SUSTAINABLE
RECYCLING
INDUSTRIES

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CRT screen recycling feasibility study for Egypt

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Executive summary

The current task is carried out within the framework of the Sustainable Recycling Industries (SRI) project being implemented by the Swiss Federal Laboratories for Materials Sciences (EMPA) as mandated by the State Secretariat of Economic Affairs (SECO) of Switzerland. Within this project, CRT screens have been identified by earlier studies as a major E-waste flow in Egypt for which no environmentally sound solution exists within the country. It is therefore the main objective of this study to identify possible domestic recycling options for end-of-life CRT screens and evaluate their cost and environmental impact.

1. Introduction

CRT screens are no longer manufactured and the remaining stock in households and offices is continuously being replaced by the newer LCD technology. Large amounts of End-of-Life CRT screens appear therefore in the Egyptian E-waste sector. This E-waste flow has been identified to be among the most problematic ones due to its large volumes, hazardous components as well as the non-existence of environmentally sound recycling options within the country [1]. The main sources of EoL CRT screens are computer monitors and TVs. The stock of CRT computer monitors in Egypt has been estimated to be close to 147'000 tons by EcoConServ during a survey in 2016 [2]. The scenarios considered by EcoConServ put the resulting annual flow of EoL monitors between 12'240 tons and 13'350 tons. A similar estimation for EoL CRT TVs has been made through the Best of Two Worlds project in 2013 . The estimated number of CRT TVs in use in 2017 is around 12 million which, assuming and average weight of 25kg per TV, corresponds to about 300'000 tons. The estimated annual flow of EoL CRT TVs was further estimated to be 11'375 tons in 2017 [3]. The total amount of EoL CRT screens can therefore be estimated at around 24'000 tons in 2017 and, although expected to decrease in the future, volumes will remain elevated for many years to come.

A major part of CRT screens consists of materials which are difficult to valorize while posing environmental and health hazards if not properly treated. In a market which is largely controlled by the informal sector and therefore purely profit-oriented, these fractions are either dumped or sold to industries which will use them as raw material without consideration of their hazardous nature. Environmentally sound recycling of CRT screens requires important investments in adequate machinery and results in high treatment cost, often surpassing the profit realized by selling the valuable fractions. Although the export of E-waste fractions for which no sound solution within the country can be identified is considered a valid option, this is not the case for CRT screens. The technical requirements for a CRT-recycling facility are minor and, if no alternative solution can be found, landfilling of the hazardous fractions can be a viable solution for disposal. The major problem seems to be the economic feasibility due to the competition by the informal sector as well as a missing financing scheme for hazardous waste fractions. These issues are, however, currently being addressed on a political and institutional level. The goal of this document is therefore to present an overview of the viable options and scenarios in which domestic recycling of CRT screens could be addressed in an environmentally sound manner by the formal E-waste sector in Egypt.

The remainder of this document is structured as follows: In section 2 the dismantling process and composition of CRT screens is introduced. Section 3 discusses the current recycling practices of the formal and informal sector while in section 4 possible options for the treatment of hazardous fractions are presented. In Section 5 the cost of CRT processing is discussed and in section 6 three scenarios are considered for which the economic results are calculated. Section 7 contains some recommendation and section 8 the conclusions.

2. CRT screen dismantling & composition

Dismantling of CRT screens

The dismantling of a CRT screen can be done mainly manually with the exception of the separation of the panel- and funnel glass for which a specific machine is needed. Figure 1 shows the setup of a CRT monitor and indicates where the respective fractions are located [4].

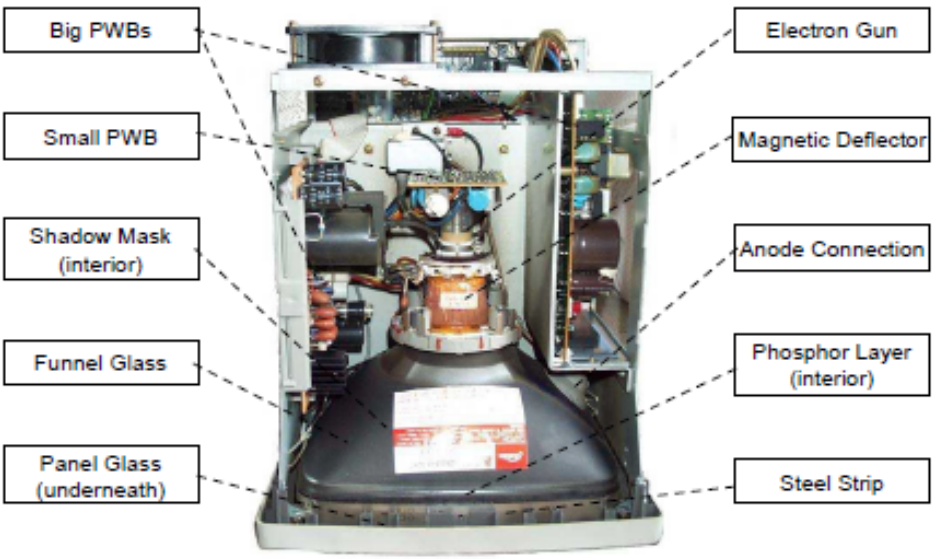

Figure 1

1. The first step in the dismantling of a CRT screen is to remove the plastic casing.
2. Once the casing is removed, the glass body, which is under a vacuum, has to be equalized in order to avoid implosion. Therefore, one has to place the side of the monitor screen with the flap (anode connection) away from his face. The flap in the monitor screen is removed with a flat screw driver and a hole is punched carefully into the CRT glass where the flap was fixed.

