and building are to be accounted for.

5.4.2 Depreciation of Equipment and Vehicles

Depreciation costs (Table 13) within the first five years of operation are between USD 13,915 to USD 16,381 depending on the required equipment and the expected lifespan for each item listed in Table 10.

5.5 Administration Costs

Expenses for administration have been estimated as listed in Table 14.

5.6 Electricity Costs

Expenses for electricity have been based on the specific electricity consumption in the dismantling facility D.R.Z – Dismantling and Recycling Centre in Vienna/ Austria (40 kWh/m². a). According to prices of USD 0.07 per kWh having to be paid for electricity in Egypt, expenses will be USD 37,000 per year.

5.7 Cleaning, Maintenance and Repair (CMR) Infrastructure

Expenses for cleaning, maintenance and repair (CMR) of infrastructure have been calculated using the experiences of the D.R.Z again. 1 USD/m² per year was the specific value used for the calculation, which leads to expenses of about USD 9000 per year for CMR infrastructure.

5.8 Business Liability Insurance and Tax

Business expenses for liability insurance and taxes have been estimated to be USD 3000 per year.

6. Profit and Loss Forecast

The profit and loss forecast, listed in Table 15 shows the expected revenues and costs for the initial five years of operation. According to the assumed input and framework conditions, revenues are fed by the sales of output fractions. For e-waste input quantities of about 2500 t/a, revenues of more than USD 3,800,000 can be achieved. 70% of these revenues are cut short by purchase and external transport costs. Operational costs are USD 638,217 in the first year of operation, reduced to USD 597,816 after five years of operation. The highest share of operational costs (54%-59%) has to be spent on infrastructural costs. Staff costs are the second highest contributor on the operational costs list, ranging from 27% up to 33%. Costs for equipment and depreciation are of minor importance compared to other cost factors. The estimated share of less than 1% of all operational costs for administration can give a rough scale for expenses that have to be provided for the business administration.

Furthermore, administration costs will depend a lot on the need for negotiations with purchasers of output fractions in neighboring countries and overseas, as almost half of the calculated administration costs are travel costs.

Table 11 Expected Purchase Costs for WEEE [USD/a].

Appliance Group	Year 1 [USD/year]	Year 2 [USD/year]	Year 3 [USD/year]	Year 4 [USD/year]	Year 5 [USD/year]
Mobile	-200,000	-206,320	-212,720	-219,440	-226,320
Telephone	-108,247	-111,668	-115,132	-118,769	-122,493
Desktop PC	-1,468,421	-1,514,823	-1,561,813	-1,611,152	-1,661,665
Laptop PC	-701,786	-723,962	-746,419	-769,999	-794,141
CRT Monitor	-85,588	-88,293	-91,032	-93,907	-96,852
LCD Monitor	-156,000	-160,930	-165,922	-171,163	-176,530
Total	-2,720,042	-2,805,996	-2,893,038	-2,984,430	-3,078,001

Table 12 Expected Sales Revenues and Disposal Costs.

				Price/Costs [USD] per ton				
Output fractions	Price/Costs [USD/ton]	Required Type of Transport	Transport Costs [USD/ton]	Year 1	Year 2	Year 3	Year 4	Year 5
Aluminium	2238	Local Transport	-11	275,196	283,892	292,808	301,945	311,412
Iron/Steel	389	Local Transport	-11	350,609	361,688	373,048	384,688	396,749
Copper	7063	Local Transport	-11	160,398	165,466	170,663	175,988	181,506
Neodym Magnet	7000	Local Transport	-11	12,703	13,104	13,515	13,937	14,374
Bronze/Brass	3400	Local Transport	-11	0	0	0	0	0
Stainless Steel	300	Local Transport	-11	2,644	2,727	2,813	2,901	2,992
Plastics	900	Local Transport	-11	402,837	415,567	428,619	441,993	455,850
Wood	0	Local Transport	-11	0	0	0	0	0
Cable with plugs	1200	Local Transport	-11	0	0	0	0	0
Cable without plugs	2000	Local Transport	-11	213,773	220,528	227,454	234,551	241,905
Processors	70000	Oversease Shipment	-410	483,129	498,395	514,049	530,089	546,708
HDD with PWB	1000	Local Transport	-11	0	0	0	0	0
HDD without PWB	700	Local Transport	-11	0	0	0	0	0
Power supply	400	Local Transport	-11	0	0	0	0	0
Drivers	440	Local Transport	-11	0	0	0	0	0
Printed Wired Board Q1	10000	Local Transport	-11	1,841,123	1,899,302	1,958,954	2,020,080	2,083,414
Printed Wired Board Q2	3000	Oversease Shipment	-410	39,659	40,913	42,198	43,514	44,879
Printed Wired Board Q3	1000	Oversease Shipment	-410	25,107	25,901	36,714	27,548	28,412
Mobile Phones without battries	0	Oversease Shipment	-410	0	0	0	0	0
Motors / Inductors / Transformers	500	Local Transport	-11	23,084	23,814	24,562	25,328	26,122
Deflection coil	1200	Local Transport	-11	25,950	26,770	27,611	28,472	29,365
Getterpill - electrogun	-1000	Oversease Shipment	-410	-684	-705	-728	-750	-774
Mixed scrap	350	Local Transport	-11	39,303	40,545	41,818	43,123	44,475
Glass	20	Local Transport	-11	414	427	441	454	469
Residual waste	10	Local Transport	-11	-13	-14	-14	-15	-15
Battries	1200	Oversease Shipment	-410	48,806	50,348	51,930	53,550	55,229
Capacitors	1000	Oversease Shipment	-410	7,322	7,553	7,791	8,034	8,285
LCD-displays	-1000	Regional Transport	-30	-52,728	-54,394	-56,103	-57,853	-59,667
Fluorescent Tubes	0	Local Transport	-11	-16	-17	-18	-18	-19
Printer Cartirages	0	Local Transport	-11	0	0	0	0	0
CRT tubes	-300	Regional Transport	-30	0	0	0	0	0
CRT-glass	20	Local Transport	-11	2,086	2,152	2,220	2,289	2,361
Phosphor-powder	-1000	Oversease Shipment	-410	-1,368	-1,411	-1,455	-1,501	-1,548
Total per year				3,899,334	4,022,551	4,158,890	4,278,347	4,412,484

