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NATIONAL E-WASTE MONITOR

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Authors
Cornelis Peter Baldé, Rohit Panchal, Vanessa Forti

Contact Information
For enquiries, please contact the corresponding author C.P. Baldé at balde@unitar.org

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ABBREVIATIONS AND DEFINITIONS

POM	Placed on Market
EEE	Electrical and Electronic Equipment
UNU	United Nations University
HS	Harmonized Commodity Description and Coding System
EU	European Union
WEEE	Waste Electrical and Electronic Equipment
EPR	Extended Producer Responsibility
ESM	Environmentally Sound Management
CRT	Cathode Ray Tube
FPD	Flat Panel Display
PV	Photovoltaic
BFR	Brominated Flame Retardant
PBDE	Polybrominated diphenyl ethers
PROs	Producer Responsibility Organizations
UNU-KEYS	E-waste classification developed by United Nations University
UNDP	United Nations Development Programme
UNITAR	United Nations Institute for Training and Research
kt	Kiloton (1 000 000 kg)
kg	kilogram
t	Tonnes (1000 kg)
Mt	Mega tonnes (1 000 000 000 kg)

EXECUTIVE SUMMARY

This report examines the overall statistics of electronic and electrical equipment (EEE) placed on the market (POM), the national stock and its subsequent e-waste generation, its disposal routes, and e-waste collection for environmentally sound management. The main findings are that 63 kt EEE were placed on the market in Lebanon in 2021, entering the stock of households and businesses. The total stock of EEE in Lebanon in 2021 is calculated at 659 kt. Once devices are broken or unused, the household survey suggests that repair and donation are the predominant intentions of Lebanese households, which is likely to extend the lifespan of the EEE. In 2021, 46 kt of e-waste was discarded from the stock and became e-waste. Once discarded, waste management infrastructure is lacking, and e-waste ends up with the municipal solid waste or is collected by the informal sector. As a result, of the 46 kt e-waste generation in 2021 only 0.09 kt was documented by two e-waste national dismantling entities in Lebanon to have been managed in an environmentally sound manner.

The statistical data can be used for national purposes to plan the number and the capacity of e-waste collection points and e-waste pre-treatment facilities, as well as for the financial planning of recycling fees and the setting of national collection targets to ensure that all e-waste will be properly managed. The statistical data can also be used for international reporting needs under Sustainable Development Goal 12 on sustainable consumption and production – specifically for indicator 12.4.2 on hazardous waste management and for indicator 12.5.1 on national recycling rates, both of which contain sub-indicators for e-waste.

It is very likely that the vast majority of e-waste is not managed in an environmentally sound manner. It might be that some cherry picking of valuable components is happening and that remaining materials are then dumped, or that entire devices are ending up in sanitary landfills or open dumpsites. This poses a risk to the environment and to the safety of workers, as e-waste contains hazardous materials that need to be separately and adequately managed. Calculations show that 71 kg of mercury, 81 t of lead and 63 t of polybrominated diphenyl ethers were added to the Lebanese e-waste stream in 2021. In addition, managing e-waste is an economic opportunity, as e-waste contains valuable materials, such as 19.5 kt iron and 2.5 kt aluminium in 2021.

To improve e-waste management in Lebanon, several practical steps need to be undertaken.

1. Design specific legislation on e-waste. Lebanon has a general Hazardous Waste Management Framework Decree, which includes e-waste. However, the country does not have a specific decree addressing the specific issues around e-waste management, such as assigning clear roles and responsibilities, the creation of a licensing system, and the establishment of a wide network of collection points or collectors able to separately collect all e-waste generated at the source. Such legislation should also be aligned with circular economy principles.

2. Introduce a financing mechanism in the legislation, such as extended producer responsibility or a polluter pays principle. Another possibility is to enact an import levy on all EEE to ensure that sufficient finances are available to maintain a sustainable e-waste management system. The transparency of the costs for running the system is important, as well as setting clear and independent monitoring protocols to yearly evaluate the effectiveness of the system.

3. Enforce legislation for all stakeholders and strengthen monitoring, statistics, and compliance mechanisms across the country to ensure a level playing field for all. The monitoring as performed in this report should be repeated on an annual basis for all EEE POM, for all e-waste that is generated, and for e-waste that is soundly managed through legislation, and it is recommended to ensure this through dedicated articles in the legislation.

4. Create favourable investment conditions for experienced recyclers and dismantlers to bring the required technical expertise to the country. A Lebanese e-waste management system could focus on establishing a wide network of decentralised collection sites and a centralized pre-processing site, which would include manual and mechanical treatment steps. These could establish business relations with international treatment facilities to ensure the end-processing of the e-waste generated locally (e.g., recovery of materials where smelters are needed).

5. Create a licensing system or encourage certification via international standards for collection and recycling. This ensures an international level playing field and that Lebanon does not end up as an importer of non-hazardous e-waste fractions with low environmental standards and resource efficiency or, even worse, through illegal imports of hazardous e-waste.

6. Develop a wide network of collection points or pick-up services to facilitate separate collection of the generated e-waste. The drop-off centres and points are to be distributed strategically and geographically through a properly designed overall plan. This should also include a programme for retailers to take back the EEE that they previously sold, the collection of smaller e-waste in supermarkets, etc.

7. Access to international recyclers. Lebanon does not have local end-processing facilities to manage specific e-waste fractions, such as printed circuit boards. However, it does have the capacity to perform the pre-treatment phase to separate the main components (e.g., printed circuit boards, compressors) and to recover some materials (e.g., iron, copper, plastics, etc.) and properly dismantle hazardous components. Lebanon can then explore possibilities to trade the products both nationally and internationally and to get access to international licensed treatment facilities for the treatment of complex components.

8. Improve awareness of e-waste stakeholders. Ensure that all stakeholders involved in placing EEE on the market, in e-waste collection, and in recycling are aware of the potential negative impacts on the environment and human health, as well as approaches to the environmentally sound treatment of e-waste.

9. Improve awareness of the general public. Create targeted awareness campaigns among consumers regarding a circular economy and its environmental benefits.

10. Strengthen the technical skills and networks of e-waste managers and public authorities. Ensure that e-waste managers have the skills and networks to legislate, monitor, and handle e-waste.

1. INTRODUCTION

1.1 What is E-waste?

E-waste refers to all electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of reuse (Step Initiative, 2014). It includes a wide range of products – almost any household or business item with circuitry or electrical components with power or battery supply. Economic development and rapid changes in technology have made e-waste the fastest growing waste stream globally. This growing e-waste poses a threat to the environment, but at the same time it provides a business opportunity to extract common, precious, and critical raw materials embedded in e-waste. There are six main categories of e-waste as defined by international guidelines on e-waste statistics [Forti et al., 2018]:

1. temperature exchange equipment
2. screens and monitors
3. lamps
4. a. large equipment (excl photovoltaic panels)
   b. photovoltaic panels, including inverters
5. small equipment
6. small IT and telecommunication equipment

The six categories have each of them a distinct size, hazardous materials that need to be depolluted, and valuable materials that can be extracted. The six categories can be further detailed using the product oriented UNU-KEYS classification. The correspondence table of the UNU-KEYS and six e-waste categories are shown in Annex 1.

1.2 Why Does E-Waste Need Attention?

In 2019 the world generated a striking 53.6 Mt of e-waste, an average of 7.3 kg per capita. Asia generated the highest quantity of e-waste in 2019 at 24.9 Mt, followed by the Americas (13.1 Mt) and Europe (12 Mt), while Africa and Oceania generated 2.9 Mt and 0.7 Mt, respectively. Among the total e-waste generated, only 17.4 per cent is documented to have been collected and recycled. The fate of the remaining 82.6 per cent is unknown [Forti et al., 2020]. The global statistics of e-waste generation and flows are shown in Figure 1.

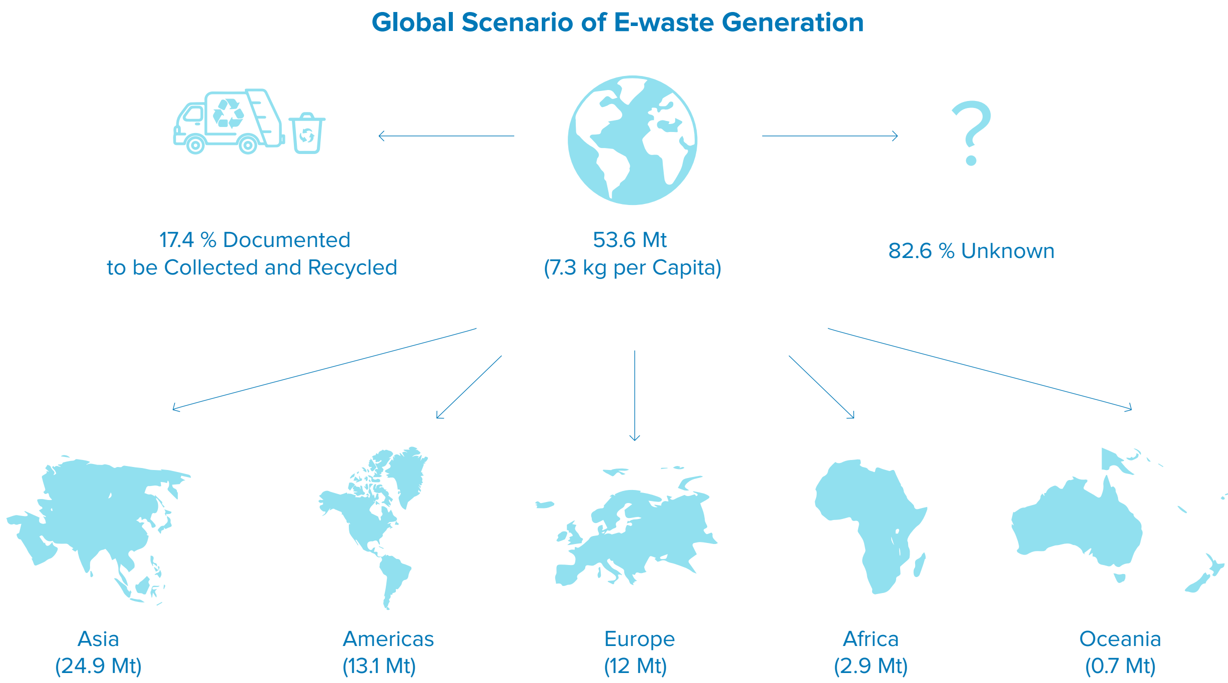


Figure 1 – Global E-waste Generation and flows (Forti et al., 2020).

The e-waste statistics, legislation and management infrastructure were assessed in the Arab Regional E-waste Monitor[1] in 2021 and placed in an international context. The e-waste generated in the Arab region[2] is about 2.8 Mt, almost similar to the entire African continent. It is alarming that the e-waste collection for environmentally sound management (ESM) in the Arab region is only 2.2 kt, which means the collection rate is only 0.1 per cent [Iattoni et al., 2021]. Furthermore, the data on collection and ESM of e-waste is available for only four countries: Jordan, Qatar, State of Palestine, and United Arab Emirates. The other countries in the Arab region lack the collection network and infrastructure for ESM, and hence they do not have e-waste statistics [Iattoni et al., 2021]. Globally, legislation on e-waste and their extended producer responsibility (EPR) has been implemented in several countries, but the Arab region does not yet have any such specific legislation.

The Arab Regional E-waste Monitor concluded that e-waste management infrastructure was only basic throughout the Arab region [Iattoni et al., 2021]. Some initiatives on the ESM of e-waste have been launched in the region, including in Lebanon, but the ESM of e-waste remains unorganized and unregulated. Today, e-waste management in the region faces several challenges, has a significant impact on the environment and on the low efficiency of resources management, and contributes to occupational and community health problems. The main drivers are (1) increasing volumes of e-waste; (2) the absence of e-waste-specific legislation; (3) limitations of management infrastructure; (4) competition between formal and informal sectors for valuable components of e-waste; and (5) legal and illegal import and export issues.

[1] The Arab Regional E-waste Monitor covers Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Somalia, State of Palestine, Sudan, Syria, Tunisia, United Arab Emirates, and Yemen, and was conducted in a way that it can be compared to other Regional E-waste Monitors and the Global E-waste Monitors.

[2] Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Somalia, State of Palestine, Sudan, Syria, Tunisia, United Arab Emirates, and Yemen.

1.3 Lebanese Context

The main legislative achievement that marks the 2010–2020 decade is the ratification of Law No. 80 (2018) for Integrated Solid Waste Management. It introduces advanced solid waste management principles, of which the polluter pays principle and the decentralization principle are the starting points for major paradigm changes in the solid waste sector in Lebanon. Currently, there is no specific legislation on e-waste management, but Lebanon has ratified such international agreements as the Basel Convention, Rotterdam Convention, Stockholm Convention, Montreal Protocol, and Minamata Convention [Iattoni et al., 2021]. Moreover, it has banned the import of hazardous materials, including e-waste, although it has allowed the export of hazardous materials to other countries.

To date, all e-waste is managed through a general hazardous waste decree, and Lebanon is in the process of establishing the EPR, which is evident in its 2019 national strategy for integrated solid waste management [Iattoni et al., 2021]. The proposed draft national strategy on integrated solid waste management includes targets for e-waste: a minimum of 2 kg per capita per year for recovery, and a minimum of 4 kg per capita per year for separate collection within five years of its introduction. The draft strategy is currently being revised, which might result in a change in the targets.

The 2020 State of the Environment Report notes that Lebanon generated 2.7 million tons of municipal solid waste in 2018, of which only about 20 per cent was diverted from disposal, while 44 per cent and 36 per cent ended in landfills and dumpsites, respectively. Over the longer term, the report notes that waste generation increased gradually due to population and economic growth during the periods 2008–2014 and 2017–2018. There were significant decreases of over 25 per cent in waste generation during the solid waste crisis in 2015 and 2016; and the increase of demolition waste generation due to the Beirut explosion in 2020 was overshadowed by the reduction of waste generation due to the COVID-19 crisis of the same year.

A 2019 assessment of the e-waste management infrastructure in Lebanon by UNIDO and the Ministry of Industry (prior to the adoption of Decree 5606/2019 regulating the management procedures of hazardous waste) identified the following issues: (1) poor/limited e-waste recycling infrastructure in Lebanon, primarily due to high energy cost considerations and, to a lesser extent, to e-waste complexity; (2) the handling of most of the e-waste stream by informal actors, particularly scrap dealers, in the absence of health and environmental safety measures and the lack of incentives for formal e-waste collectors to overcome the cost of transportation and logistics; (3) an absence of specific e-waste legislation (it is regulated only as part of hazardous waste); (4) limited awareness at the household level about e-waste handling and disposal; and (5) the unavailability of e-waste records and statistics.

1.4 About This Report

This report monitors all EEE placed on the market (POM) and the e-waste generation data for Lebanon. The statistics have improved compared to previous studies, as they are mathematically consistent with EEE stock statistics through EEE POM, stock, flow modelling per UNU-KEY. It also shows novel statistics on household disposal behaviour in Lebanon, as well as on e-waste collection and recycling for ESM. In addition, the quantities of iron (Fe) and aluminium (Al) and of various hazardous substances are also investigated.

The report also provides recommendations on how to establish an e-waste management system in Lebanon. In doing so, it is important to develop legislation with special focus on the protection of the environment and human health, with clear definitions, specific roles and responsibilities of the stakeholders, identification of the system design (e.g., producer responsibilities systems), and clear provisions for enforcement.

2.
METHODOLOGY

2.1 Classification

There are many types of EEE products in the market, and these need to be grouped into sensible and practically useful categories for comparison and for the international benchmarking of the e-waste management performance of the country. The present study uses UNU-KEYS classification, the six categories used in the European Union's Waste Electrical and Electronic Equipment Directive (2012/19/EU),[3] and the international guidelines on e-waste statistics Forti et al., 2018]. The descriptions of the classifications, and the corresponding tables, are listed in Annex 1. The UNU-KEYS categorize 54 products, and are constructed in such a way that product groups share comparable average weights, material compositions, end-of-life characteristics, and lifetime distributions. All data have been gathered and calculations have been performed at the level of the UNU-KEYS.