3. Once the pressure is equalized, the PWBs and all other parts outside the CRT tube can be removed. The deflection coil can now be removed carefully in order to avoid breaking the electron gun on top of the CRT. The copper is separated with a hammer.
4. Finally the electron gun is broken off.
5. The glass body now has to be separated into panel- and funnel glass. The steel strip protecting the area where panel and funnel glass are fused together has to be cut first, using a handheld rotating disk saw.
6. After the strip has been removed, the panel glass is separated from the funnel glass mechanically by an appropriate machine. Different options exist such as hot wire cutting, laser cutting, diamond saw or water jet separation. The best option depends on the quantity of CRT screens to be processed as well as the available investment funds.
7. Once the glass parts are separated, the phosphor layer on the inside of the panel glass has to be removed by a vacuum cleaner after which the panel glass can be used in ordinary glass recycling while the funnel glass has to be treated separately due to its hazardous nature.

The diagram in figure 2 represents the work flow when dismantling a CRT monitor. The whole process takes about 30 minutes per screen for an experienced dismantler. A video showing the process can be found on YouTube via the link in the footnote[1].

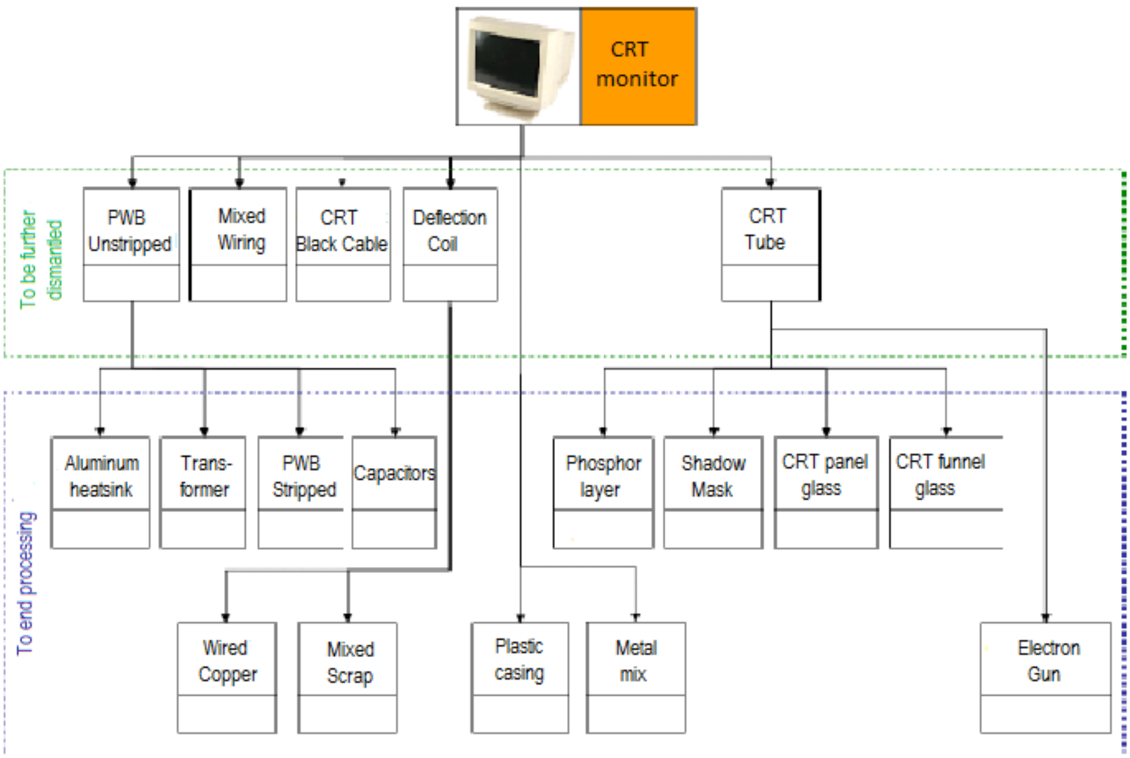

Figure 2

[1] https://www.youtube.com/watch?v=EPXdUbJqouI

Composition of CRT screens

Fraction	CRT computer monitor	CRT TV
Panel glass	31.1%	45.8%
Leaded glass	16.7%	24.7%
Plastics	19.5%	15.0%
Iron/Steel	11.5%	4.5%
Printed circuit boards	5.0%	3.2%
Deflection coil	4.5%	2.2%
Motors / Inductors / Transformers	5.0%	1.4%
Cables	2.5%	1.2%
Aluminum	1.4%	0.9%
Copper	1.5%	0.0%
Scrap	0.6%	0.5%
Capacitors	0.4%	0.2%
Phosphor	0.2%	0.3%
Electron-gun	0.1%	0.1%

Table 1

The average composition, quantified by trials at manual dismantling facilities, of both CRT monitors and TVs is indicated in table 1 and visualized in figure 3. The major components in CRT screens are glass and plastics followed by the iron/steel fraction. 80% to 90% of the mass of CRT screens are made out of these three fractions. While the iron/steel parts can be sold for some profit, the major problems reside in the glass and plastics fractions. The clean panel glass, which represents between 30% and 45% of a CRT screen, can be used as secondary raw material in glass recycling and manufacturing as it contains no hazardous material and is basically just ordinary flat glass. While it is possible to reinject this fraction in a manufacturing process, it does not realize a high market price and identifying a buyer capable of accepting important quantities is challenging. The major problems with the recycling of CRT screens is the leaded glass fraction in the CRT-tube which is used for radiation protection purposes, as well as the plastic fraction which consists mostly of ABS plastics that are often treated with hazardous, halogenated