Note: Type of Transport: Local (0-50 km), Regional (50-500km), Overseas Shipment (to a foreign country).

Table 13 Calculation of depreciation costs for equipment [USD/a].

	Depreciation				
Items	Year 1 [USD]	Year 2 [USD]	Year 3 [USD]	Year 4 [USD]	Year 5 [USD]
Administrative Working Place (PC, table, chair)	-1,200	-125	0	-250	0
Dismantling Working station (table, chair)	-2,960	-100	-133	-300	-400
CRT-treatment unit	-2,000	0	0	0	0
Cable stripper	0	0	0	0	0
Plastic Shredder	0	0	0	0	0
Truck	-4,000	0	0	0	0
Working tools	0	0	0	0	0
HSE (shoes, helm, gloves, etc.)	0	0	0	0	0
Ventilator	-740	-25	-33	-75	-100
Collection box	-2,500	-100	-133	-200	-450
Palette	-125	-5	-7	-10	-20
Scale	-240	0	0	0	0
Pallet truck (internal transport)	-150	0	0	0	0
Total	**-13,915**	**-14,270**	**-14,577**	**-15,412**	**-16,382**

Table 14 Estimated administration costs per year [USD/a].

Administration Expenses	Year 1 [USD]	Year 2 [USD]	Year 3 [USD]	Year 4 [USD]	Year 5 [USD]
Travel Costs	-2500	-2500	-2500	-2500	-2500
Office Supplies, Postal and Bank Charges	-500	-500	-500	-500	-500
Telecommunicaton/ Internet	-300	-300	-300	-300	-300
Consulting Services	-500	-500	-500	-500	-500
Marketing and Public Relations	-500	-500	-500	-500	-500
Permissions and Quality Management	-500	-500	-500	-500	-500
Total	**-4800**	**-4800**	**-4800**	**-4800**	**-4800**

Table 15 Profit and Loss Forecast [USD/a].

	Year 1 [USD]	Year 2 [USD]	Year 3 [USD]	Year 4 [USD]	Year 5 [USD]
Funds	0	0	0	0	0
Remuneration Take-Back-System	0	0	0	0	0
WEEE Purchase Costs Including External Transport Costs	-2,744,792	-2,831,523	-2,919,367	-3,011,585	-3,106,009
Sales Revenues and Costs	3,899,334	4,022,551	4,158,890	4,278,347	4,412,484
Net Revenues	**1,154,542**	**1,191,028**	**1,239,523**	**1,266,762**	**1,306,475**
Management	-14,616	-17,388	-17,388	-17,388	-17,388
Administration	-15,624	-15,624	-15,624	-17,577	-17,577
Workers	-147,042	-150,948	-154,854	-161,028	-164,934
Total Staff Costs	**-177,282**	**-183,960**	**-187,866**	**-195,993**	**-199,899**
Rental Costs	-297,625	-297,625	-297,625	-297,625	-297,625
Electricity	-37,000	-37,000	-37,000	-37,000	-37,000
CMR Infrastructure	-9,000	-9,000	-9,000	-9,000	-9,000
Business Liability Insurance and Tax	-3,000	-3,000	-3,000	-3,000	-3,000
Total Infrastructure Costs	**-346,625**	**-346,625**	**-346,625**	**-346,625**	**-346,625**
Total Equipment	**-94,695**	**-27,300**	**-27,440**	**-29,270**	**-29,210**
Motor Vehicle Insurance and Tax	-700	-700	-700	-700	-700
CMR Vehicles	-200	-200	-200	-200	-200
Total Transport Costs	**-900**	**-900**	**-900**	**-900**	**-900**
Total Administration Costs	**-4,800**	**-4,800**	**-4,800**	**-4,800**	**-4,800**
Depreciation Infrastructure	0	0	0	0	0
Depreciation Equipment and Vehicles	-13,915	-14,270	-14,577	-15,412	-16,382
Total Depreciation	**-13,915**	**-14,270**	**-14,577**	**-15,412**	**-16,382**
Total Costs	**-638,217**	**-577,855**	**-582,208**	**-593,000**	**-597,816**
Operating Result	**516,325**	**613,173**	**657,316**	**673,762**	**708,659**

7. Conclusion

In this paper, a feasibility study for a proposed e-waste recycling facility in Egypt has been introduced. Under some achievable framework conditions, positive operating results and net income can be achieved. The dismantling facility can yield a profit of about USD 516,325 to 708,659 per year. The intrinsic values of appliances like PCs or FPD monitors/TVs are even able to finance recycling costs for devices like CRTs.

The calculations of the introduced feasibility study show that the recycling facility can be implemented and operated without the need for additional funds such as loans or grants if the estate and building for the facility are provided by the government with lower rent expenses. The future work includes recalculating profit and loss forecast under different operating scenarios with new framework conditions.

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