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Waste electrical and electronic equipment (WEEE): Flows, quantities and management, a global scenario

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Abstract:

This chapter aims to reveal the geographies of ewaste flows at global and national levels based on waste statistics data and thematic cartography. WEEE management practices are examined for each major geographical area respectively: Europe, North America, Latin America and Caribbean, South America, Africa, Asia, and Oceania. Pollution and public health threats associated with improper ewaste management practices is a crucial environmental issue, particularly in emerging economies. Generation, collection, treatment, recycling and recovery activities of WEEE fraction are analyzed within each geographical area. The role formal and informal sector is further investigated pointing out the gaps and different prospects in development of sustainable ewaste management systems across developing and developed countries.

Keywords: ewaste/weee, waste management, recycling, pollution, sustainability, informal sector, spatial analysis, public health,

1.Introduction

Waste Electrical and Electronic Equipment (WEEE) or e-waste is an emerging waste stream at global level due to the development of electronic products consumption which imposes great challenges for both industrialized and developing countries. Improper handling of e-wastes causes severe pollution and public health issues associated with dismantling activities frequently performed in poor conditions. Open burning and open dumps practices are worst options adopted by countries without a proper legislation and lack of basic waste management services. Illegal dumping practice of WEEE fraction occurs even in developed countries due to the poor environmental law enforcement of local and regional authorities. At the global level, 8.9 Mt of e-waste is documented to be collected and recycled, which corresponds to 20% of all the e-waste generated in 2016 (44.7 mt) while 1.7 Mt are thrown into the residual waste in higher-income countries which are susceptible to be incinerated or landfilled (Balde et al. 2017). In 2016, the global amount of e-waste generated is double than those generated in 2005 calculated at 20 million tons by Bastiaan et al., (2010).

Poor municipal waste management systems often involve an improper handling of e-waste stream (Quibing and Jinhui, 2014). This fraction is collected as residual waste (commingled with other fractions) and disposed of in urban dumpsites or landfills without any prior treatment leaching pollutants into surroundings. E-waste fraction is a hazardous source for mixed municipal waste fraction containing toxic materials and substances such as persistent organic pollutants (POPs) listed by *Stockholm Convention.*

Additionally, polycyclic aromatic hydrocarbons (PAHs), heavy metals (cadmium, mercury, lead, chromium), batteries, brominated flame retardants (BFRs) complete the panel of toxic leaking sources from e-waste. Obsolete EEE (e.g. refrigerators) specific for lower purchasing power communities where the lifespan of electronic products are larger may contain gasses that are ozone depleting such as chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs). On the other side, e-waste fraction contains valuable materials for industry (precious metals, Cu) recycling companies (metals, plastics) mitigating the depletion of natural resources. The informal sector is a key player in recycling and handlings of e-waste stream in countries without a proper formal e-waste management services supported by an adequate legislation. However, manual labor with poor tools exposes such individuals to severe health issues. Special legislation dedicated to e-waste management is imperative to shift the paradigm from a pollution source toward a valuable resource as shown in figure 1.

Source-separated collection schemes and recycling centers need to be further developed in transition and developing countries as a transition route from traditional waste management system based on open dumping/landfill practices to a sustainable approach of WEEE management.

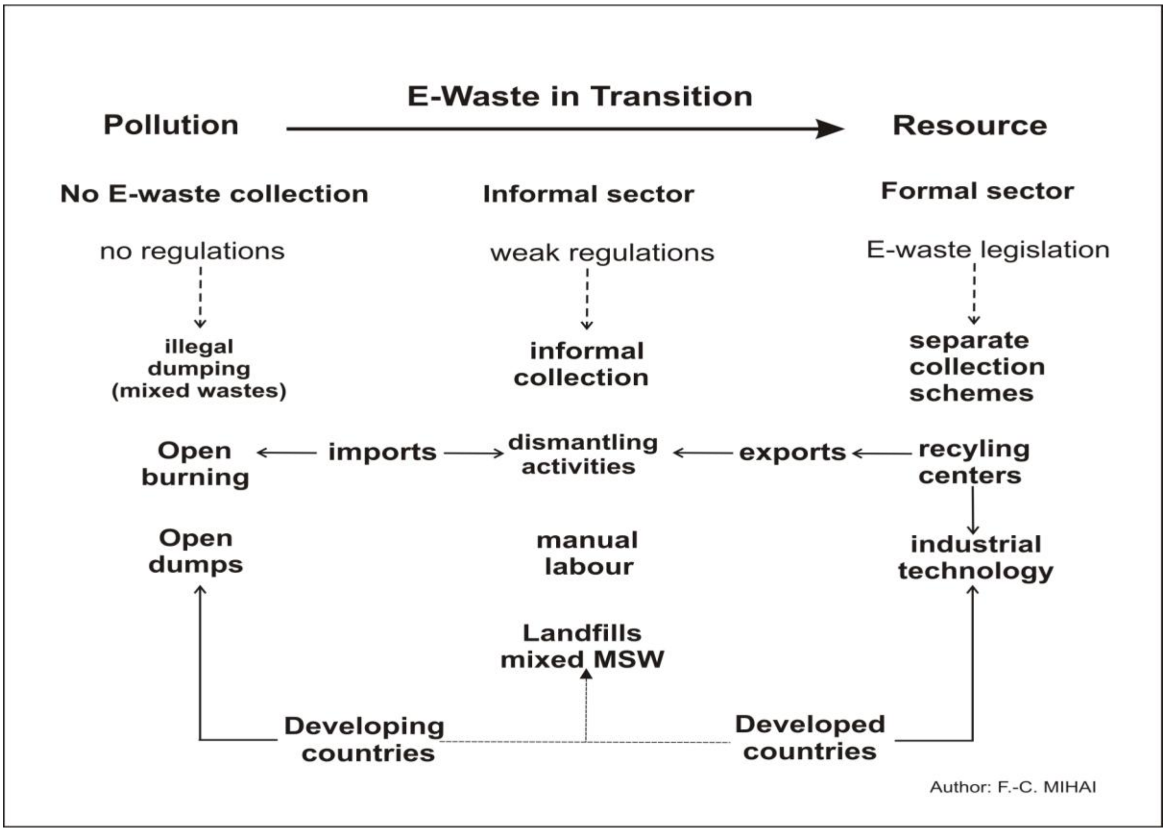

Fig.1.1 WEEE management in a transition stage

Source: Mihai and Gnoni 2016 (CC-BY 3.0) - *DOI: 10.5772/64596*

Currently, the illegal WEEE trades from industrialized countries to emerging economies poses serious challenges in terms of pollution and shipment of hazardous substances despite the official prohibition of such exports via *The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.* The fate of 76% (34.1 Mt) of e-waste is unknown which may be dumped, traded, or recycled under inferior conditions while currently available statistics are not able to track the shipment of this waste stream from richer to poor sub-regions in the world (Balde et al.,2017).

WEEE treatments in Japan, Europe, and the United States use technologies with a higher degree of mechanization including expensive equipment and high operating costs (Jinhui et al., 2013). This fact may favor the illegal traffic of weee stream from high-income countries towards developing ones in Africa or Asia where low-tech recycling practices using intensive manual labor prevail. Regional approach of WEEE management activities with higher level recovery applications may mitigate the export of such wastes from developed countries (Bastiaan et al., 2010). Urban areas generate a large quantity of WEEE based on greater purchasing power, but rural areas should not be ignored on this matter. Rural communities are susceptible to be neglected by waste operators encouraging improper disposal practices of household waste including WEEE fraction. Waste management policy must be successfully implemented at different geographical scales (eg global-EU-28-national-regional-local levels).