2.2 Measurement Framework

The measurement framework to estimate e-waste generation in Lebanon is based on the stocks and flows of e-waste. It is an internationally accepted framework, and hence it can be used for the international benchmarking of e-waste generation among various countries in the world. The governing variables for estimation of e-waste generation are (i) EEE POM and (ii) the lifetime of EEE. The EEE POM is more sensitive as compared to the lifespan of EEE. The consumed EEE POM stay as a stock in households and businesses. The time for which the EEE POM stay in households and businesses represents the EEE lifespan. The further extension of EEE lifespans occur due to repair, donation, selling, and exchange of EEE as shown in the measurement framework below. After the lifespan of EEE, e-waste is generated. The e-waste is collected as (i) to include it with unsorted household waste or (ii) separately collected by taking it to a collection or drop off point, or iii) collected by the informal sector or iv) picked up by installation companies.

[3] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:197:0038:0071:en:PDF

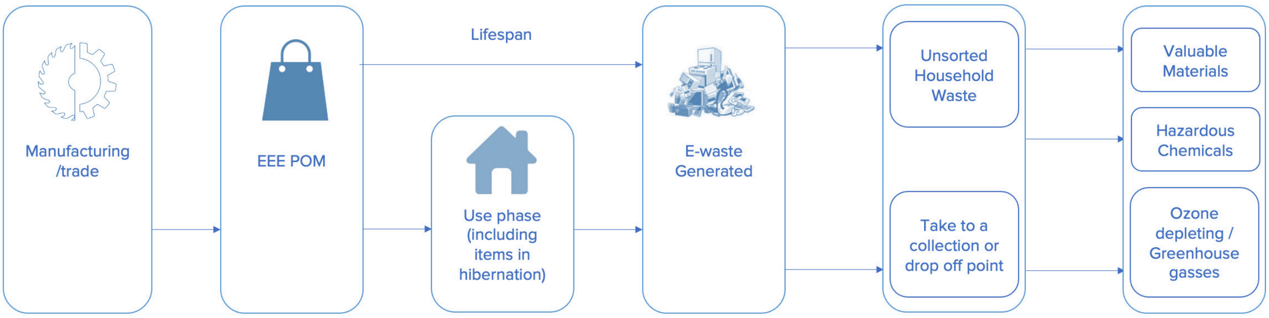


Figure 2 – Measurement Framework

2.3 Calculation Steps and Data Sources

2.3.1 EEE POM

The term "Placed on market" (POM) refers to the amount of EEE consumed in each time and geographical boundary. In the present study, Lebanon is the geographical boundary, and the period is from 1980-2021. This study uses the apparent consumption methodology to estimate EEE POM in Lebanon for the years 1995 to 2019. The apparent consumption methodology has been done for each UNU-KEY for each year separately, in which domestic production of EEE and imports of EEE are added up, and exports of EEE are subtracted for each year. See the equation below. The domestic production of EEE in case of Lebanon is negligible and hence considered as zero. The import and export data were extracted from the United Nations Comtrade database. The calculation of EEE POM is done for all EEE products consisting of 54 UNU-KEYS. The time series dataset of each UNU-KEY is back casted till 1980 and forecasted till 2021 using linear regression

POM(t) = Domestic Production (t) + Import (t) – Export (t) *(Apparent Consumption Method)*

The EEE POM for UNU-KEY 0002 (PV panels) is calculated separately using the country data of Lebanon on installed capacity in megawatt per year retrieved from IRENA database of the International Energy Agency. The annual changes in installed capacity in MW and the MW to tonnage conversion factor gives the EEE POM data of UNU-KEY 0002. The same conversion factors were used as in the global e-waste monitor (Forti et al., 2020).

2.3.2 Lifetime of EEE products

The lifetime, L(p) (t, n), is the lifetime profile of an EEE POM in year t, which reflects its probable obsolescence rate in evaluation year n after it has been placed on the market. The lifetime profile of EEE is based on the discarding behaviour of EEE consumers of the country, and is mathematically expressed as a Weibull distribution:

$$L^{(p)}(t,n) = \frac{\alpha(t)}{\beta(t)^{\alpha(t)}}(n-t)^{\alpha(t)-1}\, e^{-[(n-t)/\beta(t)]\alpha(t)}$$ *(Weibull Distribution Function)*

Products with a lifespan that does not vary greatly over time can be mathematically expressed easier as follows.

$$L^{(p)}(t,n) = \frac{\alpha}{\beta^{\alpha}}(n-t)^{\alpha-1}\, e^{-[(n-t)/\beta]\alpha}$$ *(Distribution of Product Lifetime)*

The shape (α) and scale (β) parameter of the Weibull distribution function were initially taken from Forti et al. (2018). These shape and scale parameters were further refined by using the stock and flow modelling as described in section 2.3.6 to ensure that the EEE POM, lifespans, and EEE in stock are in a consistent mass balance with each other.

2.3.3 Stock and disposal behaviour

The estimation of household stock for 25 UNU-KEYS was part of the 2021 household survey. The survey was conducted among a representative sample of six governorates (Beirut, North Lebanon, Mount Lebanon, Bekaa, South Lebanon, and Nabatieh) and consisted of 1,280 households, including all income levels and household sizes. Statistics regarding the lifetime of EEE, household stock, and functioning and non-functioning EEE in households is estimated using this questionnaire survey, as well as questions on disposal behaviour. The study was conducted by from July to September 2021. The outcomes of the household survey were extrapolated to represent the full population in Lebanon, including the refugee population. The estimation of business stock is based on the average number of EEE products per businesses. The values regarding the number of businesses in Lebanon are taken from the Index of Lebanon website.[4] The total stock of each UNU-KEY is the sum of household stock and businesses stock. Since the household stock is a part of the primary survey, the businesses stock is validated and remodelled by considering the percentage share of businesses stock to total stock. The total stock for year n is described as follows:

$$S_n = \sum_{t=t_0}^{n} PoM_t - \sum_{t=t_0}^{n} E_n$$ *(Total Stock)*

An example for UNU-KEY 0109 (freezers) is given in Table 1 to illustrate the estimation of businesses stock in Lebanon.

[4] See https://www.indexoflebanon.com/companies-in-lebanon/index.php.

Table 1 – Estimation of businesses stock in Lebanon (example – UNU-KEY 0109)

Type of businesses	Number of businesses	Average number of freezers per business activity	Total per activity
Restaurants	3,286	3	9,858
Food companies	2,212	3	6,636
Hotels	751	3	2,253
Pubs	465	1	465
Supermarkets	459	3	1,377
Pastry shops	389	1	389
Resorts	157	1	157
Night clubs	141	1	141
Ice cream shops	39	1	39
Total			21,315

- Household stock of freezers from household survey = 445,733
- Business stock = 21,315
- Total stock = business stock + household stock = 467,048
- Share of business stock to total stock (in %) = (21,315/467,048)*100 = 4.56%
- Share of household stock to total stock (in %) = (445,733/467,048)*100 = 95.44%

2.3.4 E-waste generation

The quantification of e-waste generation is based on previous years of EEE POM and the lifetime of EEE. The mathematical equation to determine e-waste generation is described below. The e-waste generated (n) is the quantity of e-waste generated in evolution year n; EEE POM (t) is the product placed on market in any historical year's t prior to year n; t0 is the initial year that a product was sold; L(p) and (t, n) is the discard-based lifetime profile for the batch of products sold in historical year t. The e-waste generated (n) is estimated for all 54 UNU-KEYS using EEE POM data from 1980 to 2021. The e-waste generated is improved and validated using the stock equation since stock is estimated using the household survey.

$$E - waste\ Generated\ (n) = \sum_{t=t_0}^{n} EEE\ POM(t) * L^{(p)}(t,n)$$ *(E-waste Generation)*

2.3.5. E-waste documented to be formally collected and dismantled

The e-waste documented to be formally collected and dismantled is collected by reviewing a due diligence report prepared by UNDP Lebanon for two local actors on e-waste: Ecoserv (an NGO) and Verdetech (a private company).[5]

2.3.6 EEE POM, stock, flow modelling

The EEE POM, stock, flow modelling is based on the mathematical relationship among EEE POM, e-waste generation, and the total stock. The stock in a year is calculated by the sum of EEE POM subtracted by the sum of e-waste generated. For all UNU-KEYS, the EEE POM for all the individual years 1980–2021 is multiplied by the respective lifespans to calculate the e-waste generated. The subtraction of the sum of EEE POM and the e-waste generated gives us the calculated stock. For each UNU-KEYS, the household survey gives us the measured stock. The value of EEE POM and lifespans were iteratively adjusted to match both the calculated and measured stock. The EEE POM values were adjusted such that the EEE POM graphs do not deviate much from the projection path. The lifespan parameters (scale and shape parameters) of EEE are less sensitive in e-waste generation estimation, and thus they were adjusted only in some cases. In this iterative process, outliers are removed and corrected. The UNU-KEYS adjusted in this process are 0114, 0201, 0202, 0203, 0204, 0205, 0506, 0701, 0302, 0304, 0305, 0306. The EEE POM stock flow modelling is explained in the figure below.

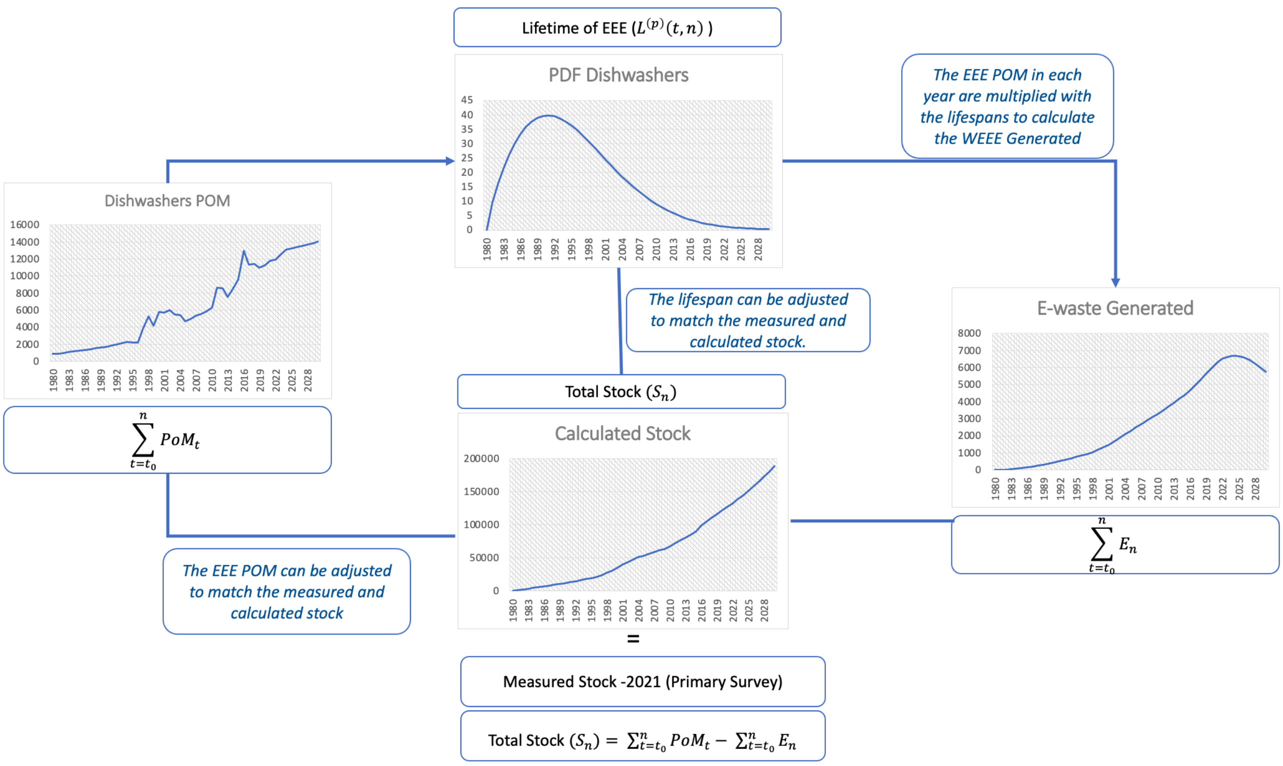


Figure 3 – Example of EEE POM, stock, flow modelling for dish washers

[5] UNDP (2021, unpublished), "Due diligence report on e-waste management facilities in Lebanon."

2.3.7. Hazardous and valuable materials

This study uses the methodology developed for the Global E-waste Monitor 2020 [Forti et al., 2020] for the calculation of hazardous and raw materials embedded in e-waste in Lebanon. The amount of raw materials found in e-waste was calculated by linking the composition data to the EEE POM per UNU-KEY, and then similar calculations using the lifespans to calculate e-waste generation. The composition data for iron, aluminium, lead, and mercury were taken from the EU Prospecting the Urban Mine Project [Huisman et al., 2017]. Composition data relative to brominated flame retardant plastics were searched for in the literature, and relevant information was found in Chen et al., 2012; Abbasi, 2015; and Yu et al., 2017. With regards to the quantification of refrigerants, a literature review was conducted to assess the amount and type of refrigerants used in cooling and freezing equipment. Relevant information was found for fridges and air conditioners in Duan et al., 2018.

3.
E-WASTE STATISTICS

This chapter presents the statistics on EEE POM, e-waste generated, and the disposal routes of e-waste in Lebanon.

3.1 EEE POM in Lebanon

The EEE POM in Lebanon was estimated to be around 7.8 kt in 1980, which doubled to 14.8 kt in 1990 as shown in Figure 4. The EEE POM in Lebanon further increased by a factor of eight (63 kt) in 2021. It is observed that the consumption of screens and monitors decreases from 2004 to 2021. The sharp decrease in screens and monitors is due to the replacement of heavy (22 kg/unit) EEE cathode ray tube monitors with flat panel display monitors (5.5 kg/unit). PV panels were introduced in Lebanon in 2013, with approximately 2 tons EEE POM, and they show a steep rise to 41 tons in 2021.

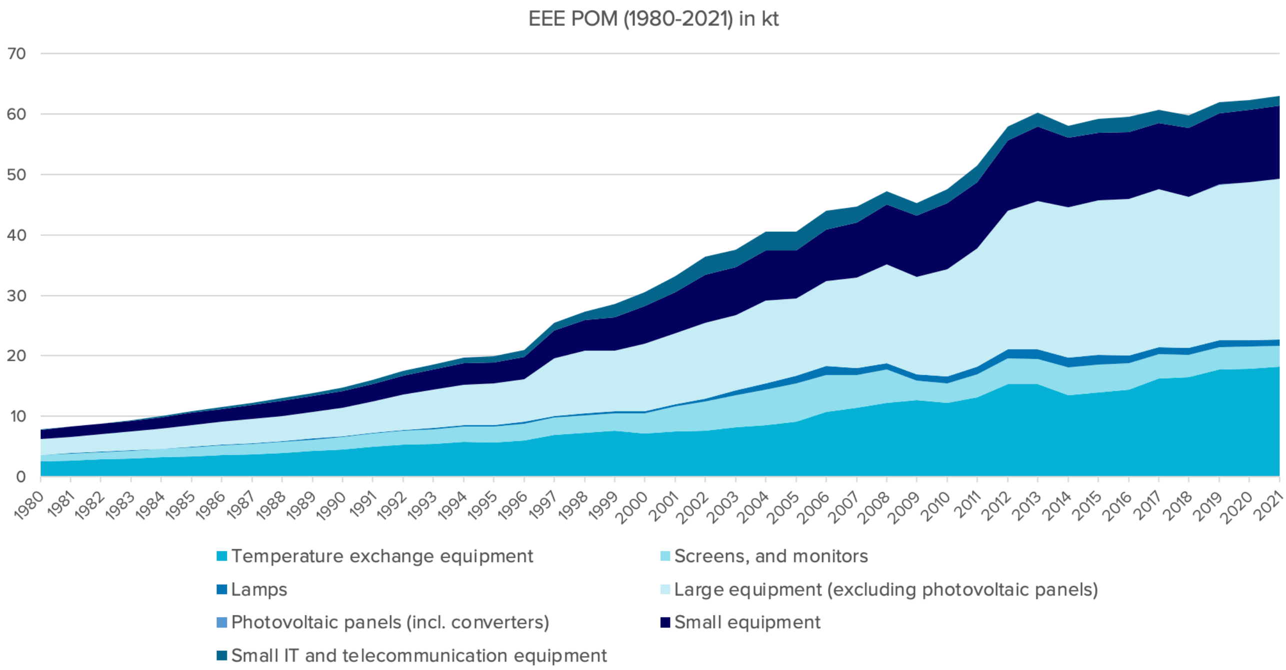


Figure 4 – EEE POM in Lebanon in kt (1980–2021)[6]

[6] The EEE POM was calculated using apparent consumption methodology and EEE POM stock flow modelling for 1995 to 2019. It is back casted till 1980 and forecasted till 2021 using linear regressions.