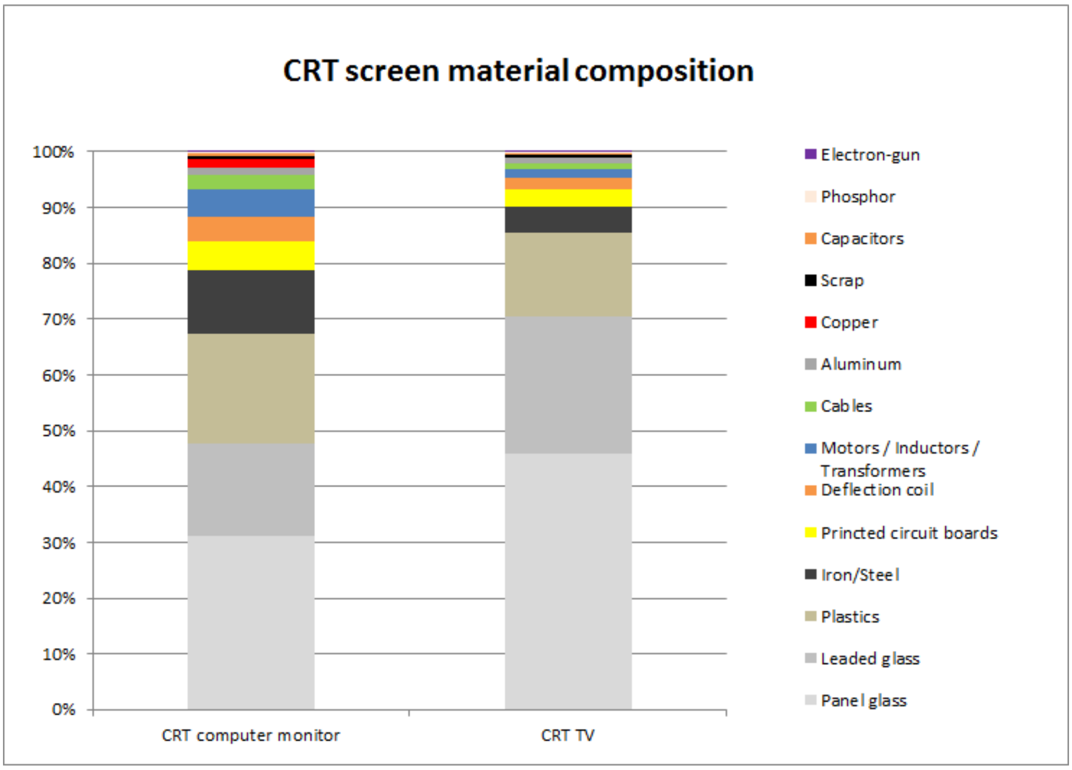

Figure 3

flame retardants. The leaded glass fraction represents about 17% of the weight of CRT monitors and 25% of the weight of CRT TVs. While earlier, when CRT screens were still manufactured, this fraction could be used for glass-to-glass recycling and therefore reused in the CRT industry, this option does no longer exist today. The plastics fraction in CRT screens represents between 15% and 20% of the total mass of the screen. Recycling of these plastics is possible, in order to be a viable solution the parts containing BFRs have to be removed and disposed of separately however. The contaminated parts can be identified either using expensive technology or by low tech approaches that result in increased labor cost and are not 100% effective. The various possibilities of identifying BFR plastics are described in [5]. While separating the hazardous fraction and recycling the non-hazardous plastics would be the best practice, the economic viability of this option has to be further investigated.

The third largest fraction, composed of low quality steel and iron can be sold to local ferrous metal smelters and yield a price of around 0.255$/kg.

The remaining 10% to 20% of a CRT screen are represented by 10 further fractions for which the following information is relevant:

Printed circuit boards

Per CRT screen there are 2 to 3 boards as indicated by figure 1. After removing the boards, they should be further dismantled, meaning that capacitors, transformers, inductors and aluminum heat sinks should be removed and treated as separate fractions in order to maximize profits. There are two types of boards, the larger ones containing little precious metals which sell therefore at low prices around 0.4$/kg, and the small board which is of higher quality and sells for about 2.3$/kg.

Deflection coil

Together with the boards, the deflection coil is the most valuable part of a CRT screen due to the important amounts of copper that can be recovered from it. The composition of deflection coils is around 35% copper, 38% iron and 27% plastic and scrap. After the coil is removed from the CRT tube, it is crushed with a hammer and the copper, steel and plastic parts are separated. Copper prices are around 4.5 – 4.8 $/kg while the low quality iron will sell for around 0.22$/kg.

Motors / Inductors / Transformers

Some inductors and transformers can be removed from a CRT screen. If working, it might be possible to resell them to refurbishment workshops. Else their value lays in their copper content. Information on prices are not available at the time but can be estimated from the copper content in the recovered parts. If the copper cannot be separated from the other materials, the whole should be stored separately from the pure copper fraction as these parts would reduce the purity of the copper fraction and therefore its price.

Cables

The cables recovered from a CRT screen are of different nature. The thick black copper cable is the most valuable and can be dismantled manually using a cutter or a wire stripper. The variety of other cables can either be sold to dealers for a rather low price and with the risk that they will finally be burned by the informal sector, or they can be stripped or shredded mechanically. The second option is the more viable one for obvious reasons and will also lead to higher profits. It has to be determined if cables are sold to an adequate formal facility with the required machinery or if it is worth to buy a cable stripper/shredder in addition to the CRT treatment unit. The copper content in mixed scrap cables is around 30%, the one in the thick black cable around 70%. We assume an average copper content in all cables from CRT screens of 40%, meaning that, if appropriately processed, mixed cables would yield about 1.93$/kg.

Aluminum

Aluminum is mainly found in the form of heat sinks on the wiring boards and eventually some of the smaller parts recovered during the dismantling of the outer parts of the screen are made of aluminum as well. It is mostly hard aluminum which sells for about 1.15$/kg.

Copper

Most of the copper is found in the deflection coil, cables and inductors & transformers on the printed circuit boards. At times other copper parts can be recovered from the outer parts of the screen as well. These should be collected together with the previously discussed copper fractions depending if they are pure copper or mixed copper-plastic or copper-metal parts.

Mixed scrap

Mixed scrap from the dismantling process can be collected together. If no hazardous materials are contained this fraction it can be landfilled at a conventional site. If hazardous materials such as leaded glass or flame retarded plastics are contained in the mix, it should be sent to Nasreya landfill in Alexandria.