For this purpose, a proper monitoring process of WEEE flows is imperative at global and regional levels. Waste management area faces several challenges to provide basic waste statistics data from reliable sources which may be further compared with other regions. WEEE global monitor started by United Nations University (UNU) offers for the first time a comprehensive estimation of domestic e-waste generation at the global level for 2014 and an updated report for 2016. The calculation of e-waste generated is based on empirical data, a model, and statistical routines starting form Comtrade database from which sales are determined and adjusted, then product lifespan is applied to calculate the e-waste generation per country (Balde et al., 2015). This chapter provides a critical overview of WEEE management for at global scale combined with spatial analysis and regional insights of each major geographical area.

2. Mapping ewaste flows: new geographies

Geography is a manifestation of complex interactions between natural and diverse socio-economic systems at various spatial scales. Waste management sector has particular features across the globe in terms of technology, economic, social, governance, demographic and public policy options adopted by each country, region or local administrative area. Geographical inequalities regarding access to basic waste management services are obviously between high-income and developing countries. A global level, almost 3 billion people lack access to waste collection services and there are huge discrepancies between urban and rural areas (Mihai, 2017). In this context, significant amounts of ewaste, as part of mixed household generated, are disposed of via unsound practices such as open burning or illegal dumping on surroundings (public lands, roadsides, water bodies etc). Open burning of e-waste fraction may release dioxins into the atmosphere.

E-waste management enables complicated patterns of flows due to the illegal trade of ewaste between countries, the shared of waste management activities between formal and informal sectors particularly in developing countries or between the official take-back system, civic amenity sites and waste collection systems (door-to-door or collection points) in other industrialized countries. Disposal of e-waste in mixed residual household waste accounts for 1 to 2 kg per inhabitant in the EU represents roughly 8 % of e-waste generation (Balde et al., 2015). E-waste is a special waste stream with complex interactions at national and international levels which must be further guided by a specific legislation. Such regulation at national level constitutes a basic step to developing formal and proper e-waste management activities at regional and local scales. Most of the European countries have implemented such legislation under EU supervision via e-waste directive including non-EU countries except for Belarus and Republic of Moldova. At the global level, 60 countries adopted such regulations in 2013 and 7 countries has joined this group until 2017 such as Albania, Ukraine, Russian Federation, India, Cambodia, Kenya and Chile as shown in figure 1.2.

Generally, high-income countries have a dedicated legislation for this waste stream except for New Zeeland or oil-based economies from Arabian Peninsula despite the fact they are large contributors of e-waste generation rates on per capita basis.

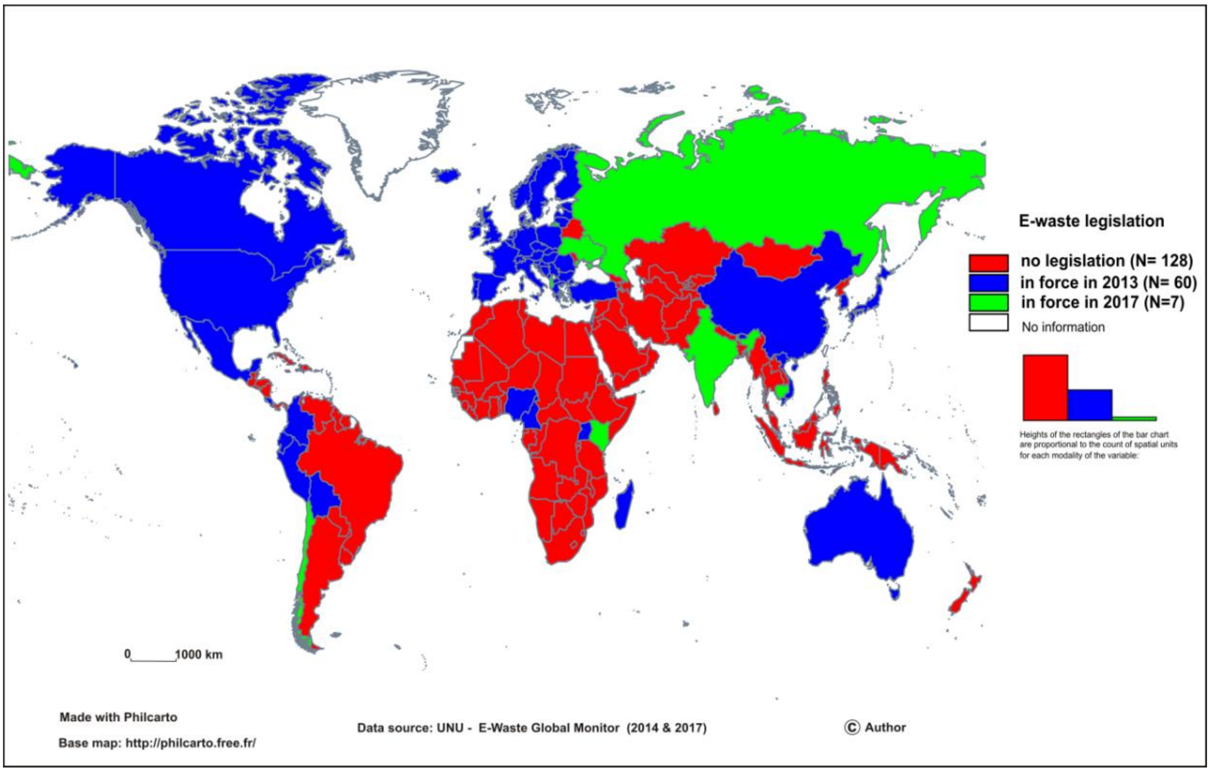

Fig. 1.2 WEEE legislation coverage between 2013-2017

Most populated countries with emerging economies (China and India) adopted such regulations where this waste fraction is expected to increase in following years. However, the existence of such legislation does not necessarily imply a successful implementation or provision of proper e-waste management systems (Balde et al., 2015). There are several Asian countries without such legislation in force in 2017 as same for Central and South America or Oceania. Africa is most poorly covered continent by e-waste legislation as revealed in figure 2. Informal sector plays a key role in diverting such wastes from open dumping and burning practices in developing countries across the world. Unfortunately, these activities are performed in rudimentary conditions with high risks for human health and environment. There are huge geographical disparities regarding per-capita e-waste generation rates between high-income countries of western and northern Europe, USA, Canada and Australia (20-28.3 kg. per capita/yr) related to low-income countries of Africa and Asia (0.1-1 kg. per capita/yr). The maxim value counted is 28.3 kg.per capita/yr in case of Norway which is over 140 times higher than per capita e-waste generation rate from Burundi, Malawi, RD Congo, Liberia or Niger in Africa (0.2) or 94 times higher than an inhabitant from Afghanistan (Asia). More than half of world countries (115) have e-waste generation rates below or close to the global average (7.6 kg. per capita/yr) and moreover, 35 countries have an e-waste generation rate below 1 kg.per capita/yr including Africa, Asia, Central America and Pacific Islands.