The EEE POM consists of 28.8 per cent temperature exchange equipment, 5.6 per cent screens and monitors, 1.6 per cent lamps, 42.3 per cent large equipment, 0.06 per cent PV panels (including converters), 19.1 per cent small equipment, and 2.5 per cent small IT and telecommunication equipment (Figure 5).

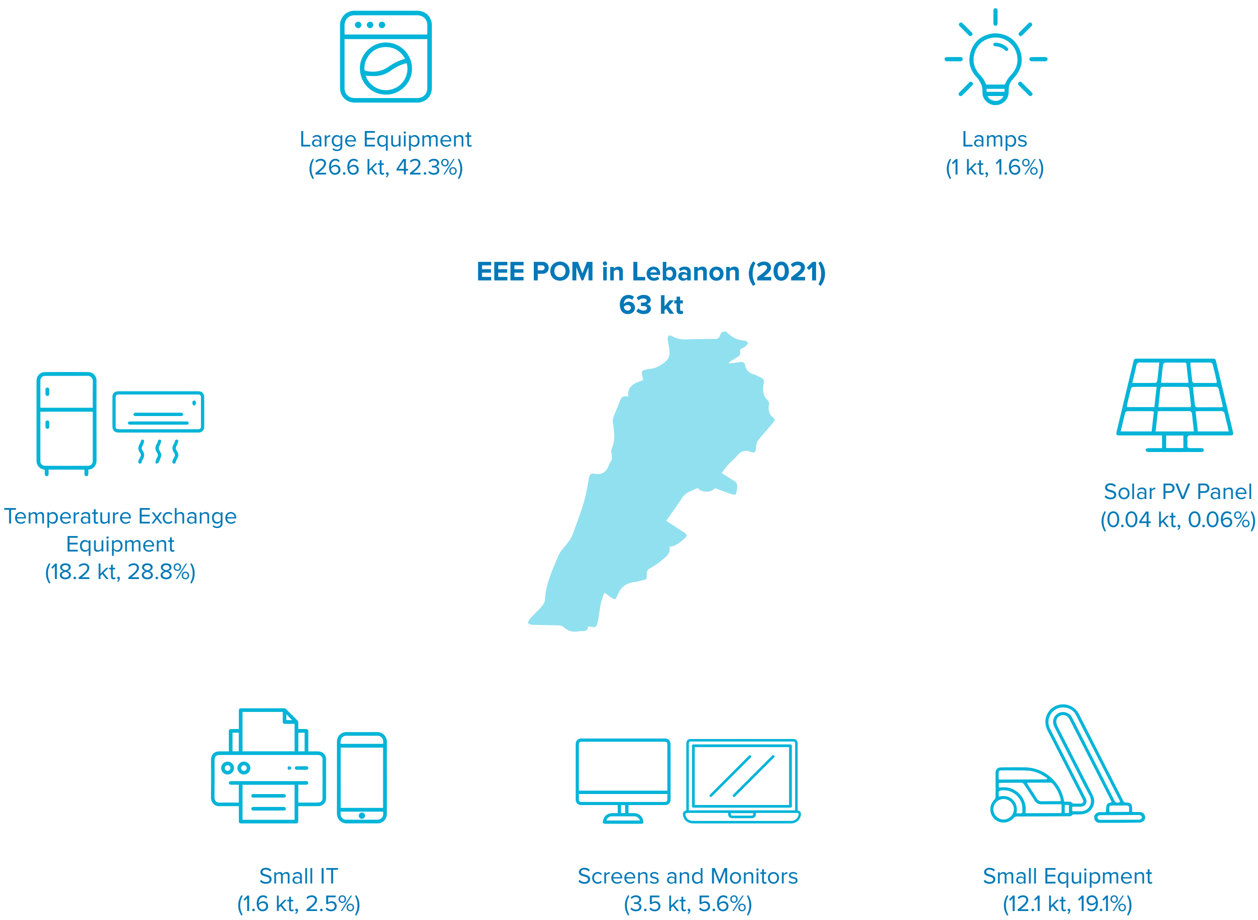


Figure 5 – EEE POM in Lebanon disaggregated per category in kt (2021)

The EEE POM in kg/inhabitant compared to other Arabic states is shown in Figure 6. The highest EEE POM is found in the Gulf States, with over 20 kg/inhabitant EEE POM; and the lowest in the African part of the Arab region, with lower than 3 kg/inhabitant EEE POM. Lebanon is in the middle, with 10.2 kg/inhabitant.

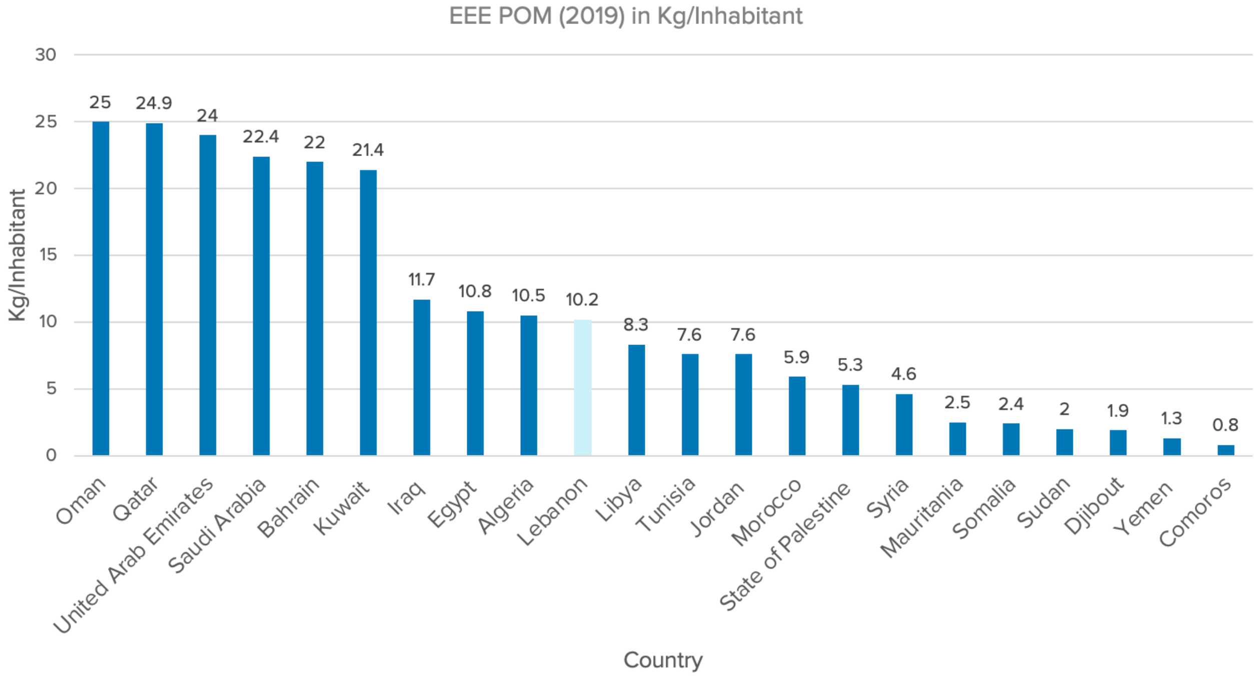


Figure 6 – EEE POM in Lebanon in comparison to the Arabic region (kg/inhabitant, 2019)

3.2 E-Waste Generated in Lebanon

The e-waste generation in six categories is given in Figure 7, and shows that the e-waste generation in Lebanon was around 29 kt in 2010 and increased steadily to 46.5 kt in 2021. The e-waste generation methodology provides a projection of generated e-waste, which is insensitive to sudden annual fluctuations that may arise due to recessions, when consumers tend to discard less or economic upturns when consumers tend to replace and discard more equipment. The effects of COVID-19, when national lockdowns started and consumer demand for EEE – especially personal computers, laptops, tablets, and mobile phones – are not yet appearing in the e-waste generation figures, as there is naturally a delay between the products being placed in the market and being discarded. The same applies for the extensive electric blackouts that occurred in 2021, which resulted in an increase in demand for PV, power storage, and inverters. An increase in waste generation of large equipment is observed between 2010 and 2021 as shown in Figure 7, due to a significant increase in kitchen equipment and washing machines in the underlying datasets. Also, the PV panels waste increases steeply from 2010 to 2021. The decreasing trend in waste generation for screens and monitors is noticed, as the heavy cathode ray tube monitor waste is replaced by the flat panel display monitor waste. Similarly, the small IT and telecommunication waste decreases due to the introduction of light-weight products.

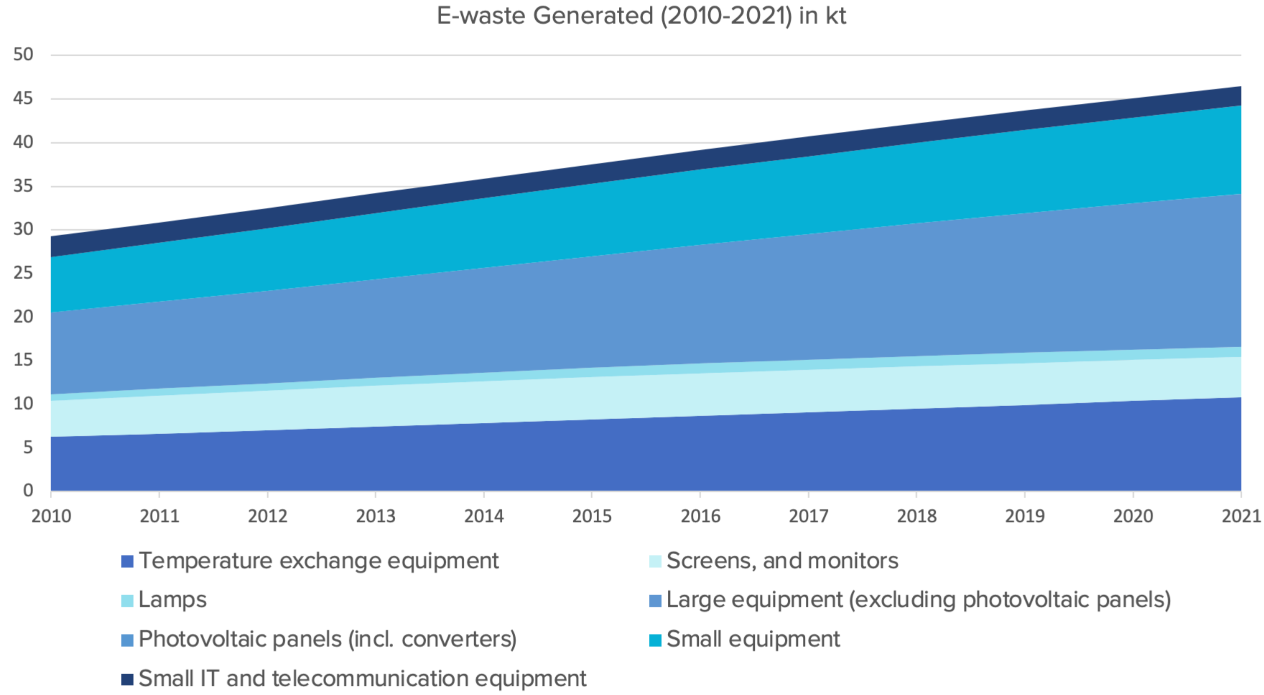


Figure 7 – E-waste generated in Lebanon in kt (2010–2021)

In 2010 the demand for EEE consisted of 22 per cent small equipment, 32 per cent large equipment (excluding PV panels), 22 per cent temperature exchange equipment, 3 per cent lamps, 14 per cent screens and monitors, 8 per cent small IT and telecommunication equipment, and 0 PV panels. Ten years later e-waste generation increased to 46.5 kt and 7.8 kg/inhabitant with changes in e-waste composition. In 2021 e-waste consisted of 38 per cent large equipment (excluding PV panels), 23 per cent temperature exchange equipment, 22 per cent small equipment, 10 per cent screens and monitors, 5 per cent small IT and telecommunication equipment, 3 per cent lamps, and 0.0004 per cent PV panels, as shown in Figure 8.

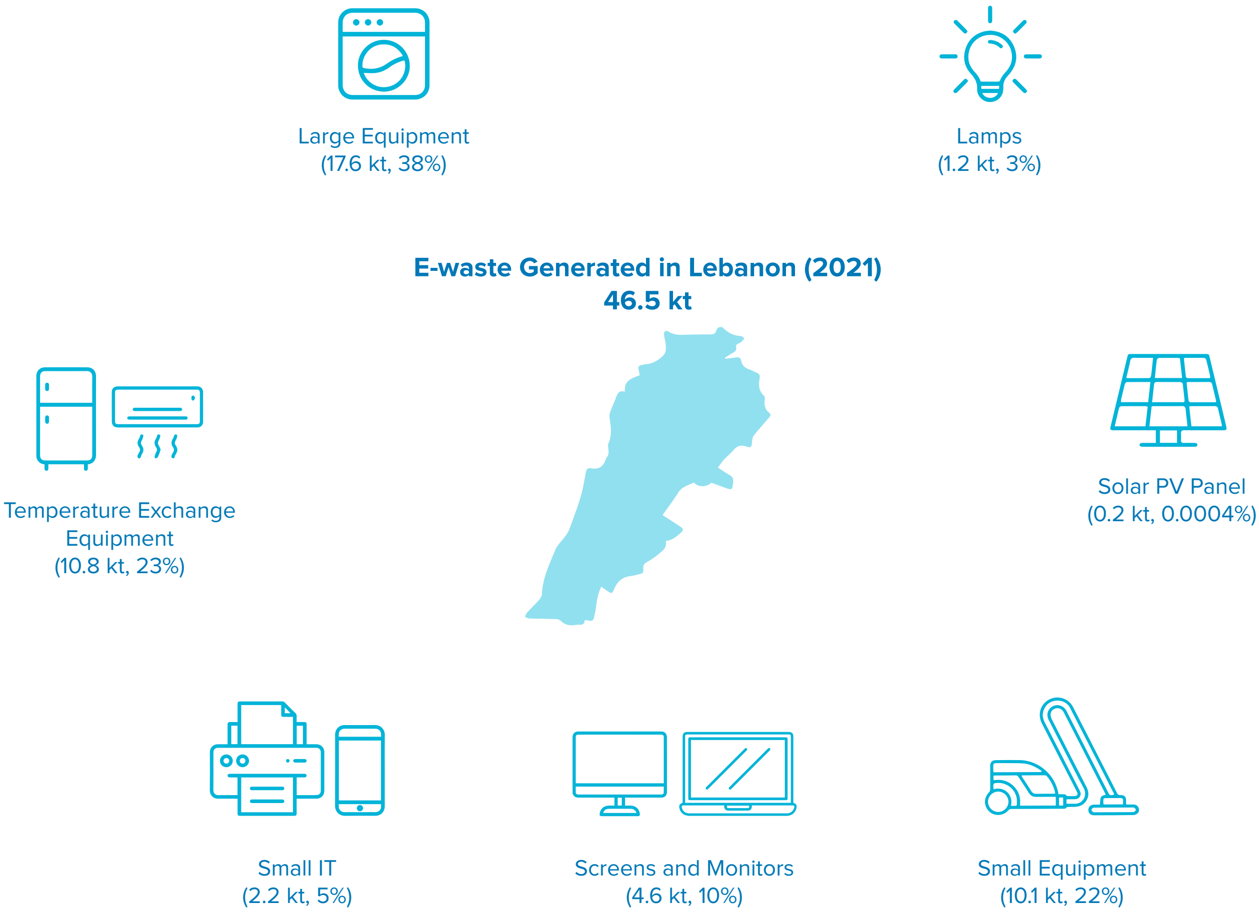


Figure 8 – E-waste generated in Lebanon disaggregated per category in kt (2021)

The benchmarking of e-waste generation (in kg/inhabitant) of Lebanon with other countries is shown in Figure 9. The highest e-waste generation is found in the Gulf States (over 13 kg/inhabitant) and the lowest in the African part of the Arab Region and Yemen (lower than 2.1 kg/inhabitant). Lebanon is between these figures with 7.2 kg/inhabitant.