Capacitors

Capacitors have to be collected separately. Large capacitors about thumb size (diameter > 2cm) should be handled with special care. In older screens, produced before 1987, these large capacitors might contain PCBs, which are very hazardous to human health. Such large capacitors have to be stored separately and all direct contact must be avoided. PCB capacitors have to be sent to Nasreya landfill in Alexandria. Smaller capacitors contain electrolytes and direct contact should also be avoided if possible. These capacitors should also be stored in closed barrels. Their exterior is made out of an aluminum sheet and it might be possible to sell this fraction to aluminum smelters. This possibility and the resulting prices will have to be further investigated.

Phosphor powder

The inside of the CRT front panel glass is covered by a layer of fluorescent phosphor powder. This white powder contains several hazardous substances such as cadmium, barium and lead. After the mechanical separation of the panel glass, the powder should be removed with a vacuum cleaner and sent to Nasreya landfill in Alexandria. Dust formation during the whole dismantling process has to be avoided to minimize exposure by inhalation.

Electron gun

The electron gun contains a high quality nickel-steel alloy and can be sold to steel smelters. Direct contact should be minimized as a getter platelet is attached to the electron gun which contains hazardous barium. In the smelting process barium will end up in the slag and not pose further problems. High quality steel yields a price of about 0.28$/kg, it has to be determined to what price the electron guns might be sold to steel smelters.

3. Current recycling practices

Formal sector

The formal sector currently does not treat with CRT screens due to the low overall value of the recoverable materials inside and the problematic fractions which result in rather high costs if properly treated. If CRT screens are occasionally collected, they are either sold to refurbishment shops or sent to the landfill as a whole.

Informal sector

The informal sector does deal with CRT screens. Screens that are still working are refurbished and resold. Especially in the case of CRT monitors which are refurbished as TV screens and sold as such to people in the more rural areas. If the screens cannot be refurbished, they are dismantled manually and the valuable fractions are recovered and sold. The mixed panel and funnel glass is sold as is, either to the glass manufacturing industry or to producers of ceramic glazing. In both cases the lead will be found in the new products, where, although quite stable, it is still hazardous and users of the new products might eventually be exposed. The plastic fraction is either dumped or crushed and sold to plastic companies that produce plastic chairs, household tools and other products. Separation of the parts containing brominated flame retardants does not happen and the hazardous substances are diluted instead of removed. The cables are sold to dealers and will finally end up being burnt to recover the copper. Parts that cannot be sold are often simply dumped to avoid the cost of landfilling. Due to the fact that hazardous fractions are sold or dumped at no cost instead of properly treated at cost, the informal sector realizes profits by processing CRT screens. As a direct consequence EoL CRT screens can be sold to the informal sector and are therefore regarded by the population to be of a certain value. Market prices of EoL CRT screens are variable and depend on the state and size of the device. If still working, the screens can be refurbished and are bought at a price of up to 100EGP (5.7$) per piece depending on the state and sze. If the screen is not working anymore, the price range is between 40 and 75 EGP (2.3-4.3) depending on its size.

4. Possible options for hazardous and difficult fractions

As a formal recycler it is important to find environmentally sound solutions for fractions which are difficult to valorize and/or hazardous. Three options exist for these fractions in the following order of preference:

1. Sell them as secondary raw materials to other industries
2. Give them away at no or low cost as secondary raw materials to other industries
3. Safely dispose of them in a landfill at cost

It is obviously preferred if a fraction can be sold rather than given away at no or low cost. In the principle of reuse before refuse it is also preferred to give away a non-sellable fraction to an industry that can actually process it in a safe way. If no other option exists, landfilling is a

viable solution as long as the landfill respects the environmental requirements to handle the specific hazardous substance.
If a hazardous fraction is reused as secondary raw material in manufacturing, certain conditions have to be respected. Hazardous substances can only end up in a new product if their characteristics are needed in this specific product. It is, for example, not environmentally viable to use the leaded glass fraction in manufacturing of ceramic glazing as lead is not needed in the glazing and this operation therefore dilutes the hazardous substance in a new product rather than actually serving as a reuse of the lead inside the glass matrix. This principle should be kept in mind when looking for viable solutions to hazardous fractions.
In the case of CRT screens solutions for the following fractions are required:

- Panel glass
- Leaded glass
- Plastics
- Capacitors
- Phosphor powder

Panel glass
As mentioned earlier, once separated from the hazardous leaded glass and cleaned from the phosphor powder, the panel glass can be regarded as normal flat glass and processed as such. It is therefore crucial to find suitable down streaming solutions for this fraction as this can lead to additional revenues and will reintroduce an important amount of the initial CRT screen to the manufacturing industry. When suitable down streaming options are identified, one has to bear in mind the important volumes that will be produced. Based on the estimations for annual flows of EoL CRT screens and the respective amounts of panel glass per monitor and TV, the total amount of panel glass would be 9’140 tons per year if 100% of the EoL screens were collected. This collection target is of course impossible, however this means that even when only 10% of all screens are collected and processed, more than 900 tons of panel glass would have to be sent for down streaming every year.

Leaded glass
The leaded glass fraction is among the most problematic ones in CRT screens. Several options exist but not all of those are suitable in Egypt. The optimal solution has to be identified based on cost, environmental viability and technological feasibility.

- ***Lead extraction***
  Pyrometallurgical and hydrometallurgical methods exist to extract lead metal from the

funnel glass. These processes are however highly technological and require important investments to build the necessary facilities. It is highly doubtable that such an installation would realize profits. If legally possible it might be viable to send this fraction to such a facility abroad. This would most probably result in additional cost for shipping and treatment, but could be considered a good solution from an environmental point of view.

- ***Substitution of raw material***
  Leaded glass can be used as a substitute in manufacturing processes requiring silicates (sand) as raw material. However, as mentioned earlier, this is only viable if the characteristics of lead are required in the new product which is only the case for crystal glass. There are no available studies about this specific recycling process available however.