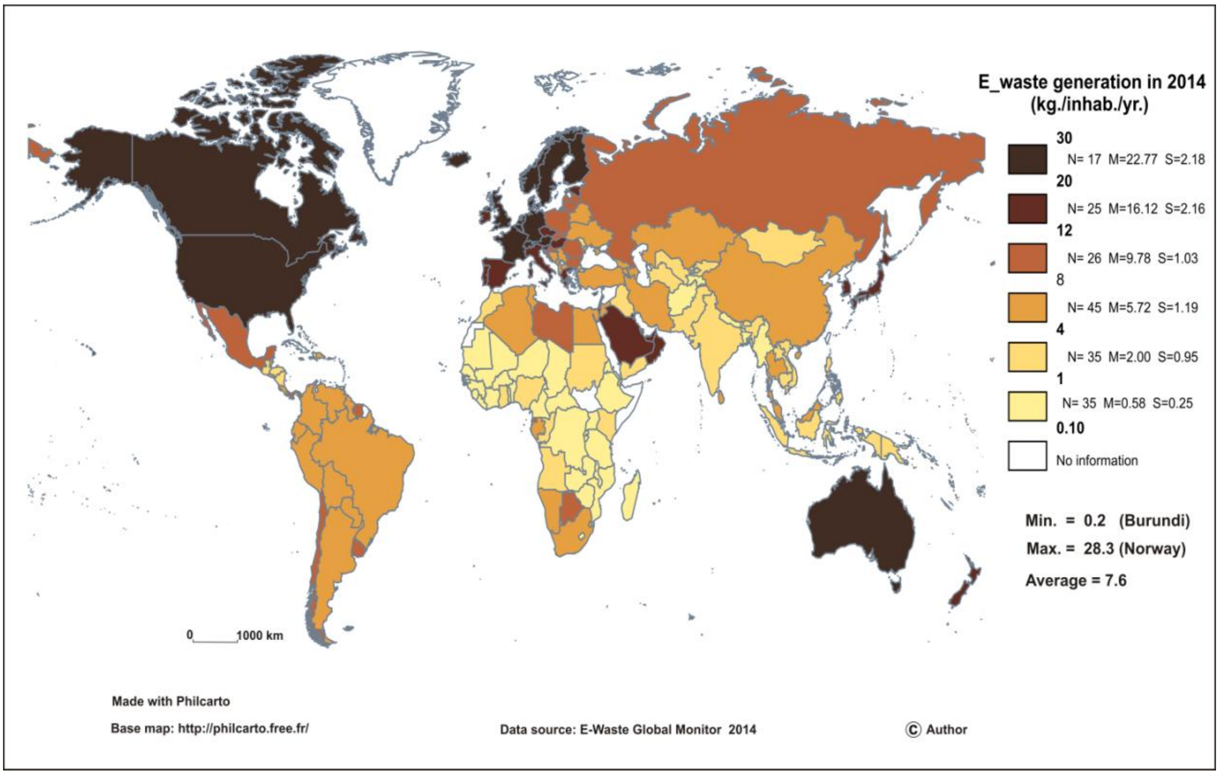

Fig 1.3. Geographical distribution of domestic e-waste generation rates in 2014

There are significant discrepancies across EU, between old members in Western Europe and new member states of Central and Eastern Europe. The Republic of Moldova has the lowest per-capita e-waste generate from Europe respectively (1.8), a similar value to Mongolia (Asia) or Honduras (Central America). Mediterranean countries generate smaller amounts of e-waste compared to Scandinavian countries and poorest e-waste generation rates are revealed in Western Balkans, Turkey, and Ukraine which have values slightly below the global average. This class (4-8 kg.per capita/yr) includes most of the countries across the globe (45) particularly in South America, northern and southern Africa, China, Iran, and Malaysia. Transition economies such as Mexico, Chile, Uruguay or Russian Federation generate domestic e-waste close or above the global average. Africa shows significant disparities across the continent between the smallest amounts of e-waste generated by most countries from Central, Eastern and Western Africa (below 1 kg.per.capita/yr) compared with Botswana (8.3) in the south with same values for Lybia in the North.

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Similar discrepancies are noted across Asian continent where powerful economies of industrialized countries (South Korea, Japan) or oil-based economies in Arabia (Saudi Arabia, Oman, UAE, Kuwait) generate higher amounts of e-waste which are significantly above the global average compared with large emerging economies of China and India. Yemen is the poorest country of Arabia Peninsula and this fact contribute to lowest domestic e-waste generation rates compared with the much richer neighborhood (above 10 kg.per capita/yr). Southeastern countries (Indonesia, Vietnam, Laos, Cambodia, Philippines) generate smaller amounts of e-waste compared to global average except for Singapore (19.6) and Brunei (18.1) which are one of the largest contributors to e-waste generation on per capita basis from Asia. The lowest domestic e-waste generation rates (below 1) are attributed to Afghanistan (0.3), Myanmar (0.4), Nepal (0.5), Tajikistan (0.8). In Central America and Caribbean region, touristic islands states generate the most of domestic e-waste on per capita basis with values above 10 such as Antigua and Barbuda, Barbados and Bahamas which is by far the largest contributor in Central and South Americas (19.1). Haiti as the poorest country of Americas has the lowest per capita e-waste generation rate such as 0.6 similar with Mali, Rwanda and Burkina Faso in Africa. No country of South America overlaps the threshold of 10 kg.per capita/ day e-waste generation rate ranging from 9.9 in Chile to 4 in Bolivia. Oceania region is dominated by Australia and New Zeeland (20-19) followed by Pacific Islands of Marshall (5.5) and lowest values attributed to Papua New Guinea (1.1)

Figure 4 reveals the geographical distribution of per capita domestic e-waste generation in 2016 on per capita basis. In a great measure, same global patterns are valid for 2016. However, there are several countries without available data in Africa (RD Congo, Liberia, Somalia, South Sudan, Equatorial Guinea) Asia (North Korea, Syria, Turkmenistan, Uzbekistan), Caribbean (Cuba, Haiti,) Oceania (Marshall Islands, Nauru).

The global average has increased from 7.6 kg.per capita.yr in 2013 to 8.1 in 2016 with a minim value for Niger (0.4) in Africa and maximum level is attributed to the same country respectively Norway (28.5).