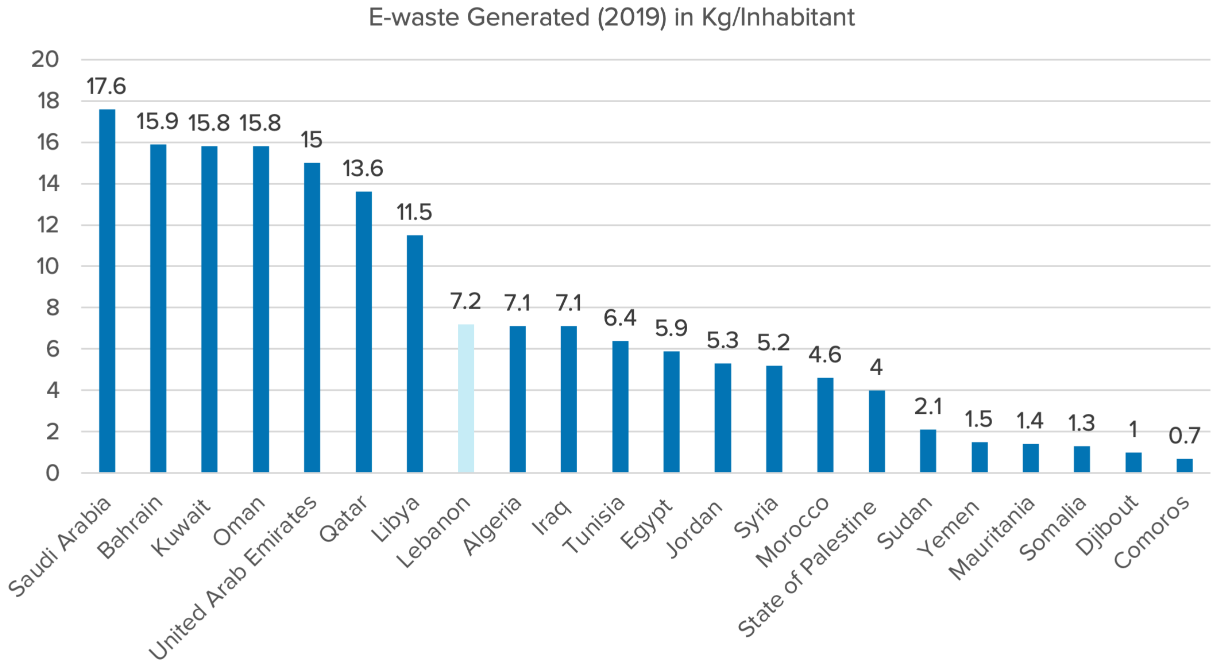


Figure 9 – Benchmarking of e-waste generation of Lebanon compared to the Arabic region (kg/inhabitant, 2019)

3.3 E-Waste Documented to be Formally Collected and Dismantled

The amount of e-waste documented to have been formally collected and dismantled in Lebanon in 2020 was 0.09 kt [Ecoserv and Verdetech, 2021] – only 0.2 per cent of the total e-waste generated as calculated in this study (45.1 kt). The total e-waste collected and recycled in 2020 (0.09 kt) is mostly comprised of small IT (64 per cent), while the remaining 17 per cent is small equipment, 11 per cent is screens and monitors, 7 per cent is temperature exchange equipment, and 2 per dent is large equipment. Lamps represent only 0.3 per cent of the total e-waste documented to be formally collected and recycled, as shown in Figure 10.

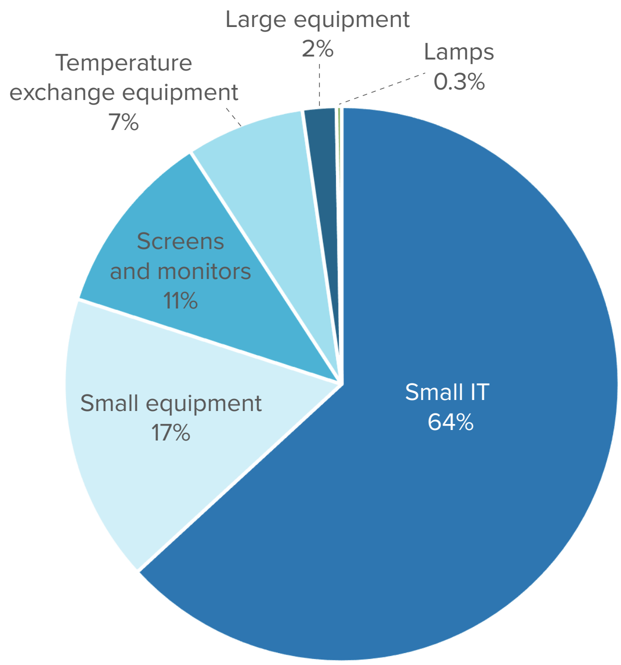


Figure 10 – Composition of e-waste documented to be formally collected and dismantled (2020)

These statistics demonstrate that a great effort is needed to promote e-waste collection and recycling in the country. Ecoserv and Verdetech are already active in this effort, but initiatives are needed to set up an e-waste management system that ensures that all e-waste is collected and sent to appropriate recycling facilities, as well as to increase the capacity of the entities that have been already recycling e-waste in Lebanon.

3.4 Disposal Behaviour of Households in Lebanon

The response rate of the 2021 survey on e-waste possession and general questions about behaviours towards e-waste disposal was very high, with over 1,200 households completing that part of the survey. The survey suggests that the majority of Lebanese households intend to extend the lifespan of the EEE goods that they no longer need or that are no longer functioning. Approximately 65 per cent of households intend to repair their older EEE, 12.5 per cent intend to donate them, and only 0.6 per cent say they expect to sell them. The survey also suggests that 12.1 per cent of households prefer to store their e-waste at home, rather than dispose of it; around 9 per cent dispose of e-waste through regular unsorted household waste; and far fewer (0.6 per cent) take it to a collection point (Figure 11).

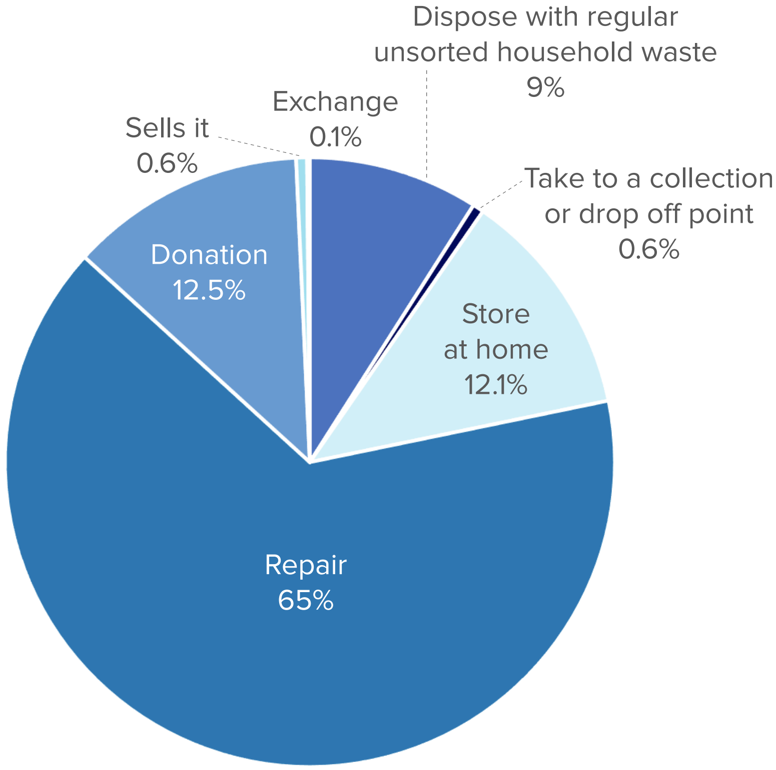


Figure 11 – Behaviour of households in Lebanon regarding e-waste (2021)

3.5 EEE POM and E-Waste Mass Flows in Lebanon

The EEE POM, EEE stock and e-waste generation, the disposal routes, and e-waste collection for environmentally sound management can be integrated all together to construct national mass balances. Figure 12 shows that in 2021 63 kt EEE were placed on the market in Lebanon, and 10 times more (659 kt) is currently in stock/in use. From the total stock, 554 kt is with households and 105 kt is estimated to reside with businesses. The amounts in stock with businesses need be further improved using specific business surveys, prior making specific interventions or deprioritizing it. Of this stock, detailed outcomes from the household survey indicate that 95 per cent of the items are functioning and 5 per cent are not functioning.

Every year 46 kt of e-waste is generated in Lebanon, and only 0.09 kt is documented to be managed in an environmentally sound manner. It is very likely that the vast majority of e-waste is not managed in an environmentally sound manner. It might be that some cherry picking of valuable components is happening and that the remaining materials are then dumped, or that entire devices are ending up in sanitary landfills or open dumpsites. An examination of the Basel Convention National Reports does not indicate whether Lebanon imports or exports hazardous e-waste under the Convention.

The household survey also gathered information about the disposal routes for the investigated UNU-KEYS. It should be noted that the response rates for the UNU-KEYS was lower, and only up to 100 to 300 responses were gathered per category. Hence the mass balances per disposal route for the EU-6 are less accurate than EEE POM, stock amounts, and e-waste generation. It was assumed that the disposal and collection from households was the same for businesses. From the 46 kt e-waste generation, 11 kt is directly disposed of in municipal solid waste, ending up in sanitary landfills or open dumpsites. Around 1 kt is collected by the informal sector and 1 kt is picked up by installation companies, most likely ending up in non-environmentally sound end treatment/disposal. Around 22 kt are sold or repaired and 11 kt are donated, which could lead to an extended lifespan. The extended lifespan is included in the calculations of e-waste generated and, thus, after the extended lifespan it is likely to be disposed of with residual waste, collected by the informal sector, and not managed in an environmentally manner.

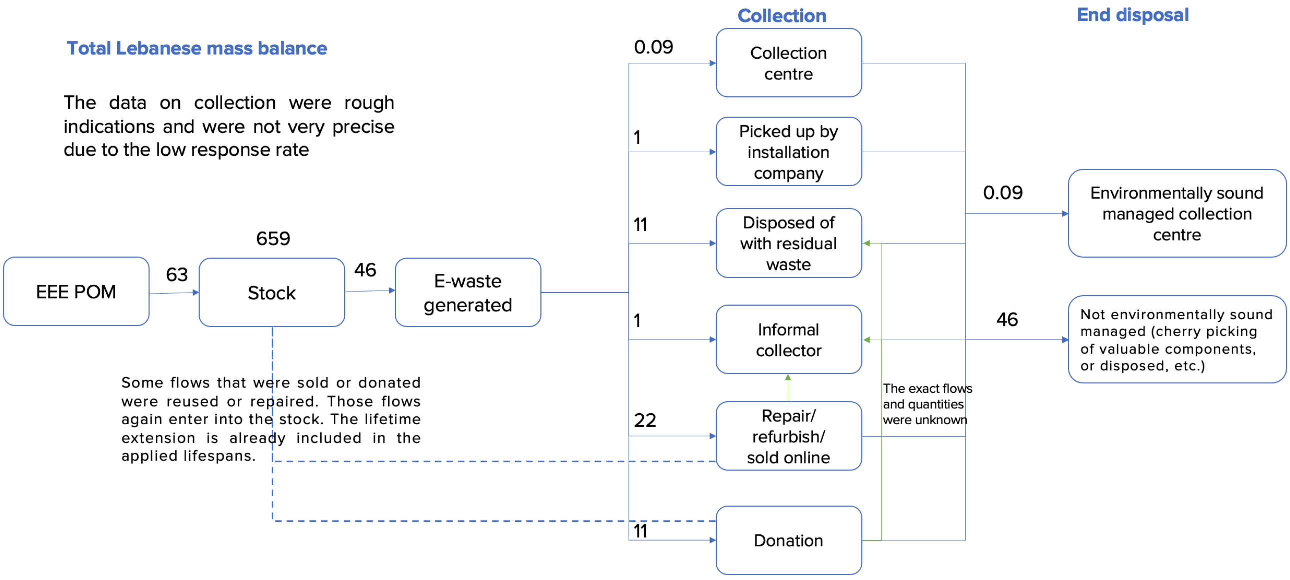


Figure 12 – Mass balance of e-waste in Lebanon in 2021

The detailed mass flows per e-waste category are further shown and illustrated in Annex 2.

3.6 Hazardous and Valuable Materials

Hazardous substances

In this report, the presence of hazardous materials such as lead (Pb), mercury (Hg), and polybrominated diphenyl ethers (PBDEs) was researched. Figure 13 show that the amounts of hazardous chemicals in the e-waste generated are declining, which is due to the phasing out of these chemicals in production. Most of the mercury (71 kg) is found in lamp waste, and is declining due to the shift from compact fluorescent lamps to LED lamps. Only 1 kg is embedded in screens, monitors, and equipment containing screens as well as in small IT and telecommunication equipment, which are not likely to be phased out. Lead (81 t) is found in screens, monitors, and equipment containing screens; 2 t is embedded in both small equipment and small IT and telecommunication equipment; while 1 t is in large equipment. The amount of lead is decreasing due to the shift from the use of cathode ray tube screens to flat panel display screens. PBDEs are mostly present in screens, monitors, and equipment containing screens. Smaller amounts are present in small equipment (3 t) and in small IT and telecommunication equipment (2 t). The PBDE is embedded in plastics and functions as a flame retardant. While PBDE is being phasing out of the e-waste stream, flame retardants as such are not phasing out, but rather are being substituted by other flame retardants of which the quantities and toxicological profiles are currently unknown. Thus, they continue to pose a risk to human health.