- ***Substitution of smelting flux in secondary lead smelters***
  In smelting processes silicates are used as smelting flux. As the slag produced by the lead smelting process contains high amounts of lead in any case and has therefore to be disposed of accordingly, the substitution of sand by granulated leaded glass as smelting flux is a viable process. It is however doubtable that the lead smelters would pay for the material as it is substituting sand which they get for free in any case. Additionally, it seems that the management of the lead smelters in Cairo believes that the use of this material would damage the furnace and refuse to take it so far. This is however rather unlikely as granulated leaded glass is basically a silicate as well. Also, this process is already used in other countries in secondary lead and copper smelting. Discussions would have to be sought to see if the lead smelters would agree to use the leaded glass fractions and how much of it they could process and how the glass would have to be prepared before delivery.

- ***Disposal in Nasreya landfill***
  The lead inside the glass matrix is actually quite stable and the leaded glass could be landfilled in an adequate facility. The general problem with this is the high incurred cost of transport and landfilling fee, as well as the important amount of space required.

Plastics

The majority of CRT casings are made out of ABS plastics, but other plastic types are possible as well. In order for the plastic to be recycled it must be sorted into pure fractions as even a small percentage of impurity in the recycling process leads to an important loss of quality in the end product. Additionnaly, plastic casings of CRT screens are often treated with brominated flame retardents which are hazardous. Such parts have to be identified and removed before entering the recycling process. The separation process can either be done manually by checking for labels and testing for physical properties like breacking behaviour. This is rather labor intensive and slow. Another option is density separation in a floating pool after the casings have been crushed to smaller pieces. Using saltwater solutions of specific densities, the different types of plastics can be separated. It is also possible to identify BFR treated parts in this way . The whole process requires a certain investment in infrastructure to crush and separate the plastic fraction and its economic viability depends on the identification of a market for the obtained plastic fractions. The brominated fraction should be disposed of as hazardous waste either in an adequate landfill or by high temperature burning. Co-processing in cement kilns is possible, depends however on the limits about halogens in the “fuel” as those are harmfull to some parts of the installation.

Capacitors

As mentioned earlier, there are two types of capacitor that can be found in CRT screens. Capacitors of a diameter larger than 2cm and found in screens manufactured before 1987 contain with high probability PCBs which are hazardous to human health and the environment. These have to be collected apart and disposed of as hazardous waste.
For the smaller and newer capacitors it may be possible to sell them to aluminum smelters due to their aluminum content. The aluminum yield per ton is not known and prices are therefore unclear as well. Additionally it has to be verified that the processing of these capacitors in aluminum smelting processes are environmentally viable.

Phosphor powder

The phosphor powder contains heavy metals and has therefore to be disposed of as hazardous waste. The amount of phosphor powder per screen being very small, this does not incur very high cost.

5. Cost of CRT recycling

The total cost for the recycling of CRT screens is composed of several aspects: Collection, transport, dismantling, disposal, labor, rent of work- and storage space. Additionally there is some investment necessary for equipment in the beginning. Income is only generated through the selling of recovered fractions which are valuable. The goal of this section is to estimate each cost aspect and calculate the possible revenues in order to assess the economic feasibility for a CRT recycling workshop in Egypt. The numbers for required workers, dismantling time, space and infrastructure requirements are based on a business calculation tool for e-waste dismantling facilities provided by international experts while the cost for transportation, landfilling, labor etc. are based on information gathered from local sources based on the situation in November 2017.

Collection

Due to the fact that the informal sector is currently buying EoL CRT screens, these devices are regarded by the population as valuable even when they stop working. Broken CRT monitors are sold around 40 EGP while working CRT monitors go for 60-70EGP. Prices up to 100EGP are possible depending on the size and state of the screen. Let us assume the average price for EoL CRT monitors is 50EGP while the average price for CRT TVs is 75EGP due to their larger size. This corresponds to 2.85$ and 4.25$ per piece respectively. On average, the average weight of CRT monitors is around 14kg while CRT TVs weigh around 25kg. The price per ton is therefore in the range of 204$ for monitors and 170$ for TVs. Buying larger quantities at official auctions from the government and private sector might result in lower prices per ton. Also, the implementation of extended producer responsibility (EPR) including a take back scheme is currently being discussed by different stakeholders from the government and the ICT producing sector. In the future this mechanism might lead to a collection at the cost of the producers of TV screens and computer monitors which would have a positive impact on the cost faced by the recycler concerning collection of input material.

Transport

Transport is needed at different steps of the recycling chain. The collected material has to be brought to the processing facility and transport is needed as well for down streaming of the recovered fractions, valuables and hazardous alike. Let’s assume that collection happens only at the level of greater Cairo and all valuable fractions such as copper, aluminum, steel and printed wiring boards are sold to factories and exporters in greater Cairo. The cost of transportation is in the region of 350EGP/ton when outsourced. If any fraction has to go to Nasreya landfill in Alexandria the cost is higher due to the further distance, here we use 1050EGP/ton as estimation. Based on the high cost of outsourcing of transportation, it might be economically more favorable to buy trucks in order to handle the transportation internally. This option would have to be further investigated in a more detailed business case.

Dismantling

Proper dismantling of CRT screens takes around 15 minutes per screen provided all the necessary hand tools and a machine for the separation of the panel and funnel glass are available. The dismantling time for 1 ton of computer monitors is therefore 17.9h/ton and in the case of TV screens 10h / ton. The cost for dismantling consists of the cost for labor including protective equipment such as helms, shoes, gloves etc., tools and working stations for each dismantling worker, collection boxes and the CRT treatment unit for the separation of panel and funnel glass.

Disposal

The cost of disposal in landfills depends on the material. In the case of hazardous material such as leaded glass or phosphor powder, a fee of 500EGP/ton (28.5$/ton) is required for save disposal in Nasreya landfill in Alexandria. Additionally, the higher cost for transportation of around 1050EGP/ton appears due to the distance of 220km between Cairo and Alexandria. Disposal of non-hazardous material in a local landfill in greater Cairo region costs 25-50EGP per truckload of 6-8tons. Here we assume a cost of 5EGP/ton plus the cost of local transportation. The total cost of disposal depends on the availability of downstreaming solutions for the glass and plastic fractions. Different scenarios will be discussed in the next section where a the disposal cost of 500 EGP/ton for disposal in Nasreya landfill and 5 EGP/ton for disposal in local landfill are retained.