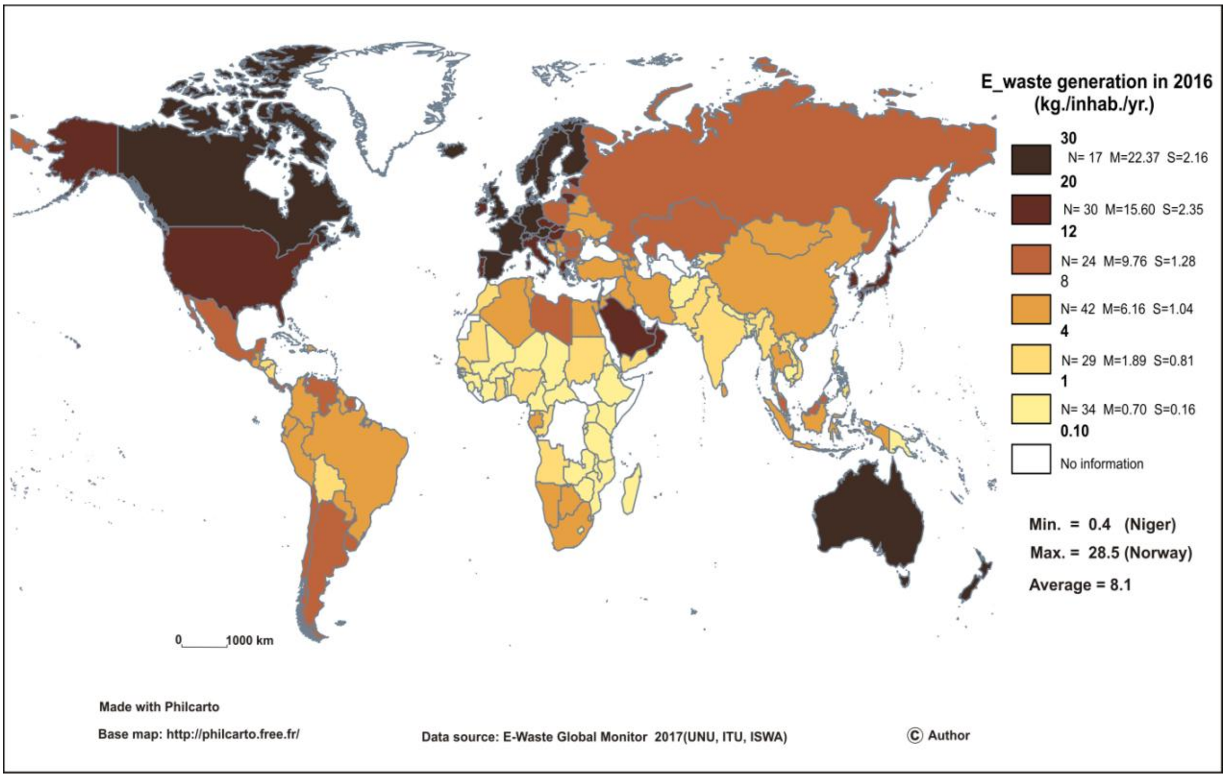


Fig 1.4. Geographical distribution of domestic e-waste generation rates in 2017

This country generates over 70 times domestic e-waste than Niger (Africa) or 47 times more than Afghanistan (Asia) on per capita basis. The lowest per-capita e-waste generation rates in other geographical regions are 0.7 in Oceania (Solomon Islands) or 1.8 in Europe (Republic of Moldova). The global quantity of e-waste in 2016 is mainly comprised of Small Equipment (16.8 Mt), Large Equipment (9.1 Mt), Temperature Exchange Equipment (7.6 Mt), and Screens (6.6 Mt) according to Balde et al.,(2017).

There are 105 countries which generate domestic e-waste below the global average with 10 countries fewer compared to 2013. Such major disparities between high-income countries and developing countries in terms of the population access to basic goods and services are reflected in such estimations. Examples of positive changes compared to 2013 are noted for Argentina and Venezuela in South America, Costa Rica (Central America), Indonesia, Kazakhstan, Mongolia, Malaysia in Asia taking into consideration the classes on the map. On the other hand, a decrease of domestic e-waste generation on per capita is observed for Bolivia (South America) or Botswana (Africa).

3. WEEE management in Europe

WEEE management in the EU area has been organized for several years by European Directives, thus representing an international reference point for other national legislation (Ongondo, 2011). The first WEEE Directive (EC, 2002) entered into force in February 2003. The Directive provided for the creation of collection schemes where consumers return their WEEE free of charge. These schemes aim to increase the recycling of WEEE and/or re-use. Next, in December 2008, the European Commission proposed to revise the Directive in order to tackle the fast increasing waste stream.

The new WEEE Directive (EU, 2012) became effective in February 2014. One of the most important innovation is the introduction of different recycling targets now based on incremental percentages of EEE put on each national market in a predefined period. This new approach overcomes the previous one based on a fixed percentage (i.e. 4 kg per head of population) equal for all Member States, which has been verified as not in line with current market conditions. An enforcement towards designing collection systems oriented to maximize the reuse of whole appliances has been also introduced together with new targets about recycling and recovery of secondary materials. Recently, in April 2017, a report from the commission to the European Parliament and the Council has been published regarding some proposal for reviewing the 2012 Directive.

By analyzing fundamental concepts of the EU system for WEEE management, the directive is based on the Extended Producer Responsibility (EPR): basically, producers, manufacturers, and companies involved in sales and distribution should have the capacity and the economic responsibility to operate a take-back solution either directly or indirectly (e.g. by a consortium) in a country and to provide take-back logistics to end users and businesses (Mayers, 2007; Zoeteman et al., 2010l; Khetriwal et al., 2011).

The aim is to increase collection and recycling rates of WEEE as well as improve the quality and recyclability of the EEE. In addition, the directive includes the provision of national WEEE collection points and processing systems, which allows consumers to put WEEE into a separate waste stream to other waste, resulting in it being processed, accounted for and reported to the national enforcement authority. Furthermore, EPR principle forces producers to help to pay for the costs of collecting, transporting, recycling and responsibly disposing of these products and materials at the end of their life. The producer pays an upfront fee proportional to how much product they place on the market, and this levy helps fund the collection and recycling infrastructure needed. Producers have the option to set up and manage their own EPR scheme, but most choose to delegate this responsibility to a third-party organization by signing up to a collective compliance scheme.

Differently from other national legislation, the EU WEEE Directive covers everything that requires an electric current, a battery, or solar energy in order to operate: in detail, they are categorized into 10 different groups regarding their industrial sectors or their components from large and small household appliances, IT, telecommunications, consumer, and lighting equipment, medical devices, toys, leisure and sports equipment, automatic dispensers, monitoring and control equipment, photovoltaic panels.

Under this common legislative framework, different systems for registration, reporting and WEEE take-back exist in each EU member state.

By analyzing collection and treatment system organization in the EU two organizational models could be outlined (Savage et al., 2006; Mar-Ortiz et al., 2011; Dieste et al., 2017):

• the *National Collective Scheme*: at national level, may operate one or more collective schemes: each scheme must be responsible for the collection of different categories of WEEE; no competition is allowed; annually, each scheme has to communicate data about collected and recycled WEEE to the national ministry of the environment which in turn will report to the European Commission. A manufacturer company shall still organize by itself its own collection system: it must guarantee that no overlapping with other brand products is possible in its end of life management systems;

• the *Clearing House Model*: collective schemes operating at the national level can treat the same categories of WEEE, thus allowing a competition between them.

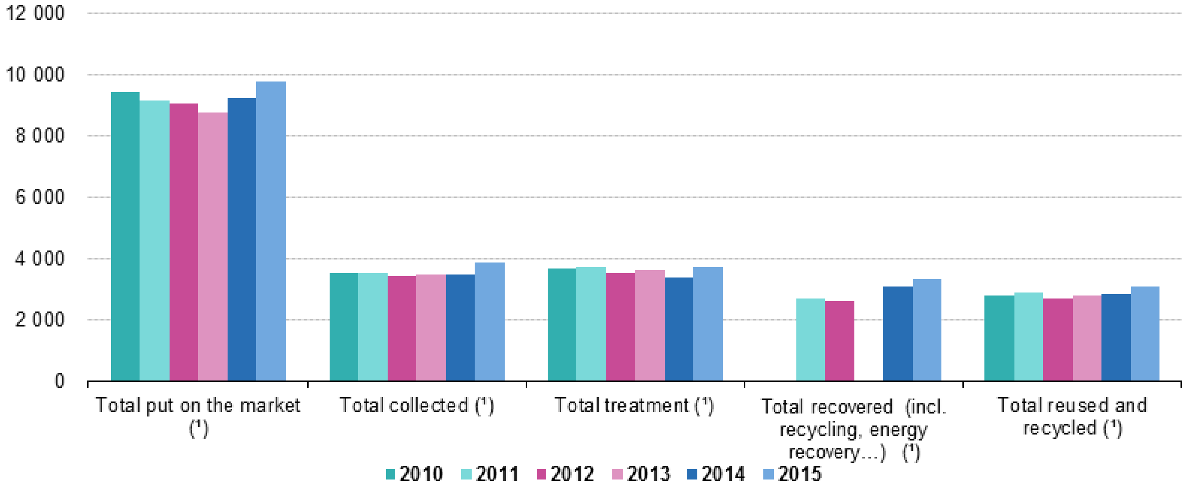
Each scheme in both organizational models is responsible for the collection, transportation, and treatment of WEEE.

This twofold system has caused the proliferation at the national level of "actors" involved in WEEE management: a recent study has outlined that there are currently more than 150 different producer responsible organizations in Europe, making it difficult to follow the actual performance of the overall system (Friege et al., 2015).