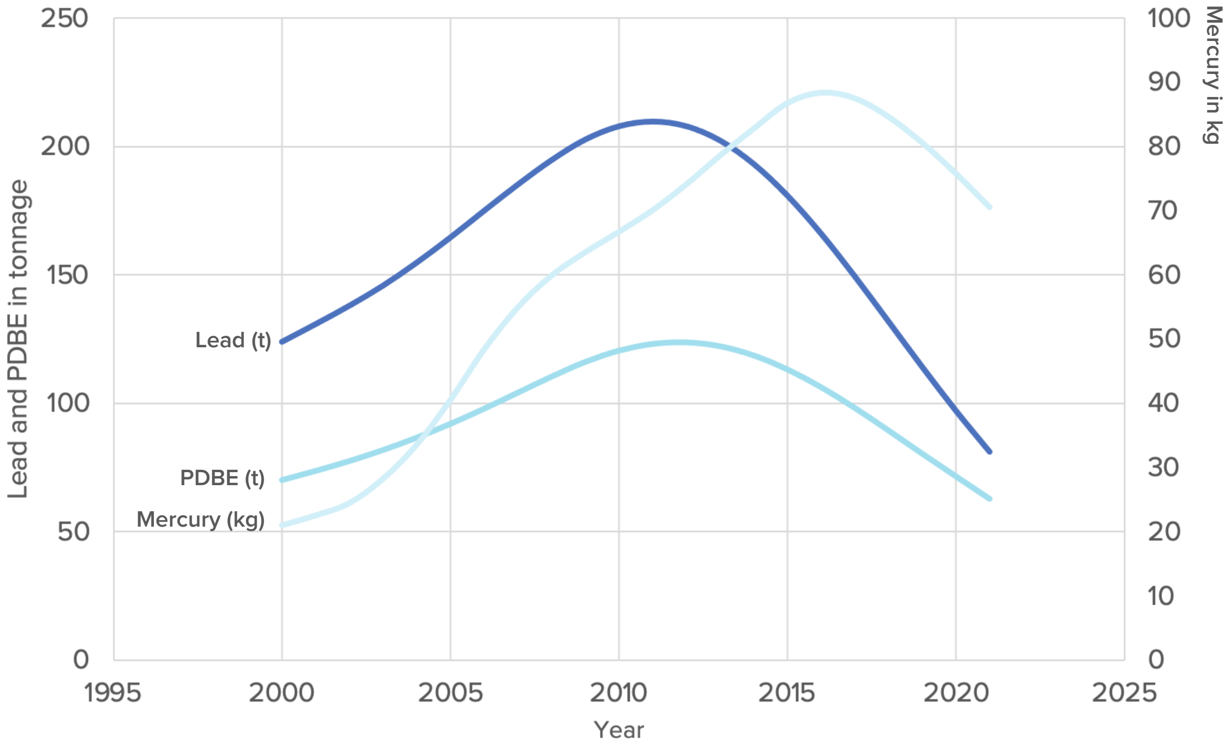


Figure 13 – Amount of hazardous chemicals in e-waste generated

Ozone depleting and greenhouse gasses

This report also analysed the quantity and type of refrigerants found in e-waste generated. The category temperature exchange equipment is the only category that contains refrigerants. As shown in Figure 14, refrigerant CFC-12 has been phased-out since 2010, and HCFC-22 is on the road to a complete phase-down in 2030. Those refrigerants are ozone depleting substances (ODS) and regulated under the Montreal Protocol. In Lebanon the joint Ministry of Environment-UNDP National Ozone Unit is facilitating the phase-out process in collaboration with the country's industrial sectors. However, while the phase-out means they will no longer be placed on the market, they can still be found in the waste stream, as they are in use for several years before being discarded. All other refrigerants are increasing and are greenhouse gasses, thus contributing to global warming, and these are regulated in Lebanon under the guidelines of the Montreal Protocol. In 2021 the refrigerants found in e-waste generated include HCFC-22 (79 t), HFC-410A (21 t), and CFC-12, HFC-134a, and HFC-32 (2 t each). If this e-waste is managed in an environmentally sound manner, then the gasses are separately collected and disposed of. However, since e-waste management infrastructure is almost absent in Lebanon (see Annex 2 – mass flow for temperature exchange equipment), there is a substantial risk that these gasses are being emitted into the environment.

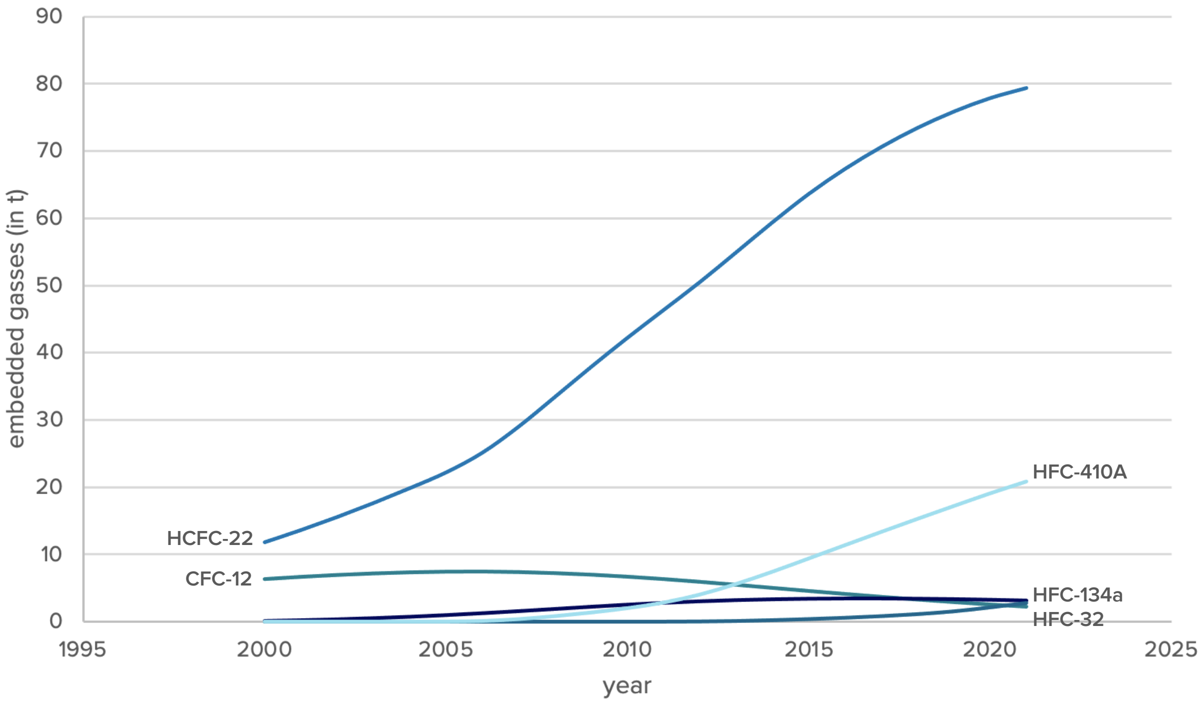


Figure 14 – Amount of refrigerants in e-waste generated by type

Valuable materials

E-waste also contains many valuable materials, and this study investigated the two most common: iron and aluminium. Results show that e-waste in Lebanon includes 19.5 kt iron in 2021, of which the majority is in large equipment, followed by temperature exchange equipment. There is 2.5 kt aluminium in 2021, most of which is found in small equipment, followed by temperature exchange equipment and then by large equipment.

3.7 Usage of the Statistical Data

The statistical data presented in sections 3.1 to 3.6 can be used for several purposes.

1. National purposes to plan the number and the capacity of e-waste collection points. For instance, 10.8 kt of temperature exchange equipment is generated annually, which means roughly an average of 200 tons per week. This can then be mapped against population density to determine the expected return percentages of drop off at retailers and at municipal collection points as well as pickup services so as to plan their respective capacities. For instance, in the first year it might be expected that 10 per cent of the population and companies will return the devices through municipal collection points, but in the following years higher percentages can be expected.

2. The collected e-waste needs to be treated. Some treatment can take place in Lebanon, whereas it might also be chosen that some items are to be exported for treatment. (More about this in section 3.2 in this report.) The statistics can be used for providing licenses to companies to manage the e-waste that are expected to be generated and collected.

3. The data can also be used to financially plan the costs involved to manage e-waste. Managing e-waste typically costs money to separate it, to dispose of hazardous and invaluable fractions, etc. Such costs need to be covered from the fees that can be levied upon placing the goods on the market.

4. The data can be used in the upcoming political discussions on setting national collection targets to ensure that all generated e-waste will be managed. Such targets should be realistic, but still ambitious enough to contribute to e-waste management. One could consider design targets that move along the e-waste generation, such as collection targets that gradually increases from 10 per cent to as much as 85 per cent over a period of X years.

5. These statistical data can also be used for international reporting needs under Sustainable Development Goal 12 on sustainable consumption and production. Specifically, they would be very useful for indicator 12.4.2 on the treatment of hazardous waste and for indicator 12.5.1 on national recycling rates and tons of material recycled. Both indictors contain sub-indicators for e-waste.

4.
RECOMMENDATIONS ON E-WASTE MANAGEMENT

Lebanon produces 46 kt of e-waste annually, but only manages 0.09 kt in an environmentally sound manner. To address this shortfall, the government is currently drafting e-waste legislation. The following recommendations are based on a set of guiding principles that were used to develop e-waste management systems and legislations to establish the Solving the E-waste Problem (StEP) initiative and are adapted to the Lebanese context. These principles are intended to provide guidance to all stakeholders in countries developing solutions for e-waste management (StEP, 2016). These recommendations are guiding elements that should be tailored and implemented, taking into account local conditions for Lebanon.

4.1 Legal Aspects

1. Establish a clear legal framework for e-waste collection and recycling.

In establishing a clear legal framework for e-waste collection and recycling, it is important to observe the following principles (StEP, 2018):

• The legislative objective should focus on the protection of the environment and human health through sustainable management of e-waste and clear goals and targets. This is currently the case for Lebanon,[7] where national e-waste legislation is currently under development. To date, Lebanon has adopted Decree No. 5606/2019 on the determination of the fundamentals of hazardous waste management, which lists e-waste as hazardous waste. Thus, all e-waste is managed through the hazardous waste legislation. The regulatory authority responsible for waste management is the Ministry of Environment. The Ministry of Interior and Municipalities also issues regulations on waste management, but the responsibility of hazardous waste management lies exclusively with the Ministry of Environment. The government has been working on introducing the circular economy principle through legislation and pilot demonstration projects.

[7] Environmental Code Law 444/2002 Integrated Solid Waste Management Framework Law 80/2018, Decree 5606/2019 – HW Management Framework Decree 5605/2019 - Waste Sorting at Source.

• The definitions need to be clear and to ensure that all stakeholders have the same understanding of the main concepts: e.g., what is e-waste, who are the producers and/or the collectors, etc. Based on Lebanese legislations, there is no clear definition for e-waste and batteries. In Annex 1B of Decree 5606/2019 e-waste and batteries were classified as Hazardous waste. This classification is based on the Basel Convention (Annex VIII – List A), which was endorsed by the Lebanese Parliament in 1994 through Law 387/1994.[8]

Complementary legislation might have to be issued in reference to this classification so as to enable individuals to transport their e-waste to drop-off centres without having to undergo hazardous waste transport licensing. Also, it is important to note that definitions of e-waste must be broader than the hazardous waste characteristics that are found in the Basel Convention. A suitable broader definition are the UNU-KEYS and the six e-waste categories.

• Clarity on the roles and responsibilities of the stakeholders in an e-waste take-back system is essential. This has been addressed in the solid waste management strategy developed in 2019 and that is currently under final review before the approval of the Council of Ministers. Currently in Lebanon there a lack of decentralization of responsibilities down to the municipal level. It is therefore essential to decentralize roles and responsibilities to the correct level and to continuously reflect on the roles of public and private actors.

• The system design (e.g., producer responsibilities systems) is essential to ensure that all fractions of EEE are treated and recycled in an environmentally sound manner. Lebanon has proposed a national strategy on integrated solid waste management to establish separate collection targets for e-waste: a minimum of 2 kg per capita per year for recovery, and a minimum of 4 kg per capita per year for separate collection within five years of its introduction. The draft strategy is currently being revised, which might change the targets. The strategy has been submitted by the Ministry of Environment to the Council of Ministers and will come into force once adopted [Iattoni et al., 2021]. It is further recommended that targets expressed as a percentage of e-waste generated can be considered. The percentage can be annually increased up to 85 per cent.

• The new legislation might foresee a transition period before it is fully enforced so as to enable current practitioners and stakeholders to change their status and practice before being held immediately accountable.

• The national legislation should be aligned with internationally recognized conventions, such as the Basel Convention.

[8] As for EU definitions:
Waste Batteries and Accumulators (Directive 2006/66/EC): any source of electrical energy generated by direct conversion of chemical energy and consisting of one or more primary battery cells (non-rechargeable) or consisting of one or more secondary battery cells (rechargeable) which is waste within the meaning of Article 1(1)(a) of Directive 2006/12/EC (any substance or object in the categories set out in Annex I which the holder discards or intends or is required to discard).
Waste Electric and Electronic Equipment (Directive 2012/19/EU): equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current which is waste within the meaning of Article 3(1) of Directive 2008/98/EC, including all components, sub-assemblies and consumables which are part of the product at the time of discarding. Article 3(1) of Directive 2008/98/EC defines waste as any substance or object which the holder discards or intends or is required to discard

• It is important to ensure transparency in the system to avoid misuse of funds, and so cash flows can be continuous and stable. It is also necessary to have in place a decentralized operational and financial management at the municipal level.

• It is recommended that a special article about e-waste monitoring be included in the legislation to ensure that a national strategy to monitor e-waste is developed and implemented with the respective stakeholders. This includes the periodicity of data updates, establishment of a national register, and the establishment of the data updating protocols, data sources and annual publications. It should be developed with the most important stakeholders, such as ministry of environment. National Statistical Office, customs, a to be established e-waste registry where collected and treated amounts of e-waste are registered.

• It is recommended that the monitoring is compliant with the international standards needed for Sustainable Development Goal reporting under Goal 12. This involves the use of the UNU-KEYS classification, yearly computations of EEE POM and e-waste generated, and the amounts collected and treated under the e-waste legislation. The lifespans, stock amounts, and other unregulated e-waste flows that are calculated in this report are more expensive to monitor, and it is recommended that these be updated every five years.

2. Introduce extended producer responsibility (EPR) to ensure that producers finance the collection and dismantling of e-waste and that the costs for running the system are transparent.

Lebanon is in the process of establishing EPR regulations, and the adoption of EPR for e-waste is also envisioned in Lebanon in its 2019 national strategy for integrated solid waste management [Iattoni et al., 2021]. In Lebanon the regulatory authority responsible for waste management is the national Ministry of Environment. The main responsibility is to propose legislations and regulations also based on the EPR principle. Should the EPR be implemented, producers, importers, and retailers will have responsibilities for the execution, while the national government will have a major role in introducing the EPR and monitoring. In the context of EPR, since the Ministry of Economy and Trade has a role in the management of Lebanon's economic and commercial affairs, it is a key stakeholder in the implementation and monitoring of the EPR.

The EPR is based on the polluter pays principle. In particular, it makes producers responsible for the end-of-life management of the products that they place on the market and of the impacts caused on human health and the environment. Such responsibility should, in principle, incentivize the minimization of waste, promote the design for an easy disassembly of products, and support the collection and recycling of the products once they have become waste. The EPR also needs to be financially supported to ensure an effective and sustainable operation. It is crucial that e-waste regulations clearly describe the responsibilities for financing the different elements of the collection and recycling system, and how costs will be allocated to individual stakeholders to ensure the fair collection and allocation of finances [StEP, 2018].

It is preferable that EPR-based legislation makes producers responsible for financing collection and recycling costs. Producers shall contribute to the financing of the e-waste management system according to their market share per EEE category placed on the market. Legislations should include the setup of an entity that act as an e-waste register that calculate each producer's market share and the associated collection target [StEP, 2018].

It is important to note that the manufacturer or producer is not always located in the country where its product is placed on the market. Therefore, it is important to foresee in the EPR-related legislation that the importer assumes the responsibility of the foreign manufacturer. In this respect, it is important to develop registers to track the importers when implementing an EPR scheme; and collective systems should be promoted over collection systems that operate by brand markets, as it encourages the collection of all types of end-of life electronics.

It is paramount that the funds secured for e-waste management are used to cover costs directly related to e-waste management only, and are not diverted for other purposes. This is to ensure transparency and the system's cost effectiveness [StEP, 2018]. The EPR-based legislation should request producers to be transparent in the reporting of volumes and in the cost structure of the collection and recycling system. In parallel, legislation should also allow a certain degree of freedom to allow stakeholders to comply with the legal requirements in the way that is more convenient to them (e.g., it could be to establish a collection and recycling solution in partnership with other producers or individually).

3. Enforce legislation for all stakeholders and strengthen monitoring, statistics, and compliance mechanisms across the country to ensure a level playing field for all, including socially disadvantaged groups and women.

The enforcement of e-waste legislations or related policies is not yet developed in Lebanon, mainly because the e-waste specific legislation/EPR is in development. However, monitoring and enforcement of the legislation and EPR principles across the country is key to creating favourable conditions for all stakeholders, especially for private licensed companies that are complying with the national legislation and regulations, and to limit the phenomenon of free-riding. The Ministry of Environment and municipal authorities are responsible for monitoring and enforcing compliance with the laws and regulations in force. Enforcement consists of adequate monitoring and surveillance of collectors, transporters, recyclers, and producers, as well as preventing licensed companies from being disadvantaged by ones that do not comply with the laws.