Labor

Unskilled worker

While the legal minimum salary in Egypt is currently 1300EGP per month, a trustworthy and reliable labor force will cost around 3000EGP per month including social insurance. This corresponds to 170$/month. Assuming a 5 days week with 8 working hours per day and a total of 10 days of vacation per year, the hourly salary would be 18EGP/hour which corresponds to almost exactly 1$/h. The labor cost for dismantling one ton of CRT monitors can be estimated to be 18$ while the labor cost for dismantling one ton of CRT TV screens is estimated at 10$.

Skilled worker

The dismantling area will be supervised by skilled workers where it is assumed that a skilled worker supervises up to 8 unskilled workers. The salary of a skilled worker is assumed to be

2/3 higher than the one for unskilled workers which would result in 5000EGP/month (285$/month).

Administrative staff

10% of the total staff is assumed to be administrative staff with a salary of 5000EGP/month, equal to the one of a skilled worker.

General Manager

The person in charge of the CRT treatment workshop will require a higher salary than skilled workers and administrative staff. We will assume here a salary of 8000EGP/month (455$/month)

Work- and storage space

The amount of space required depends on the number of tons treated per year. Workspace requirement estimation can be made based on table 2 and the assumed amount of input material per year. The cost per square meter is between 15 and 30 EGP depending on the area. It is important that an industrial zone is selected for this kind of workshop in order to get the required licenses such as the EIA and industrial license.

Administrative space:	$15m^2$	per administrative worker
Dismantling space:	$55m^2$	per dismantling worker
Receiving area:	$20m^2$	per sorting worker
Machinery area:	$20m^2$	per machine such as CRT treatment unit, cable stripper etc.
Sanitary area:	$2.5m^2$	per staff member
Storage space:	$0.7\ m^2$	per ton of input
Additional space in hall:	$1\ m^2$	Per ton of input

Table 2

Investments

The required investments include the previously discussed CRT treatment unit for the separation of panel and funnel glass. The cost point for such a machine is 10’000-30’000$. Depending on the model screen sizes from 10 to 40 inches can be handled and processing capacities from 30 to 80 screens per hour are indicated by the manufacturers. The life span of such a machine is estimated to be 25 years. It is assumed here that a small cable stripper unit is bought as well since the investment of such a machine is rather low at around 1000$ while allowing to realize higher profits by processing the recovered cables directly inside the workshop. Further investment is needed to buy pallet trucks and lift trucks for internal transport in the facility. Finally equipment for dismantling stations such as tables, chairs, hand-tools etc. as well as protective equipment for the workers is needed as well as ventilators and collection boxes. The assumed cost and life spans of all the above are assumed as indicated in the following table.

Equipment	Cost / unit [$]	Units for 5% collection target	Life span
CRT treatment unit	15’000	1	25
Cable stripper	1000	1	25
Lift truck	5000	1	20
Palette truck	500	4	20
Pallete	5	60	10
Scale	250	1	20
Dismantling station	200	9	10
Tools	150	9	1
Protective equipment	50	9	1
Ventilator	10	11	10
Collection box	50	48	15
Administrative working station	500	2	5

Table 3

6. Economic feasibility assessment

In order to analyze the economic feasibility of a CRT recycling workshop in Egypt, we consider the three scenarios described in table 3.

1. Worst case scenario	All difficult fractions have to be landfilled at cost, EoL CRT screens have to be bought at local market prices
2. Expected scenario	Panel glass can be sold to local glass recyclers, all other difficult fractions have to be landfilled at cost, EoL CRT screens can be bought at reduced cost through auctions
3. Best case scenario	Panel glass and plastic fraction can be sold, leaded glass can be given away for a reduced cost, collection is outsourced at no cost to UNDP first and EPR scheme later on.

The following numbers are assumed to be the same for each scenario:

- **Collection target: 5%**
  Based on the estimations about available EoL CRT screens in the introduction, we assume in each scenario that the weight-mix of collected CRT screens will be 47.4% of TV screens and 52.6% computer monitors. A collection target of 1200 tons per year will be assumed, corresponding to 22'750 TV sets and 45'090 CRT computer monitors and representing 5% of the annual flow of EoL CRT screens.
- **Investment: CRT treatment unit**
  Depending on the technology, one CRT treatment unit can process 30-80 CRT screens per hour. The collection target can therefore be treated with one single machine which costs 10'000 - 20'000 $ depending on the technology. In all calculation an initial investment of 15'000$ and a lifetime of 25 years is assumed.
- **Labor force**
  For the assumed amount, the following staff is required:
  - 8 dismantling workers
  - 1 supervisor for the dismantling area
  - 1 administrative workers
  - 1 manager
- **Space requirements**
  The required amount of space to run a facility capable of processing 1200 tons of CRT screens per year is estimated to be 1580m^2 including space for storage. Rental cost is assumed to be 20$/m^2 per year, resulting in an annual rental cost of 31'600$.

Scenario 1:

If all difficult fractions have to be landfilled at cost and the before mentioned market prices have to be paid in order to collect the material, the operation of a CRT recycling workshop cannot be done without subsidies. Figure 4 indicates the cost structure of the workshop based on this scenario. The overall economic result in this case is **-92.5$ / ton**. As can be seen from the figure, the purchase cost is the most important in this scenario and the main reason why it is not possible to realize profit with the recycling of CRT screens. Although the cost for disposal only represents 3% of the total operation cost, the fact that over 80% of the recovered materials have to be disposed of at cost instead of generating revenue from selling them as secondary raw materials also has an important impact on the overall performance.