Furthermore, a slight contribution to the WEEE collection service in the EU is due to the informal collection service, usually more adopted in developing countries: Papaoikonomou et al. (2009) analyzed the informal recycling sector in Greece usually carried out by marginalized social group; a survey analysis was conducted aiming to assess how to develop structured social enterprises to improve this alternative WEEE management. This complex organizational system is causing an uncertain data management system about the WEEE quantities collected and recycled at EU level. An official source of data is EUROSTAT: statistical data about WEEE collected and recycled in the EU are provided based on national communications. Firstly, it has to be noted that, more than other waste flows, the WEEE quantity collected yearly is heavily influenced by the economy trend in the specific area of analysis (Kumar et al., 2017; Awasthi et al., 2018) rather than other factors (e.g. population dimensions). This statement is confirmed by data provided by EUROSTAT regarding EEE put on the market for the EU 28 between 2010 and 2015 reported in Figure 1.5. From 2010 to 2013, the amount of EEE put on the market dropped has decreased by about 7.2 % likely due to the recession following the global financial and economic crisis; data about the last two years show a clear increase as amounts of EEE put on the market increased again in 2014 and 2015 to 9.3 million tons and 9.8 million tons respectively. This is an increase of 3.4 % over the period 2010 to 2015. However, the 2015 level is still lower than in 2008, the year when the financial and economic crisis started.

It has to be noted that some national data have been estimated by EUROSTAT as national communication are still lacking.

Data about WEEE recycling have been also reported: by EUROSTAT through the so-called "*recycling rate of e-waste indicator*", which is defined as the 'collection rate' multiplied by the 'reuse and recycling rate'. The first contribution is defined as the volumes collected of WEEE in the reference year divided by the average sum of EEE (electrical and electronic equipment) put on the market in the previous three years. The latter is calculated by dividing the weight of the WEEE that enters the recycling/preparing for re-use facility by the weight of total treatment of WEEE.

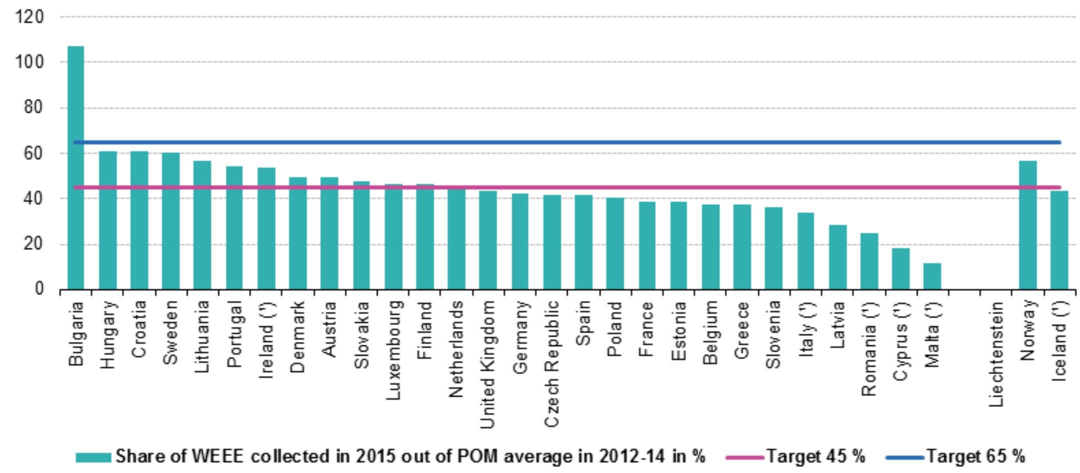


(¹) 2015: estimate for Italy, Cyprus, Malta, Romania, Iceland
Source: Eurostat (online data code: env_waselee)

Figure 1.5- Quantity of EEE put on the market and waste EEE collected and treated, EU, 2010–2015 (1000 tons) (*source EUROSTAT*).

By analyzing data for each Member States in 2015 reported in Figure 1.6, the total amount of collected WEEE varied considerably across the EU Member States, ranging from 1.6 kg per inhabitant in Romania to 14.7 kg per inhabitant in Sweden. Different performance between Member states in the collected amounts could be due to differences in EEE consumption levels as well as the different performance levels of existing waste collection schemes.

Finally, it has to be pointed out that – similarly to another national system – the main criticality of the EU WEEE management system is the illegal trade of waste to developing countries. Some recent reports (Huisman et al., 2015; Illés et al., 2016) estimate that in Europe, only 35% (3.3 million tons) of all the e-waste discarded in 2012, ended up in the officially reported amounts of collection and recycling systems. The other 65% (6.15 million tons) was either exported (1.5 million tons), recycled under non-compliant conditions in Europe (3.15 million tons), scavenged for valuable parts (750,000 tons) or simply thrown in waste bins (750,000 tons). New EU members must improve the current e-waste collection schemes. Larger cities should be served by special collection points located in various areas to facilitate the e-waste collection services as shown in figure 1.7



Note: ranked on 'Share of WEEE collected...' data
(¹) 2015: 2014 data instead and average 2011 - 2013

Source: Eurostat (online data code: env_waselee)

Figure 1.6 Total collection rate for WEEE in 2015 as a percentage of the average weight of EEE put on the market in the three preceding years expressed in %. (*source EUROSTAT*).

Fig.1.7 WEEE collection point in Iasi city (Tatarasi area), Romania (photo FC MIHAI, June 2018)

By analyzing non-EU states, a best practice is also the Swiss system: even if it does not fall under the European Directive, it is a well-established system working for two decades (Streicher-Porte, 2006; Khetriwal et al., 2009; Wäger, 2011). Producer responsibility for the take-back of electrical and electronic equipment in Switzerland is covered by the Ordinance on the Return, Take-back, and Disposal of Electrical and Electronic Equipment (ORDEE). The ORDEE legislation came into force on July 1998 and, it has been modified in January 2005 by extending the scope of the Ordinance to increase the number of categories of electrical and electronic equipment covered. Collection and disposal are financed on a private-sector base and currently carried out by three organizations. Based on voluntary sectoral solutions, an advance recycling contribution is included in the purchase price of all ORDEE equipment.

4. WEEE management in North America

The legislative approach adopted by the U.S. for managing waste produced by electronic and electric products has followed a distinct pattern compared to other nations as it is heavily influenced by its federal organization, which contributes to defining a not standardized way of facing with this waste flow (Kahhat et al., 2008).

First of all, it has to be noted that no specific legislation is working for electric products, such as washing machines, refrigerators, etc.; thus, in this chapter, the analysis focuses only on e-waste, i.e. waste from electronic products. By analyzing legislation about e-waste, there is no U.S. federal law that requires the recycling of e-waste or prohibits it from being exported to developing countries: in details, there are currently 26 states with e-waste laws (plus the District of Columbia). In addition, some electronic wastes – like cathode ray tube, TVs and monitors are classified as hazardous waste in the U.S. because of the hazardous materials inside. An existing law, the federal Resource Conservation, and Recovery Act– defined for the first time in 1976 and updated several times - cover some toxic electronic waste but not all of them, thus, determining in practice, that all electronic components exported for recycling are exempted. This determines that the classification of whether e-waste is considered a hazardous or non-hazardous waste stream varies by states. A lack of a common federal legislation causes an uncertain management of this waste flow: historical data collected and estimated by the EPA in 2014 shows that only about 42% of e-waste in the US were recycled (US EPA, 2016). While this is an improvement from 2005 when less than 20% was recycled (US EPA, 2007) a majority of WEEE still end up in landfills or are incinerated, resulting in considerable loss of valuable materials and dispersion of hazardous ones. In addition, the US is one of the main exporters of e-waste, which contributes to national resource depletion especially for value-added materials, e.g. rare earth materials (BAN, 2002; Duan et al., 2013; Tansel et al., 2017). As state legislation varies from state to state, they are not usually characterized by common principles. For example, some states make it illegal for retailers to charge consumers for recycling programs, which shall contribute to do not increase e-waste collection.