When enforcing e-waste legislation/EPR it is important to take into account the following aspects [StEP, 2018]:

- Identification and registration of the producers, and collecting information about their participation in individual or collective collection schemes;
- Communication among environmental, customs, and port authorities, e-waste registers, and producer responsibility organizations (if they exist) to ensure transparency; and report on the accessibility of collection services, statistics on e-waste collected, and quantities of EEE placed on the market;
- Authorities or independent third parties should audit the information acquired by the registers, producer responsibility organizations, or other bodies; and clear sanctions could help in discouraging the behaviour of stakeholders that do not comply with the laws;
- Legislation should cover enforcement costs in the financial mechanisms if there is a lack of national resources and staff to implement the enforcement actions.

4. Create favourable investment conditions for experienced recyclers to bring the required technical expertise to the country, targeting both female and male recyclers.

An EPR-based legislation must allow for the creation of an efficient e-waste collection and management system, but at the same time it should allow for a certain degree of freedom for relevant stakeholders to enable the system to develop strong business partnerships that will drive the improvement of the overall e-waste management system (StEP, 2018).

4.2 Implementation

5. Create a licensing system or encourage certification via international standards for collection and recycling.

The legislation should require that the recyclers and collection points are licensed and that their activities are compliant with the regulations in place. Lebanon has 33 formal recycling companies for a number of waste streams (e.g., plastics, paper, and glass), but none for e-waste [Iattoni et al, 2021], and only a small quantity (0.09 kt in 2020) of this specific waste stream is dismantled, which is performed by few companies [(Ecoserv and Verdetech, 2021].

In countries where e-waste is primarily handled informally, it is important that these actors are provided with incentives and options to become part of the EPR-based system, through organization and gradual formalization with appropriate training on safe e-waste collection and handling. In parallel, it is important that legislation enable informal collectors to continue their collection efforts in order to make use of the highly efficient informal collection system that already exists (StEP, 2018). Local authorities are responsible for setting up a licensing system for recyclers. Recyclers should be encouraged to certify their activities according to international standards.

6. Develop a wide network of collection points or collectors to separately collect all e-waste generated at the source.

It is important to encourage the establishment of a wide network of drop-off centres, collectors, and recyclers to ensure that all the e-waste collected is sent to proper recycling facilities and follow legal routes. Legislation should aim to channel the collected volumes by the informal/ unregulated network to recognized reuse/repair shops or licensed recyclers.

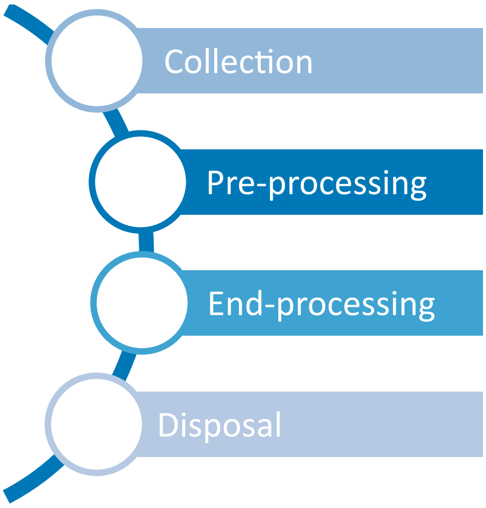
In Lebanon, most e-waste currently ends up in the hands of scrap-dealers or is mixed with regular municipal waste. A large proportion remains stored in households and businesses, and only a minor percentage is handed over to specialized e-waste actors. The activities of scrap-dealers are mostly characterized as cherry-picking, that is, selecting valuable items or components and taking out the easy to remove metal parts while discarding all the rest. The valuable items, components, and metals are then sold for export. Under these circumstances, almost all Lebanese e-waste ends up burned or buried at landfills or dumpsites.

The private sector currently does not feel any urgency in terms of their responsibilities to handle the end-life of their EEE in an environmentally safe manner as there is no fully enforced system for e-waste that challenge them to do so. Thus, it is strongly recommended that the national government design and implement a national framework for e-waste management system and that it monitor its development. Municipalities should have a key role in the network as they are responsible for urban cleaning and waste collection; the private sector should be responsible for operating the management facilities; and consumers should follow local instructions for disposing of their e-waste.

Collection points should be established in major cities and urban areas. Other ways of correctly disposing e-waste could be to request retailers and producers to take back waste products brought directly by the consumer, and organized door-to-door collections could be considered for large appliances, though this may represent higher costs for municipalities. Municipalities currently do not have the capacity to set up a collection system, and thus financial support is at the core of waste management governance. Municipalities are currently allowed to charge citizens for waste collection. It is important that the e-waste funds are used for e-waste management, and are transparently managed, and that sufficient is available to prevent poor implementation.

7. Develop e-waste management infrastructure, including good and easy access to international licensed treatment facilities.

When developing the e-waste management infrastructure it is important to understand the different stages of the e-waste management system, which consist of:



At a minimum, the six main categories of e-waste need to be separated at the source, as the four main steps are different for the various types of e-waste. Generally, the six e-waste categories discussed here (temperature exchange equipment, screens and monitors, lamps, large equipment/PV panels, small equipment, and small IT and telecommunication equipment) follow six different e-waste management streams, as they have distinct sizes, valuable materials that can be extracted, and hazardous materials that need to be depolluted.

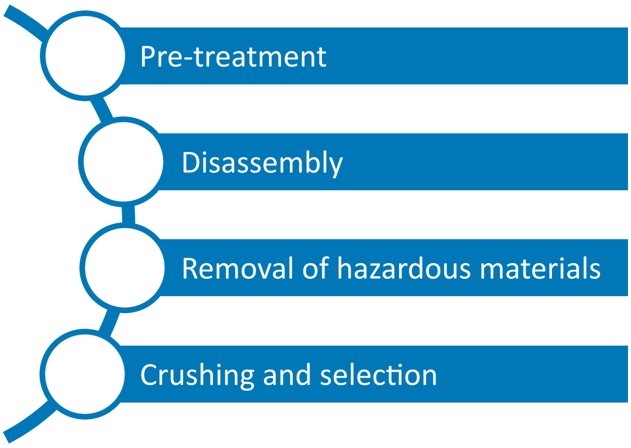
Importantly, it needs to be assessed which part of the e-waste will be managed in Lebanon, and which management will happen internationally.

Collection: E-waste can be collected by (i) municipalities, (ii) designated organizations, (iii) producers via retailers where consumers can return a product that has reached it end of life, and (iv) municipal collection points and/or pick-up services. The e-waste is then transported to the treatment/recycling facility.

In Lebanon, Ecoserv is currently active in the collection of e-waste from bins in designated drop zones, which is carried out on a weekly basis or upon demand and according to geographic area. In 2021the company also launched a door-to-door service via a mobile app [(Ecoserv and Verdetech, 2021]. However, Ecoserv has concentrated its collection on ICT equipment due to the challenges related to lack of storage space, the time-consuming dismantling processes, and inadequate transport. Similar initiatives and challenges have been initiated and faced by Verdetech. It is evident from the report that local companies and NGOs require government support and the establishment of a formal waste management system that coordinates the collection and ensures that the e-waste is sent to licensed recycling facilities.

Once the e-waste has reached the treatment/recycling facility, it may be treated in a variety of ways. The type of processes used may depend on various factors, such as: the available technologies, type of waste to be treated, economic viability to recover a particular material vs another, availability of a fund mechanism to support the recycling of hazardous materials with a low value, etc. In general, the treatment and recycling of e-waste should entail a pre-processing, end-processing, and disposal phase.

Pre-processing:



Pre-processing is usually done manually and includes a pre-treatment phase where it is ensured that different material fractions can be directed to the appropriate recycling processes. This phase includes the removal of components that may cause safety issues when further processed, either mechanically or manually. In Lebanon a few local NGOs are collecting e-waste and batteries from households and institutions, but they do not possess a treatment process. Products should then be disassembled into their main components: cables, batteries/ capacitors, plastic case, concrete, printed circuit boards, toner cartridges, etc.

Next, hazardous materials such as the refrigerants in cooling/freezing equipment and the material in fluorescent lamps/cathode ray tubes are safely removed prior to sending the waste to further processing [Bonoli, 2015]. Typically, the pre-treatment continues with size reduction, using a shredding or crushing process. Depending on the requirements of the size of output materials, it may be necessary to repeat the reduction process multiple times. E-waste then undergoes a manual or mechanical separation to separate the metal fractions (e.g., aluminium, iron, copper) and plastic fractions. In this step, magnetic separation can help to efficiently separate ferrous from nonferrous metals and other diamagnetic materials, such as plastic or glass.

Finally, depending on the differences in density of the materials used in EEE, gravity separation will help in separating the heavy fractions from the light fractions (Figure 15).

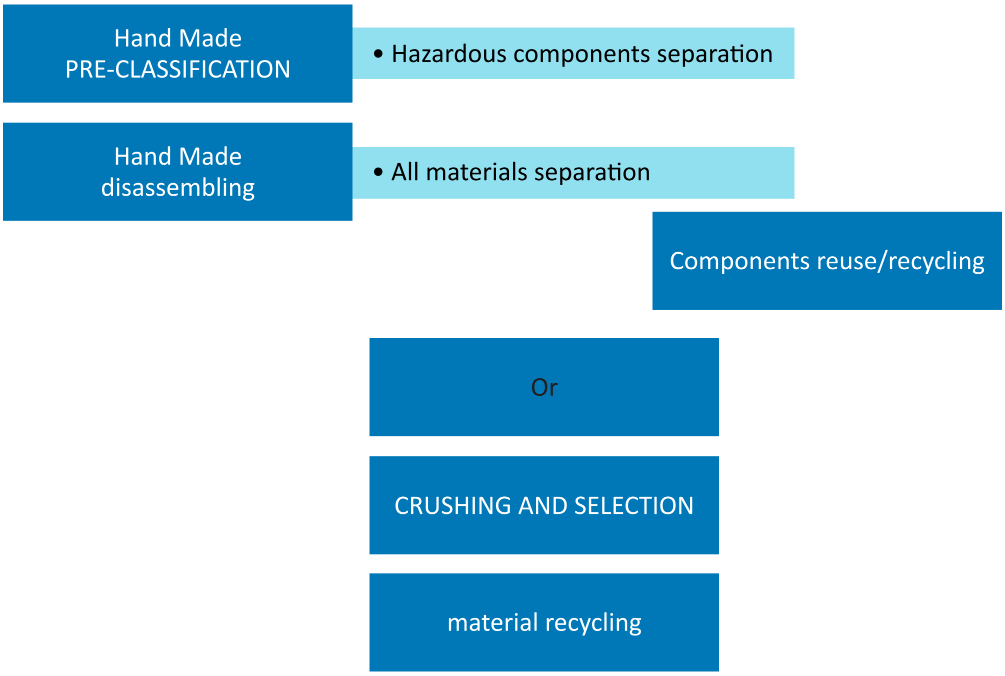


Figure 15 – Example of a generic process for treating e-waste [Bonoli, 2015]

The pre-processing of e-waste is often performed domestically by countries, as tasks such as disassembly, separation, and the crushing and grinding of basic material fractions require a relatively low technological investment and allow for the extraction of several materials (e.g., plastic, steel, copper, iron, glass) that can be easily traded as raw materials either domestically or internationally. The same is applicable to printed circuit boards that have a positive value and that can be sold to overseas facilities that have the technology to recover their high-value materials.

Evidence from Ecoserv shows that a facility that carries out purely manual dismantling, though time consuming, can recover limited types of materials from e-waste. By manual dismantling, Ecoserv is able to recover iron, glass, aluminium, plastic, e-plastic, printed circuit boards, wires, printers, and toners. Iron, glass, aluminium, and wires are sold in the local market, while plastic is sold to an NGO. Other materials are being stored while awaiting export (printed circuit boards), future upcycling programmes (e-plastic), or an adequate solution for treatment (toners). Ecoserv reports that it currently stores three tons of toner without any clear treatment or disposal plan. Thus, it is strongly recommended that action be taken in order to ensure their adequate treatment [Ecoserv and Verdetech, 2021].

Of course, the processing of e-waste can also be done mechanically. The example below shows a generic process for crushing and selecting e-waste scrap using mills, screeners, and separating machines.

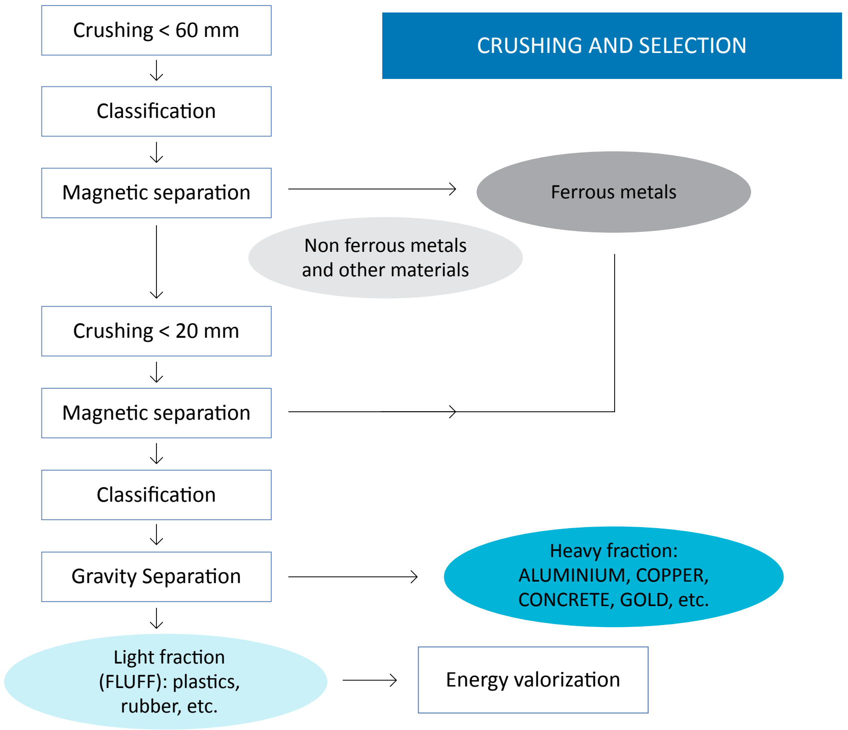


Figure 16 – Example of a generic process for crushing and selecting e-waste scrap [Bonoli, 2015]

End-processing

The end-processing refers to smelting and refining processes that are usually performed by selected industries operating at the global level. The recovery of precious metals, such as those from printed circuit boards or cobalt from batteries and other precious or rare-earth metals, require a high investment and a reliable e-waste management system that ensure a continues supply of e-waste to the facilities. In fact, end-processing facilities can only operate at a profit by processing high volumes of materials, which is impossible on the national level. In fact, globally only a handful of these facilities are necessary to provide these specific recycling and resource recovery solutions [StEP, 2016].

It is essential that local recyclers establish a business model that allows specific material fractions to be exported and imported to end-treatment facilities, and that this process is not heavily burdened with time-consuming bureaucracy.

Disposal

The e-waste fractions that cannot be recycled due to their hazardous content need to be disposed of in a safe manner. The disposal of the residues should be different for hazardous and non-hazardous waste. Hazardous waste needs to undergo necessary treatments prior to being either disposed in a landfill, incinerated, or used for waste-to-energy purposes. All possible disposal methods in Lebanon should be explored. Landfilling is strongly discouraged and other more sustainable options should be promoted.

Other important aspects to take into account when exporting e-waste or waste scrap to an international licensed treatment facility

• When exporting e-waste to another country for treatment is must be ensured that legal requirements are fulfilled (e.g., compliance with the Basel Convention) and that the procedures are clear so as to avoid lengthy delays or the impossibility to export waste fractions to the licensed international treatment facilities. Close monitoring of waste streams is necessary to guarantee their arrival at the specialized facilities for treatment.

• When exporting e-waste or waste fractions it is important to analyse the dynamics and market in both the origin and receiving countries, identify potential buyers of metal scrap or other products, assess the potential buyers, be aware of the quality criteria of the shipped waste, and be informed on the price conditions.