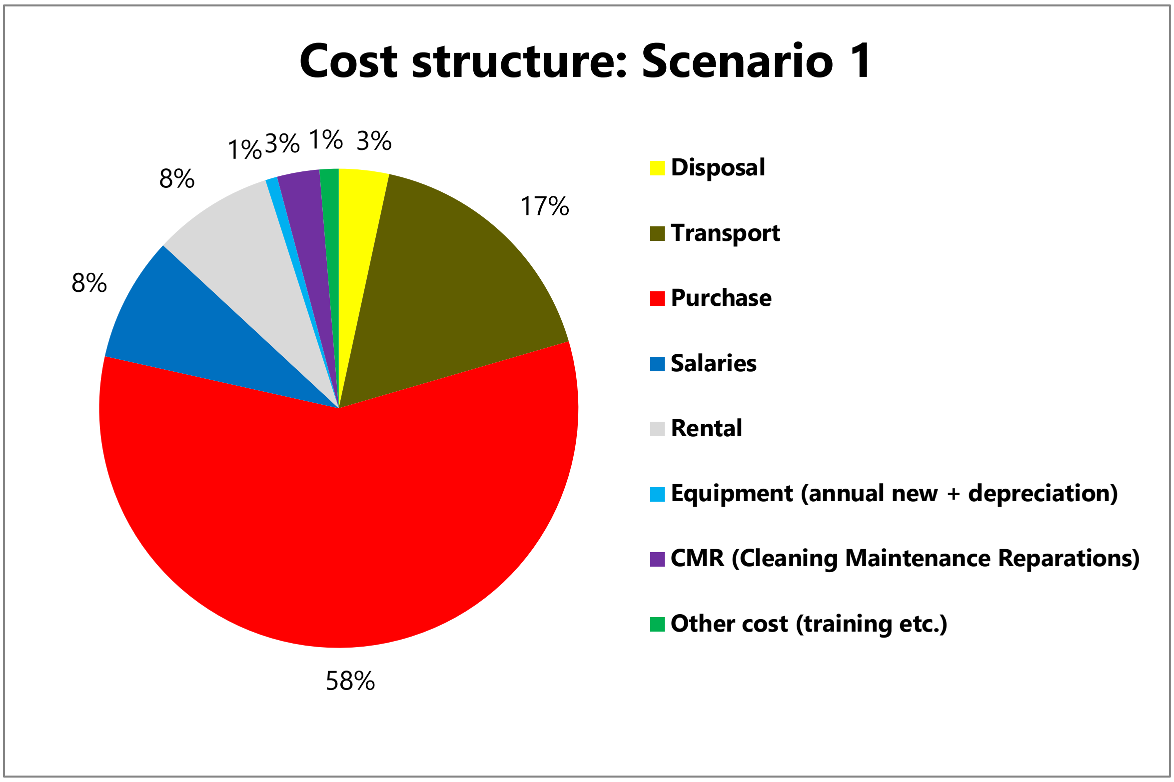

Figure 4

Scenario 2:

Here it is assumed that the panel glass fraction can be sold to glass recycling industries for 30$/ton and that the screens can be obtained at a 30% price reduction at auctions from the government and private sector. Based on these changes, the overall economic performance improves to **-24.7$ / ton**.

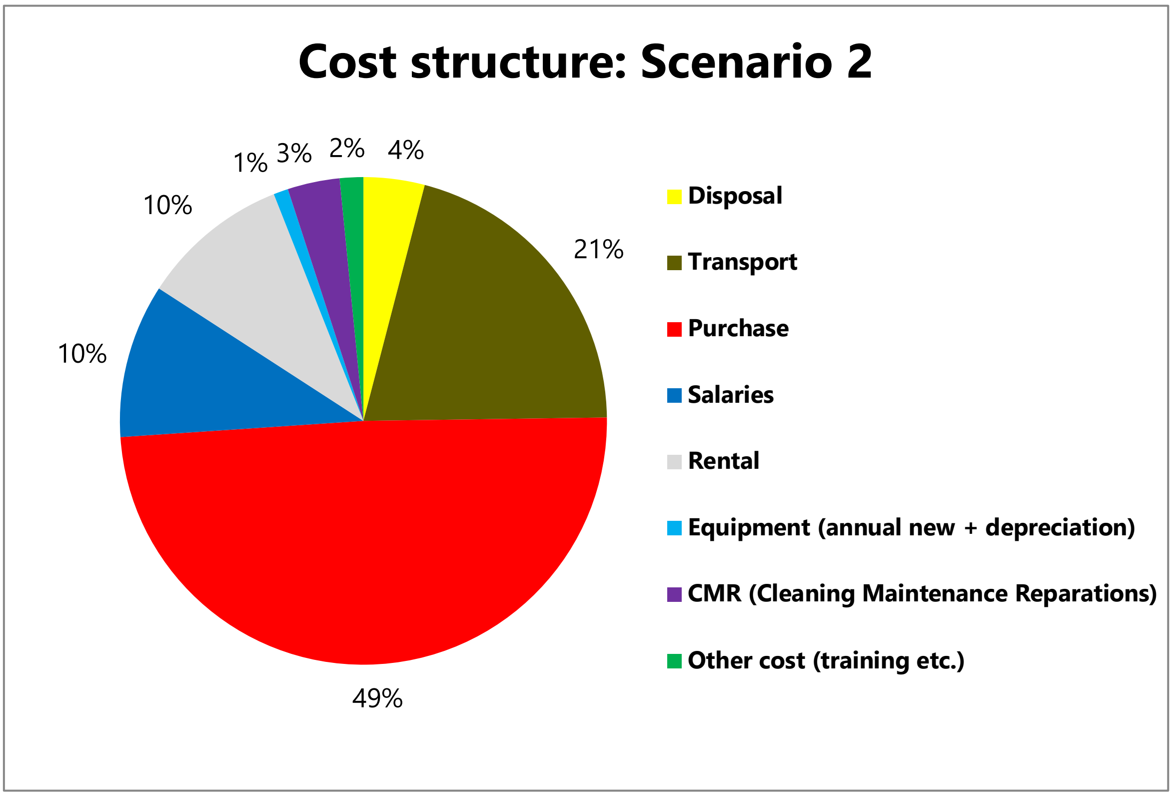

Figure 5

Scenario 3:

In this scenario we assume that both the panel glass fraction and the plastic fraction can be sold for 30$/ton and 100$/ton respectively. Additionally the leaded glass is supposed to be co-processed in a suitable industry for a reduced cost of 10$/ton. Finally the collection is as-

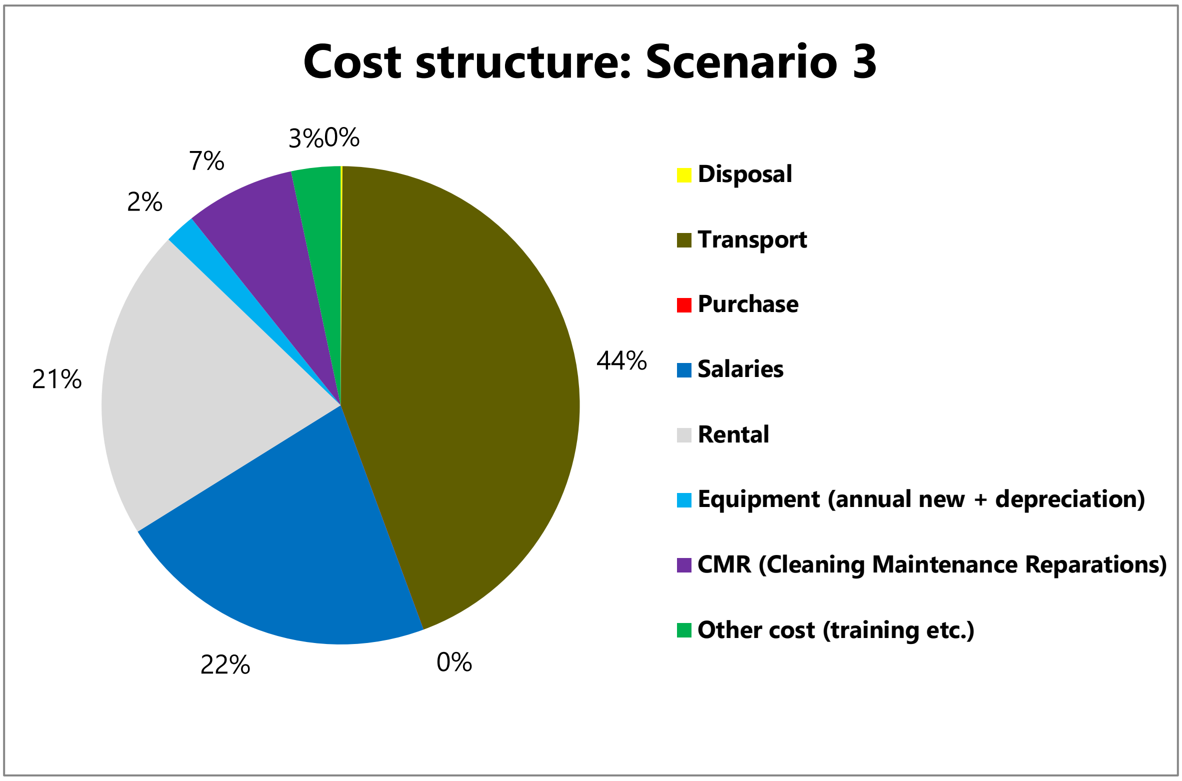

Figure 6

sumed to be handled by the UNDP GEF project at first and an EPR scheme later on. With these optimistic numbers, the overall performance becomes positive, realizing a profit of **126$/ton**. This shows that if down streaming solutions for the glass and plastic fractions can be found and the screens can be obtained at no cost, it is possible operate a CRT dismantling facility with an overall positive economic result in Egypt.

Important remark

The above presented numbers are based on a preliminary and simple analysis. They should only be considered as indicators and by no means replace a detailed business case study. They indicate however the main challenges of a CRT recycling facility, namely the high purchase costs and the identification of suitable down streaming solutions for glass and plastics. With the right policies and industrial partnerships, it seems to be absolutely possible to set up a local CRT dismantling facility in Egypt.

7. Recommendations

1. Due to the large volumes of EOL CRT monitors and TV screens that appear in the Egyptian e-waste sector, it is important to find a long-term solution for this waste stream. The results from this study show that, with the proper policies and partnerships, such a solution can be economically feasible. A domestic solution should therefore be targeted.
2. The results from this study should only be used as indicators. Further assessments of the possible industrial partnerships, prices for glass and plastic fractions as well as possible down streaming solutions for the leaded glass fraction are necessary in order to prepare a realistic business case.
3. Due to the high cost of transportation, the possibility of buying trucks and handling the transportation internally should also be investigated.
4. The most crucial point seems to be the high cost to purchase the EOL CRT screens and it is essential to find a solution to this problem. Since the implementation of an EPR scheme for e-waste in Egypt is currently being discussed, it would be interesting to set up a pilot project for CRT processing as a first implementation of EPR.

8. Conclusions

End of life CRT screens represent an important part of the e-waste generated in Egypt. It is estimated that in the year of 2017 around 24’000 tons of EOL CRT screens have been generated and that this number will remain high in the foreseeable future. As of today, the formal sector does not treat with this fraction due to its overall negative value while the informal sector processes CRT screens applying cherry picking operations and disposes or sells the hazardous fractions, which leads to negative environmental and health impacts. It is therefore crucial to develop a viable solution for this e-waste stream in Egypt. Since the volumes of EOL CRT screens will remain high for the foreseeable future and the infrastructure requirements of a CRT processing workshop could easily be met by a facility in Egypt, a domestic down streaming solution should be targeted. Based on the results of this study, such a facility can only be economically feasible, if down streaming solutions for the glass and plastic fractions can be identified and the high cost of collection can be reduced through subventions or the application of an EPR scheme. While this document presents a preliminary assessment of the economic performance based on the local market prices and international experience, further investigations are needed concerning possible partnerships with glass and plastic industries and concrete solutions to reduce the collection cost are required.

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