The Extended Producer Responsibility (EPR), which has been successfully applied in other countries (e.g. Europe, Japan, Canada) with positive results, has only informally been adopted in the US by some big electronics companies - e.g., Apple, Dell- and some retailers, e.g., Bestbuy, Staples, Goodwill (Ongondo, 2011; Nash and Bosso, 2013). The adoption of the EPR principle is declined in different ways in state legislation: as an example while in California, the e-waste EOL process is financed by an explicit fee paid by customers, other states require manufacturers to cover (partially or totally) the costs involved in collecting and recycling their products. Another effect to be outlined is a lack of systematic data analysis about the collection rates of each electronic product as well as its recycling rate. Sources of data are many: some states provide data based on specific legislation outcomes, non-profit – the most important is the Electronic Takeback Coalition- and private organizations, as well as EPA. For compensating this lack of data, EPA has developed a mathematical model – called Sales Obsolescence Method (SOM) – for estimating consumer electronic generation – and consequently, the quantity of e-waste - from historical sales.

EPA applies lifespan assumptions to historical annual apparent consumption (i.e., sales). Apparent consumption equals single year U.S. manufacturer shipments plus U.S. imports minus U.S. exports. In 2016, EPA revised the lifespan probabilistic distribution adopted in the SOM model from a uniform distribution to a Weibull distribution. Consumer electronic products included in the EPA report series are electronic products used in residences and commercial establishments such as businesses and institutions and are categorized as video, audio, and information products.

However, a holistic analysis of these data has not yet been done. For example, a statistical analysis systematically capturing the End-Of-Life (EOL) processes for specific electronic products are still not available. Some data about collection and recycling rates are collected by EPA or other organizations but no systematic correlation between them and their operational context is available (Namias, 2013). The problem is that the EOL management could be carried out by certified versus uncertified organizations. Certification programs, launched in 2010, provide electronics reuse and recycling organizations an accredited third-party auditing program to demonstrate that they meet certain standards for safely recycling and managing collected electronics.

Recently more effort has been dedicated to defining a common framework: a first structured attempt has been developed by EPA aiming to support the federal government by defining a National Strategy for Electronics Stewardship, which details the federal government's plan to enhance the management of electronics throughout the product lifecycle (US EPA, 2011). The focus of this strategic plan is to improve the design of electronic products and enhance management of used or discarded electronics. Regarding this issue, since 2006, a voluntary standard called Electronic Product Environmental Assessment Tool (EPEAT) has been introduced by the Green Electronics Council aiming to provide an environmental assessment tool for purchasers of IT products.

A manufacturer of an IT product could register in EPEAT based on the devices' ability to meet certain required and optional criteria that address the full product lifecycle, from design and production to energy use and recycling. Then, a score is assigned based on the level of Bronze-rated products meet all of the required criteria in their category. Silver-rated products meet all of the required criteria and at least 50% of the optional criteria, while Gold-rated products meet all of the required criteria and at least 75% of the optional criteria.

This fragmented legislative and organizational system is similarly adopted in Canada, where WEEE legislation is defined at a province level (Lepawsky, 2012). The total WEEE generated in Canada was 725 Ktons in 2014 (Kumar and Holuszko, 2016) thus determining an average value of 5.9 kg per inhabitant. WEEE flows are divided into 6 main categories (Balde et al. 2015): from small to large equipment to monitors refrigerators and lamps. Similarly to the US, a no-profit organization called Electronics Product Stewardship Canada has been developed in 2003 aiming to support provinces in supporting the sustainable design of electronics and carrying out EOL programs. Several provinces currently require Extended Producer Responsibility (Ean PR) for some WEEE categories (mainly ICT devices): these programs are funded by consumers by an eco-fee paid at the purchase of the new equipment. Recycling activities are developed under the Canadian territories as several companies provide these services.

U.S. and Canada are characterized by similar unstructured WEEE management system. Although U.S. is still one of the main producers of WEEE, it lacks a national common reference framework to manage the collection and final treatment of this waste flow. Thus, U.S. is characterized by low levels of collection and recycling levels and it is mainly due to its fragmented legislation. Rules depend on the state legislation, which usually varies a lot from an area to another one. Higher efforts have been applied in the design phase of electronic products, aiming to support recyclability trough standardized eco-design processes. Similar programs for certifying electronic products are now working also in Canada.

5. WEEE management in Latin America and the Caribbean

Compared to European countries, the legislation about WEEE in Latin American countries lacks comprehensive, coordinated and collaborative schemes; it seems to be more similar to US condition rather than the European one. This determines a high level of uncertainty causing lack of data about quantity collected as well as of EOL management. A recent report (Balde et al., 2017) outlines for Latin America that the quantity to be generated in 2016 is equal to 4.2 Mt. More disaggregated aggregated data (Step, 2016) quantify each national condition: estimated e-waste quantity generated (expressed in kg per inhabitant) in 2014 for Brazil and Argentina is about 7, for Chile and Peru estimated values are 9.9 and 4.7 respectively; Brazil is also the biggest producer of e-waste with an estimated value of 1,411.9 kilotons produced in the same year. Recently legislative interventions have been developed in some countries.

In Brazil, the National Solid Waste Policy adopted in 2010 has defined a mandatory take-back system for WEEE and its components (de Oliveira et al., 2012; Campos, 2014; Migliano et al., 2014; de Souza et al., 2016), the EPR principle has been also introduced for manufacturers, importers, distributors, and retailers. The Brazilian Ministry of Development, Industry and Trade Foreign has proposed in 2013 a national classification for WEEE (Moura et al., 2017) introducing four waste category: the *Green Line* category – which includes PCs, printers, monitors, and cellular – the *Brown Line* category– including TV, monitors and audio products; the *White Line* category – including heavy equipment such as refrigerators, freezers, stoves, washing machines, and air-conditioning – and the *Blue Line* one for mixers, blenders, flatirons, and drills. Costa Rica has started since 2003 to develop its own strategy for WEEE management based on similar initiatives developed in the Netherlands (Arroyo-Araya et al., 2007; Abarca-Guerrero et al., 2018).

Colombia – in cooperation with the Swiss E-waste program - has decided to structurally support the development of sustainable take-back and recycling systems for electronic waste in by introducing its e-waste policy in 2017. On the contrary, there are several countries with poor or no legislation. Argentina is characterized by dispersed and no homogeneous regulations: as an example, the Province of Buenos Aires approved a provincial law on special wastes including WEEE; the mandatory system has been defined similarly to the European one. Bolivia has no formal recycling system; Chile does not have specific legislation for e-waste management; only a formal system for dismantling and preparation for abroad transshipment is yet working. Due to a lack of a legislative framework for managing WEEE, some companies have created take-back schemes waiting mandatory rules will be imposed. These initiatives mainly focus on mobile phones (Araújo et al., 2012). A particular concern in Latin America area is the contribution of the informal collection and dismantling systems, which is widespread in several areas: some attempts – especially in Brazil (Gutberlet, 2015; Ghisolfi et al., 2017; Echegaray and Hansstein, 2017) - are developing to include or coordinate it in the formal system aiming to avoid unfair competition and environmental problems. By analyzing the condition of Caribbean countries about WEEE management, very few information is currently available.

A lack of legislation about WEEE management has been recently pointed out by a study developed by a private organization (ITU, 2016): several initiatives are developing by private companies and NGOs. One example is the Basel Convention Regional Centre for the Caribbean Region in Trinidad and Tobago which supports Caribbean states in developing an integrated waste management system for Hazardous ones, thus including WEEE. Usually, re-use, recycling and/or disposing of are developed abroad from the area. Few data are available about quantities of WEEE generated in the study region (Saldaña et al., 2016). In Mexico, the WEEE management is defined under a more comprehensive legislation on waste management either they are defined as "special handling waste"; no specific legislative framework is defined for this waste stream.