8. Ensure that all stakeholders involved in e-waste collection and recycling are aware of the potential gender-differentiated impacts on the environment and human health, as well as possible approaches to the environmentally sound treatment of e-waste.

All the various stakeholders involved in e-waste collection and recycling should be consulted during the establishment of the e-waste legislation; and it is important to ensure that that all stakeholders are fully aware of the potential impacts on the environment and human health caused by e-waste that is improperly disposed and treated. Adults and children can be exposed by inhaling toxic fumes and particulate matter, through skin contact with corrosive agents and chemicals, and by ingesting contaminated food and water. Children are also at risk from additional routes of exposure. Some hazardous chemicals can be passed from mothers to children during pregnancy and breastfeeding. Young children playing outside or in nature frequently put their hands, objects, and soil in their mouths, increasing the risk of exposure [Forti et al., 2020].

9. Start national awareness campaigns among consumers regarding a circular economy and its environmental benefits.

National awareness campaigns should be conducted to inform all stakeholders, including consumers and civil society, about the benefits related to the correct disposal and recycling of e-waste. It is important that users of EEE in households and businesses are provided with the necessary information and tools to contribute to the correct re-use, recycling, and recovery of e-waste.

10. Strengthen the technical skills and networks of e-waste managers and public authorities.

The effective implementation of environmentally sound management of e-waste can only be done if workers in the private, informal, and government sector have the right skills and networks to legislate, monitor, and handle with e-waste in Lebanon. This requires practical training and an awareness of the theoretical concepts on environmentally sound management provided by international and regional experts. Regional attendees at such trainings can share experiences from their work practice and build up the necessary regional networks. Such trainings could include informal sector and formal system workers who are managing e-waste on a day-to-day, and who can provide examples and instructions on how to depollute hazardous fractions and on which safety instructions should be followed. Or they could be conducted as specific business 'boot camps' where international recyclers exchange expertise with regional recyclers and build the necessary networks to stimulate recycling regionally; producers and importers learn how to set up and effectively run producer responsibility organizations; and government personnel (e.g., from the Ministry of Environment) can learn how best to legislate and implement the legislation in Lebanon. E-waste monitoring agencies, such as the Central Bureau of Statistics or Ministry of Environment, could participate in e-waste statistical trainings to learn about the compilation of e-waste statistics and how to set up monitoring protocols.

5.
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Annex 1
UNU-KEYS and link to six e-waste categories

UNU Key	Description	EU-6	EU-6PV
0001	Central heating (household installed)	4	4a
0002	Photovoltaic panels (incl. inverters)	4	4b
0101	Professional heating & ventilation (excl. cooling equipment)	4	4a
0102	Dishwashers	4	4a
0103	Kitchen equipment (e.g., large furnaces, ovens, cooking equipment)	4	4a
0104	Washing machines (incl. combined dryers)	4	4a
0105	Dryers (wash dryers, centrifuges)	4	4a
0106	Household heating & ventilation (e.g., hoods, ventilators, space heaters)	4	4a
0108	Fridges (incl. combi-fridges)	1	1
0109	Freezers	1	1
0111	Air conditioners (household installed and portable)	1	1
0112	Other cooling equipment (e.g., dehumidifiers, heat pump dryers)	1	1
0113	Professional cooling equipment (e.g., large air conditioners, cooling displays)	1	1
0114	Microwaves (incl. combined, excl. grills)	5	5
0201	Other small household equipment (e.g., small ventilators, irons, clocks, adapters)	5	5
0202	Equipment for food preparation (e.g., toasters, grills, food processing, frying pans)	5	5
0203	Small household equipment for hot water preparation (e.g., coffee, tea, water cookers)	5	5
0204	Vacuum cleaners (excl. professional)	5	5
0205	Personal care equipment(e.g., tooth brushes, hair dryers, razors)	5	5
0301	Small IT equipment (e.g., routers, mice, keyboards, external drives & accessories)	6	6
0302	Desktop PCs (excl. monitors, accessories)	6	6
0303	Laptops (incl. tablets)	2	2
0304	Printers (e.g., scanners, multi-functionals, faxes)	6	6
0305	Telecommunication equipment (e.g., cordless phones, answering machines)	6	6
0306	Mobile phones (incl. smartphones, pagers)	6	6
0307	Professional IT equipment (e.g., servers, routers, data storage, copiers)	4	4a
0308	Cathode ray tube monitors	2	2
0309	Flat display panel monitors (LCD, LED)	2	2
0401	Small consumer electronics (e.g., headphones, remote controls)	5	5

0402	Portable audio & video (e.g., MP3, e-readers, car navigation)	5	5
0403	Music instruments, radio, Hi-Fi (incl. audio sets)	5	5
0404	Video (e.g., video recorders, DVD, Blue Ray, set-top boxes) and projectors	5	5
0405	Speakers	5	5
0406	Cameras (e.g., camcorders, photo & digital still cameras)	5	5
0407	Cathode ray tube TVs	2	2
0408	Flat display panel TVs (LCD, LED, Plasma)	2	2
0501	Small lighting equipment (excl. LED & incandescent)	3	3
0502	Compact fluorescent lamps (incl. retrofit & non-retrofit)	3	3
0503	Straight tube fluorescent lamps	3	3
0504	Special lamps (e.g., professional mercury, high & low pressure sodium)	3	3
0505	LED lamps (incl. retrofit LED lamps)	3	3
0506	Household luminaires (incl. household incandescent fittings & household LED luminaires)	5	5
0507	Professional luminaires (offices, public space, industry)	5	5
0601	Household tools (e.g., drills, saws, high pressure cleaners, lawn mowers)	5	5
0602	Professional tools (e.g., for welding, soldering, milling)	4	4a
0701	Toys (e.g., car racing sets, electric trains, music toys, biking computers, drones)	5	5
0702	Game consoles	6	6
0703	Leisure equipment (e.g., sports equipment, electric bikes, juke boxes)	4	4a
0801	Household medical equipment (e.g., thermometers, blood pressure meters)	5	5
0802	Professional medical equipment (e.g., hospital, dentist, diagnostics)	4	4a
0901	Household monitoring & control equipment (alarm, heat, smoke, excl. screens)	5	5
0902	Professional monitoring & control equipment (e.g., laboratory, control panels)	4	4a
1001	Non- cooled dispensers (e.g., for vending, hot drinks, tickets, money)	4	4a
1002	Cooled dispensers (e.g., for vending, cold drinks)	1	1

Six e-waste categories

	Full name
1	Temperature exchange equipment
2	Screens, monitors, and equipment containing screens
3	Lamps
4a	Large equipment (excluding photovoltaic panels)
4b	Photovoltaic panels (including converters)
5	Small equipment
6	Small IT and telecommunication equipment

Annex 2
EEE POM, e-waste generation data, and e-waste mass flows per category

EEE POM in Lebanon (in kt)

Year	Temperature exchange equipment	Screens, and monitors	Lamps	Large equipment (excluding photovoltaic panels)	Photovoltaic panels (incl.converters)	Small equipment	Small IT and telecommunication equipment
2000	7.15	3.38	0.35	11.14	0.00	6.22	2.26
2001	7.54	4.12	0.38	11.64	0.00	6.88	2.60
2002	7.58	4.88	0.44	12.57	0.00	7.93	2.95
2003	8.24	5.28	0.83	12.34	0.00	7.94	2.96
2004	8.58	5.83	1.07	13.67	0.00	8.32	3.11
2005	9.17	6.25	1.36	12.70	0.00	7.93	3.15
2006	10.79	6.10	1.40	14.08	0.00	8.47	3.19
2007	11.45	5.36	1.13	14.95	0.00	9.13	2.66
2008	12.28	5.51	1.04	16.26	0.00	9.91	2.17
2009	12.73	3.16	1.02	16.10	0.00	10.19	2.10
2010	12.21	3.25	1.13	17.78	0.00	10.90	2.30
2011	13.15	3.79	1.29	19.55	0.00	10.97	2.73
2012	15.31	4.31	1.49	22.82	0.00	11.69	2.25
2013	15.29	4.18	1.60	24.53	0.00	12.26	2.31
2014	13.50	4.55	1.70	24.79	0.00	11.53	1.98
2015	14.01	4.54	1.64	25.50	0.01	11.17	2.32
2016	14.40	4.43	1.21	25.88	0.01	11.00	2.63
2017	16.22	4.03	1.14	26.15	0.02	10.96	2.19
2018	16.50	3.70	1.14	24.90	0.02	11.45	2.06
2019	17.70	3.74	1.13	25.74	0.03	11.77	1.84
2020	17.85	3.71	1.05	26.11	0.03	11.89	1.67
2021	18.17	3.51	0.98	26.61	0.04	12.05	1.58

E-waste generated in Lebanon (in kt)

Year	Tem-perature exchange equipment	Screens, and monitors	Lamps	Large equipment (excluding photovoltaic panels)	Photovol-taic panels (incl.con-verters)	Small equipment	Small IT and telecom-munication equipment
2010	6.31	4.10	0.75	9.35	0.00	6.36	2.37
2011	6.66	4.33	0.80	9.98	0.00	6.76	2.33
2012	7.04	4.52	0.86	10.63	0.00	7.15	2.30
2013	7.43	4.68	0.94	11.32	0.00	7.57	2.28
2014	7.83	4.79	1.02	12.05	0.00	7.95	2.25
2015	8.24	4.86	1.09	12.81	0.00	8.30	2.24
2016	8.66	4.90	1.14	13.60	0.00	8.63	2.24
2017	9.08	4.89	1.17	14.40	0.00	8.92	2.26
2018	9.52	4.85	1.18	15.21	0.00	9.20	2.26
2019	9.96	4.77	1.19	16.01	0.00	9.51	2.26
2020	10.40	4.68	1.18	16.80	0.00	9.80	2.25
2021	10.84	4.58	1.17	17.57	0.00	10.07	2.22

Mass Flows For Temperature Exchange Equipment

Temperature exchange equipment includes fridges, freezers, air conditioners, professional cooling equipment, and cooled dispensers. In 2021, the EEE POM of temperature exchange equipment is around 18 kt and the e-waste generated is around 11 kt with 197 kt of total stock, as shown in Figure 17. Temperature exchange equipment waste is disposed of via several pathways: around 1 kt is collected by the informal sector; 1 kt is disposed of with residual waste; approximately 6 kt is given for repair, refurbish, or sold online; and 3 kt is given as donations. These pathways extend the lifespan of temperature exchange equipment, and thus they are not examples of environmentally sound management, with only 0.006 kt going to a collection centre.

The 2021 survey suggests that in the case of fridges, 17 per cent of households disposed of them with regular household waste, 36.2 per cent donated them, and 46.8 per cent had them repaired. In the case of freezers, around 77.6 per cent of households repaired their freezers, 17.6 per cent sold them online, and 5.4 per cent donated them. Hence, there is no formal collection of fridges and freezers, and instead they are mainly collected by the municipality along with regular household waste. In case of air conditioners, however, 51.6 per cent households gave them to informal workers via door-to-door collection, 33.1 per cent donated them, 11.9 per cent had them repaired, and only 3.3 per cent disposed of them with the municipal solid waste. The disposal route of temperature exchange equipment is shown in Figure 17.

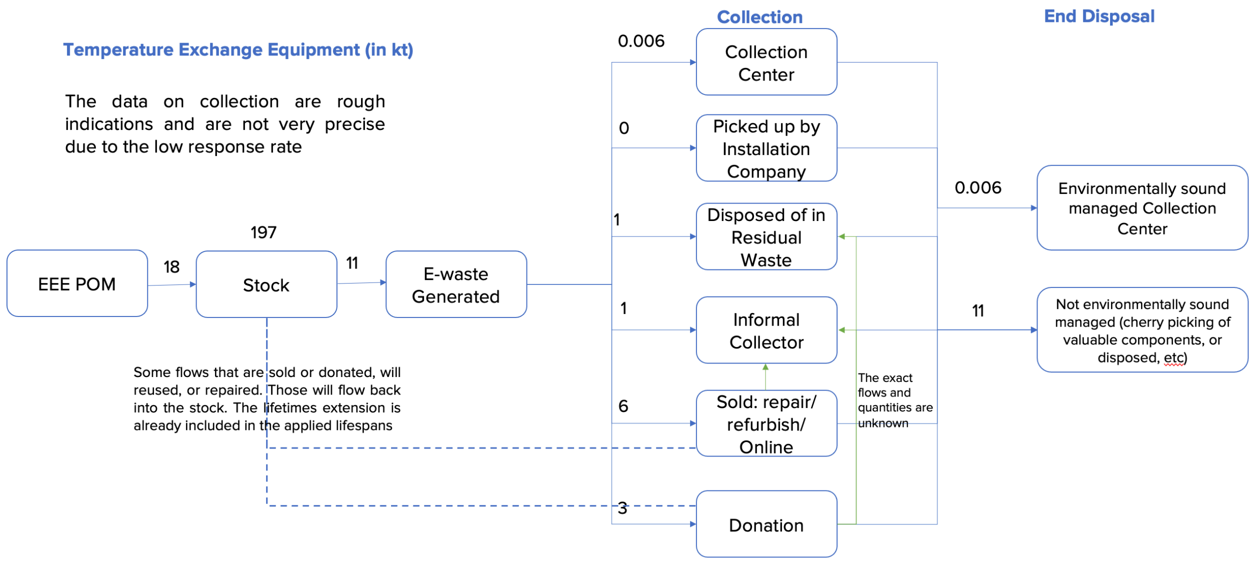

Figure 17 – Mass flows for temperature exchange equipment

Mass Flows for Screens and Monitors

In 2021, the EEE POM of screens and monitors was approximately 3.51 kt, the waste generated is estimated to be 4.57 kt, with stock of 28 kt. This includes laptops (including tablets), cathode ray tube monitors, flat panel display monitors, cathode ray tube TVs, and flat display panel TVs. The waste generated was disposed of via several pathways: around 1 kt was disposed of with residual waste; approximately 2 kt was given for repair, refurbish, or sold online; and 1 kt was donated. These pathways extend the lifespan of screens and monitors such that the vast majority is not managed in an environmentally sustainable manner, with only 0.01 kt going to the proper collection centre.

In terms of laptops, the survey revealed that 36.4 per cent of Lebanese households sold them online, 32.3 per cent sold them to refurbishing or repair shops, 17.6 per cent disposed of them with regular waste, and 12 per cent gave them as donations. Approximately half (52.3 per cent) of all households donated their non-functional flat display panel monitors, 21.2 per cent sold them to refurbishing or repair shops, and 25.9 per cent disposed of them via a mixed municipal solid waste bin. The extended producer responsibility for flat display panel (FPD) TVs resulted in nearly half (49.2 per cent) of all non-functional FPDs being picked up by the company that initially sold them. The other disposal routes included donations (27.1 per cent), sold to refurbishing or repair shops (16 per cent), and with mixed municipal waste (7.6 per cent). The disposal route of screens and monitors is shown in Figure 18.

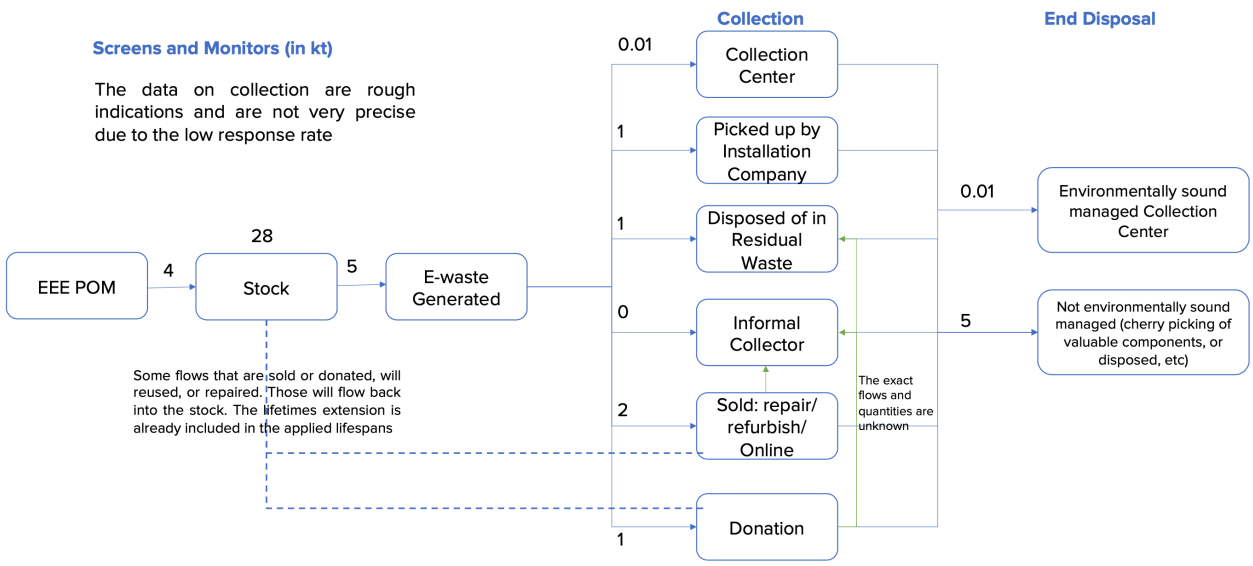

Figure 18 – Mass flows for screens and monitors

Mass Flows for Lamps

The 2021 EEE POM for the lamps category was 1 kt and the waste generated is estimated to be 1 kt. The category includes small lighting equipment (excluding LED and incandescent), compact fluorescent lamps (including retrofit and non-retrofit), straight tube fluorescent lamps, special lamps (e.g., professional mercury, high- and low-pressure sodium), and LED lamps (including retrofit LED lamps). Lamps waste in 2021 consisted of an estimated 320 tons small lighting equipment (excluding LED and incandescent), 469 tons compact fluorescent lamps (including retrofit and non-retrofit), 53 tons straight tube fluorescent lamps, 129 tons special lamps (e.g., professional mercury, high- and low-pressure sodium), and 203 tons LED lamps (including retrofit LED). The survey suggests that households mainly (94 per cent) disposed of their non-functional LED lamps with mixed municipal waste. Only 2.2 per cent sold them to refurbishing or repair shops, and the remainder do not recall their disposal route. The disposal route of lamps is shown in the Figure 19.

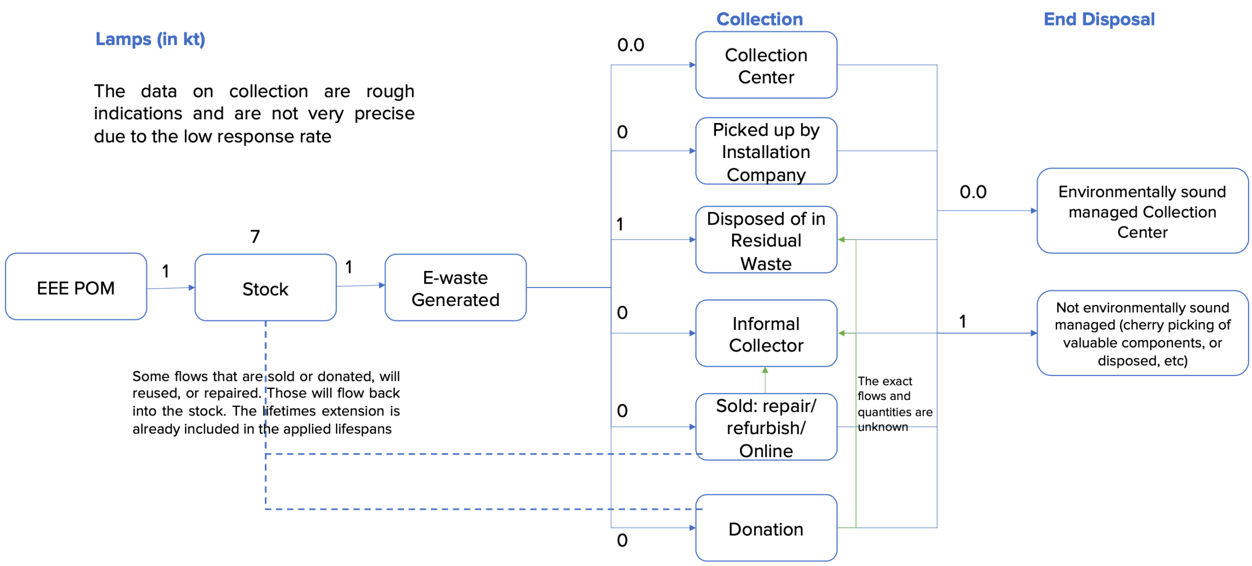

Figure 19 – Mass flows for lamps

Mass Flows for Large Equipment

The amount of large equipment placed in the market in Lebanon in 2021 was around 26.6 kt, and the e-waste generated was approximately 17.6 kt. Large equipment includes central heating (household installed), professional heating and ventilation (excluding cooling equipment), dishwashers, kitchen equipment, washing machines (including combined washer/dryers), dryers (centrifuges), household heating and ventilation, professional IT equipment, professional tools, leisure equipment, professional medical equipment, professional monitoring and control equipment, and non-cooled dispensers.

The large equipment waste generated in 2021 included approximately 12 kt that was repaired, refurbished, or sold online; 3 kt disposed of via donations by households and businesses; and 2 kt disposed of with mixed residual waste. These pathways ultimately led to overwhelmingly non-environmentally sound management, with a mere 0.002 kt of waste going to a collection centre.

The household survey regarding the disposal behaviour of non-functional kitchen equipment suggests that Lebanese households predominantly donate (70.2 per cent) such equipment, with approximately 21.4 per cent selling the equipment to a refurbishing or repair shop, and only 8.4 per cent disposing it with regular municipal waste. In the case of washing machines, around 70 per cent of households sold them to a refurbishing or repair shop, 14.2 per cent donated them, and 9 per cent dispose of them with regular municipal waste. In some instances, washing machines are collected from households by the company that initially sold them (3.1 per cent) or through informal workers (3.1 per cent). The disposal route of large equipment is shown in Figure 20.

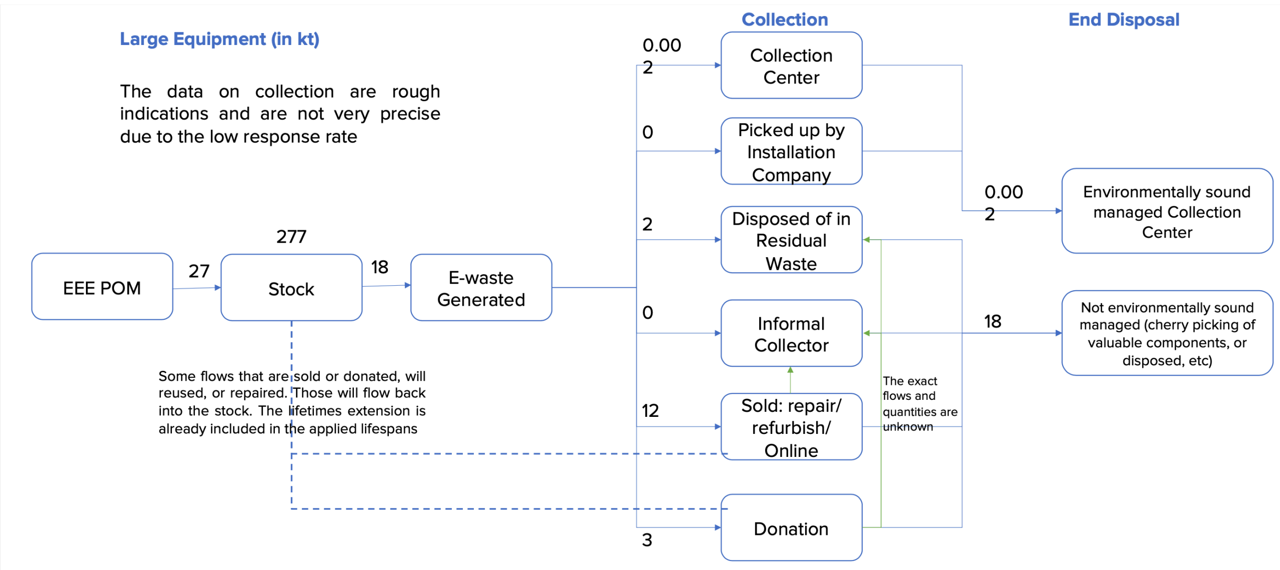

Figure 20 – Mass flows for large equipment

Mass Flows for Small Equipment

In 2021, some 12 kt of small equipment was placed on the market in Lebanon, and the waste generated was around 10 kt. This includes microwaves, equipment for food preparation, small household equipment for hot water preparation, vacuum cleaners, personal care equipment, small consumer electronics (e.g., headphones, remote controls), portable audio and video, music instruments, radio, hi-fi (including audio sets), video and projectors, speakers, cameras, household luminaries, professional luminaries, household tools, electrical toys, household medical equipment, household monitoring and control equipment, and other small household equipment (e.g., small ventilators, irons, clocks, adapters).

The disposal route of small equipment (Figure 21) shows that only a mere 0.015 kt of small equipment waste was disposed of in an environmentally sound manner. The survey revealed that around 77.8 per cent of households donated their microwaves, 6.4 per cent sold them online, and 8.7 per cent sold them to refurbishing and repair shops. Encouragingly, only 7 per cent of households disposed of microwaves with mixed municipal waste. However, the major disposal route for household luminaries was with mixed municipal waste (84.7 per cent). Other disposal routes included those brought to an e-waste collection centre (1.2 per cent), picked up by an e-waste collection centre (2.5 per cent), collected by a door-to-door informal worker (1 per cent), brought to a designated municipality drop-off point (0.6 per cent), and sold to a refurbishing or repair shop (1.7 per cent). Households mainly donated the other small household equipment (69.2 per cent), such as small ventilators, irons, clocks, and adapters. Some households sold them to a refurbishing or repair shop (11.1 per cent), some disposed of them in a mixed municipal solid waste bin (16.5 per cent), and 1.4 per cent gave them away via door-to-door collection by an informal worker.

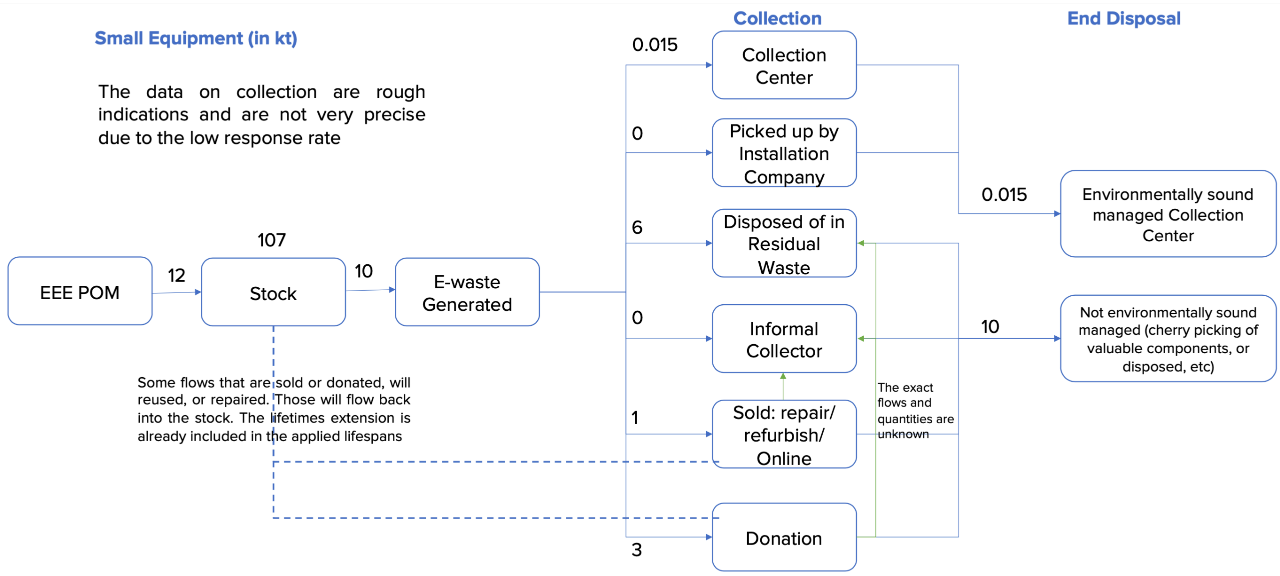

Figure 21 – Mass flows for small equipment

Mass Flows For Small IT and Telecommunication Equipment

The Small information technology (IT) and telecommunication equipment placed in the market in 2021 was 1.57 kt, and the waste generated from small IT and telecommunication equipment was 2.2 kt. Small IT includes desktop PCs (excluding monitors, accessories), printers (e.g., scanners, multi-functionals, faxes), telecommunication equipment (e.g., cordless phones, answering machines), mobile phones (including smartphones, pagers), game consoles, and small IT and telecommunication equipment (e.g., routers, mice, keyboards, external drives, and accessories). The 2.2 kt waste consisted of 102 tons game consoles, 669 tons desktop PCs, 629 tons printers, 94 tons mobile phones, 59 tons telecommunication equipment, and 668 tons small IT equipment.

Figure 22 shows that only 0.058 kt of small IT and telecommunication equipment waste comes under the ambit of ESM and the remaining waste (approximately 2 kt) is disposed of in a non-ESM. The primary survey regarding the disposal route of non-functional small IT equipment mainly includes responses regarding mobile phones. Well over half of Lebanese households (60.1 per cent) sold their mobile phones to refurbishing or repair shops. Other disposal routes of mobile phones included selling them online (16.4 per cent), donations (12.4 per cent), and mixed municipal waste (11.1 per cent). Since mobile phones contain valuable and critical raw materials, it is especially imperative that they not be disposed with mixed municipal waste.

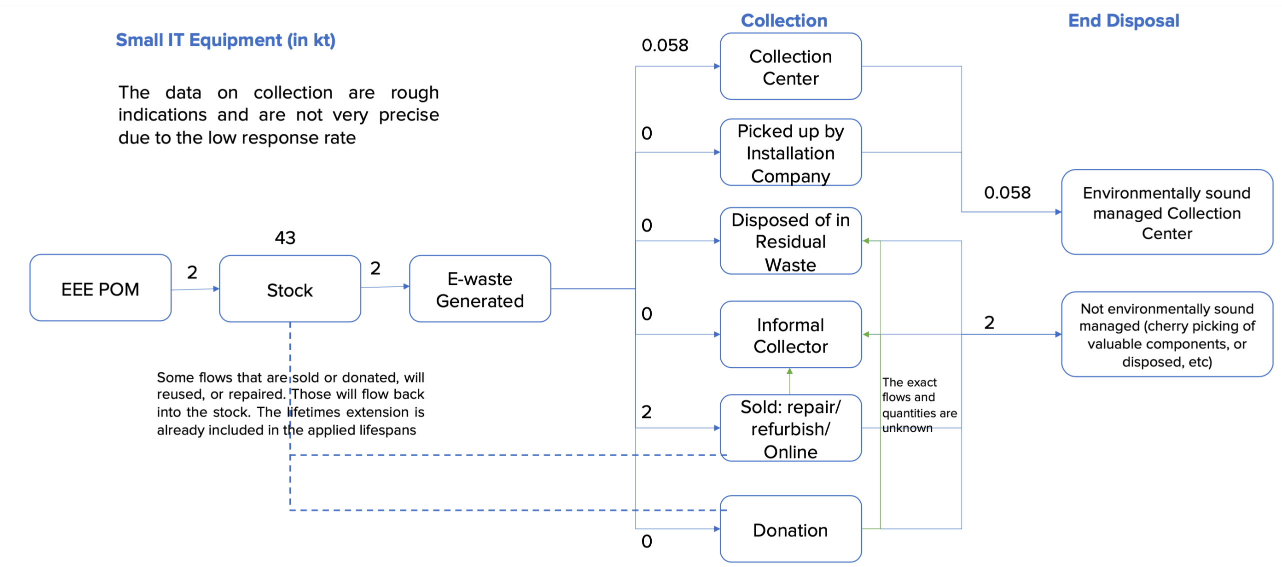

Figure 22 – Mass flows for small IT and telecommunication equipment