Similarly to other countries, large electric appliances (e.g. with and brown goods) are not included. The annual average of e-waste generation in Mexico is 350 thousand tons from which only 10% is recycled, 40% remains stored in residential homes, offices or warehouses and 50% ends up in officials or uncontrolled landfills (Cruz-Sotelo, et al., 2016). Mexico together with other Latin American states approved partnership projects for promoting and disseminating initiatives for prevention, proper management, and proper final WEEE treatment.

Expect few recent examples, Latin American and Caribbean areas are still lacking an integrated system for collection and treating WEEE. This condition is also determining a complexity in tracing the total quantity of WEEE collected yearly, thus not well-organized data are still available. Few examples are becoming applied at the national level for such WEEE flows: the European system is mainly the reference model adopted to design the waste management systems. Informal waste collection services work in several nations supporting in different ways the national system

6. WEEE management in Africa

The global quantity of WEEE is expected to grow to 49.8 Mt in 2018 (Gu et al. 2017). IT and telecommunications equipment seem to be the dominant WEEE being generated, at least in terms of numbers, in Africa and poorer regions of Asia and in Latin/South America (He et al., 2006). The heterogeneous composition of e-waste, huge logistical challenges and the complex organization of recycling stages can render the overall recycling chain economically unsustainable in OECD countries favoring the export towards the low-income countries. A rigorous enforcement of the Basel convention is needed while at the same time encouraging states that are yet to ratify the convention to do so, so as to achieve a comprehensive implementation regime globally (Ezeah and Fazakerley, 2017). This can be achieved through self-defending mechanisms, legal restructuring (to close loopholes), closer industrial associations, developing guidance for port authorities and/or ultimately implementing a blanket ban on all imports of e-waste (Manomaivibool, 2009). On the other hand, Osibanjo and Nnorom (2008) argue that the bans of obsolete electronics will massively reduce employment opportunities for the informal sector in several disposal destinations in sub-Saharan Africa. Reliable statistics on the level of e-waste being managed in sub-Saharan Africa is unavailable so far (Ezeah and Fazakerley, 2017).

By global standards, the amount of EEE consumed in Africa is relatively small. For instance, estimations of the African share of global consumption point towards approximately 1.5% in the case of personal computers (Mueller *et al*. 2009). However, on top of e-waste generated from domestic consumption, a considerable amount is imported into Africa mostly from OECD countries (Schmidt, 2006). To compound the situation, a number of studies reported under the umbrella of the E-waste Africa project, as well as other African assessments (Magashi and Schluep 2011; Wasswa and Schluep 2008; Finlay and Liechti 2008), indicate that Africa’s consumption of EEE is growing fast, which will, in turn, increase the amount of E-waste generated locally in the future (Schluep, *et al.* 2009).

Poorer countries are the natural market for working used electronics, and it has been estimated that 500 shipping containers of used electronics enter Lagos, Nigeria each month (Puckett *et al.,* 2005). Each container can hold about 350 large televisions, or about 800 computer monitors or CPUs. More than half of the E-waste collected for recycling in developed countries is sent for processing or disposal in the developing world. Over the past decade, African countries such as Nigeria, Kenya, Ghana, and Benin have become the leading E-waste disposal destinations (Sthiannopkao and Wong, 2013). Notwithstanding, except for South Africa where an increase in material recovery activity has been reported, data on the recycling of WEEE in Africa is scarce (Ongondo *et al*.2011). The absence of infrastructure for the appropriate collection and recycling of WEEE and legislation dealing specifically with WEEE are some of the challenges facing E-waste management in Africa (Dittke *et al.,* 2008).

Appreciable levels of WEEE recycling are occurring (Lombardand and Widmer, 2005), mostly driven by the informal sector (Liechti and Finlay, 2008). Industrial and large-scale consumer WEEE streams appear to be handled formally by a handful of large recycling companies whereas household streams are directed to landfills. However, neither organized takeback systems nor license provisions for sorting and dismantling WEEE exist (Ongondo, Williams and Cherrett, 2011). E-waste recycling is a lucrative business in Africa and dominated by the informal sector (Li *et al,* 2013). The system consists of a network of collectors, dealers, dismantlers, and recyclers; all of whom add value at each point of the chain. The potential economic value of some of the metal-based products (i.e. gold, copper, silver) makes recovery an attractive proposition and so plenty of job opportunities open up for those who are unable to source work elsewhere (Manomaivibool, 2009). This activity can, therefore, be described as market driven. With little or no material recovery facility or technology for E-waste recycling in place (Li *et al,* 2013), the products are often processed in backyards or small workshops using labour intensive, and very risky, primitive tools, methods and technologies such as chemical leaching, cracking and open burning, to recover the valuable precious metals (He *et al,* 2006; Osibanjo and Nnorom, 2008). The rest is disposed of in open dumps, unlined landfills or surface water bodies (Oswald and Reller, 2011; Ongondo, Williams and Cherrett, 2011). This results in ineffective resource exploitation and scarce land resources being used as landfills (Nnorom and Osibanjo, 2008).

Nigeria typifies the current state of inefficiencies in the E-waste management system in Africa. As in several other African nations, there are no formal WEEE recycling facilities in Nigeria. Reuse activities taking place to revolve around the incomplete disassembly of obsolete parts for components retrieval and reuse (Ezeah and Fazakerley, 2017). Informal recycling locations are often found adjacent to markets for used EEE. A typical example is Alaba International Market and Ikeja Computer Village in Lagos, Nigeria (Öko-Institut *et al*. 2011). With virtually no capacity for material recovery operations for WEEE (Nnorom and Osibanjo, 2008), WEEE are often comingled with municipal solid waste (MSW).

Waste collection vehicles transporting MSW comingled with hazardous E-waste are common sites in many African cities. At the site, these wastes are usually collected within and burned to reduce the waste volume before final disposal at unlined landfills that lack monitoring or leachate recovery systems of any kind (Osibanjo and Nnorom, 2007). As in other major WEEE destination countries in Africa, the market for recyclers in Kenya is expanding and becoming sophisticated with downstream vendors dismantling old technology and reselling or reusing parts for repair. The main source of parts/fractions are refurbishers, followed by WEEE recyclers and collectors. In addition, some informal businesses have already been established around recycling operations (Mureithi and Waema, 2008).

The more advanced African countries such as South Africa, Egypt and Morocco are reported to have some formal facilities in place for E-waste recycling, however, any ecological benefits of recycling are more than offset if the waste has to be transported long distances due to the negative environmental effects of fossil fuel combustion (Barba-Gutierrez et al., 2008). On the other hand, Nigeria, Kenya, and Ghana are still heavily reliant on informal sector recycling. These crude recycling techniques often result in widespread environmental contamination. In most cases, the ultimate disposal point for E-waste streams after some form of recycling and recovery is landfilling at open dumpsites. Some of the preferred but environmentally unfriendly techniques used to recycle E-waste by the informal sector in the continent include heating and manual removal of components from printed circuit boards, open burning to reduce volumes and recover metals, and open acid digestion of E-waste to recover precious metals. On average the plastic fraction of E-waste has Sn, Pb, Ni, Zn and Sb concentrations >1000 mg/kg as well as >100 mg/kg Cd (Morf *et al*., 2007). Incineration prior to landfilling usually increases the mobility of heavy metals, particularly Pb (Gullett *et al*., 2007). Ongondo et al. (2010) reported that where acid digestion is used, the waste-acid, rich in heavy metals, is often discarded onto the soil or into waterways. E-waste contaminants are sometimes also spread into the air via dust. This is a major exposure pathway for humans through ingestion, inhalation and skin absorption (Mielke and Reagan, 1998). Aerial contamination with dioxins has resulted in levels of human exposure some 15–56 times the WHO recommended maximum intake (Chatterjee, 2007). Elevated levels of dioxins were found in human milk, placentas, and hair, indicating that dioxins are being taken up by humans, from the air, water, or foodstuffs, at sufficient levels to pose a serious health risk (Chan *et al*., 2007).

There is an indication that the quantities of WEEE generated annually in Africa are on the increase. Contamination associated with E-waste has already caused considerable environmental degradation in the continent and negatively affected the health of its people. Rich countries have a self-interest in mitigating the negative environmental effects of E-waste because it will negatively affect the quality and quantity of food and manufactured goods that are imported from poor countries.

7. WEEE management in Asia

7.1 WEEE in South East Asia

Based on the data from Balde et al., (2015), total e-waste generation in Asia is 18.2 Mt of which almost 50% is generated by China (7.2 Mt). Hong-Kong and China is the highest per capita e-waste generation amounting to 19 kg/cap. Meanwhile, e-waste generation per capita in the SEA is dominated by these countries: Brunei and Singapore (around 18 kg/cap). The availability of a national legislation on e-waste in Asia is relative good as about 72% of the population in Asia is covered by a national legislation on e-waste since the most populous countries in Asia (China and India) have e-waste rules. In average, the collection rate is low i.e. 25% and 0% in East-Asia and Central and South Asia respectively. Informal sector plays important role in e-waste management. E-waste generation tends to increase in East-Asia and South East Asia which is 62.7% from 2000 – 2015 (Balde et al., 2015). China has the highest e-waste increase followed by Vietnam and Cambodia amounting to 107%, 90.19%, and 70% respectively.

a.Indonesia

Indonesia has no specific e-waste management law. However, it has a basic Act on Environment (Government Regulation and Waste Act No. 18 /2008), as well as regulations on air, water, and waste management regulated Hazardous and toxic material and Hazardous and toxic waste including e-waste. E-waste generation tends to increase, going from 500 metric kilotonnes in 2009 to nearly 745 metric kt 2014 which is the highest quantity in ASEAN (Balde et al., 2015; UNEP, 2017).

b India

In 2014, WEEE generation in India was 1200 metric kilotonne with the rate of about 1.1 kg/capita (Baldé et.al, 2015). WEEE consists of six main electronic items such as PCs, Televisions, Mobile phones, Air conditioners, Washing Machines, Refrigerators. It is predicted that total WEEE generation will be at 2.15 million tonnes by 2018. The recycling rate capacity is about 344,047 tonnes per annum. However, according to industry estimation, only 5% of the WEEE goes through the formal dismantling/recycling route, while the rest is processed by informal sector

c. China

The amount of e-waste generation in China is contributed also by WEEE exported from overseas through various illegal routes with the amount of 1.5–3.3 Mt and the value increases 70% each year (Wang et al., 2013). China self-generates more than 2.3 million tons of electronics waste (WEEE) reported by the United Nations Environment Program (UNEP, 2017). The total WEEE generation is 7.2 Mt making China as the top WEEE producer in the world (UNU, 2017). Zeng et al. (2017) predicted that this amount will reach 27 Mt by 2030. Recycling of WEEE is implemented in China and the rate tends to increase as reported by (CHEARI, 2013). The recycling rate of WEEE is 34%, 43% and 62% in 2012, 2013, and 2014 respectively and most of the e-waste is recycled informally (Wang et al., 2013). In 2009, Regulations on the Management of the Recovery and Treatment of Waste Electronic and Electrical Products was enacted. In 2011, it came into force and makes waste recycling a mandatory. It regulates also EPR implementation as well as fund establishment to subsidize e-waste recycling (Honda et.al, 2016)

d.Malaysia

As per As per UNU's Global E-waste monitor 2014, Malaysia generates 232 metric kilotonnes WEEE waste. Some regulations under the hazardous waste framework exist in Malaysia, such as "Environmental Quality Act, 1974", Public Cleansing Management Act 2007" and "Environment Quality (Schedule Waste Regulations 2005) (UNEP, 2017). These rules are applicable for e-waste handling and processing. It is estimated that WEEE-waste in Malaysia is 7.8 kgs/per capita leading to 90,000 tons increase per year (Balde et al., 2015). Sector informal is involved in e-waste collection, transportation, and disposal step.

e. Vietnam

Vietnam generates approximately 116 metric kilotonnes WEEE per year including illegal imports of e-waste shipped from other countries. Meanwhile, the generation per capita is 1.3 kgs/per capita (Balde et al., 2015). Vietnam has a basic Act on Environment "Law on Environmental Protection 1993 amended in 2005". It has also regulations on water and hazardous waste management. The Prime Minister's Decision No. 50/2013/QD-TTg (9 August 2013) on Prescribing Retrieval and Disposal of Discarded Products became the first legislation considering e-waste as a specific waste enacted in 2013. In September 2015, Regulations on Hazardous Waste Management came into force (Hai, et.al, 2015).

f. Thailand

There is an increasing trend in e-waste arising in Thailand, going from 300,000 tonnes in 2009 to nearly 490,000 tonnes projected for 2016. The Department of Industrial Works (DIW) estimated that 20,000 tonnes are from EEE manufacturers alone in 2009 and this amount increase (Jiaranaikhajorn, 2013). According to the PCD (Pollution Control Department) study, this amount goes to different routes with various percentage which is 51.3%, 25.3%, 15.6% and 7.8% to be sold to informal sector or junk shops, stored by consumers, disposed of along with other wastes, and donated to given to relatives for further use, respectively. No specific law for e-waste management exists in Thailand. The government has proposed a draft of the legislation, called the Thai Draft WEEE Bill, in November 2014. The Bill is based on EPR principles. However, Bill has not been passed until 2016.

7.1 WEEE in Higher Income Countries

a. Japan

According to UNU, E-waste generation is increasing in Japan. In 2009, there is 1.9 Mt, while in 2014 there 2.2 Mt e-waste generation. This amount is predicted to be 2.3 Mt in 2016. early 2.2 Mt. Fortunately, Japan has e-waste-specific laws such as The Law for Promotion of Utilization of Recyclable Resources, the Law for the Recycling of Specified Kinds of Home Appliances (often referred to as the "Home Appliance Recycling Law") and the Law for

Recycling of Small Electronic Appliances ("Small WEEE Law"). With these laws, consumers are obliged to pay e-waste transportation and recycling cost conducted by retailers or municipalities and pay costs for transportation and recycling. Referring to Echegaray & Hansstein (2017), recycling has been acknowledged as an important tool for environmental pollution and depletion reduction, as well as for energy savings increase. WEEE recycling may be as a secondary source of valuable metals giving some benefits, i.e, steady supply of metals, natural resource conservation, environmental pollution control, material cycles management (Hai et al. 2015; Oguchi et al, 2013).WEEE recycling process chain in Japan involves four different major routes consisting of the formal route, second-hand market for reuse, a collection of unused items by informal sector and by the local authority and treated as general waste stream (Menikpura et al, 2014). The formal route of recycling covers 65% of collected WEEE (676,000 tons), of which 82% was recycled to recovered valuable metals/materials (AEHA, 2014).

b. South Korea

There is a trend of e-waste arising growing from 13 kg/capita in 2009 to nearly 16 kg/capita in 2014. It is predicted that the amount will be nearly 18 kg/capita by 2018, according to the UNU estimates. Totally, over 800,000 tonnes of WEEE was generated in 2014 making Korea the third-largest generator of e-waste in East and Southeast Asia, behind only China and Japan. Korea has an e-waste specific laws since E-waste management has been being started in 1992 when the Producer Deposit-Refund scheme was introduced. Another law, the Act on the Resource Circulation of Electrical and Electronic Equipment and Vehicles has been enacted also since January 2008. Korea targets to increase recycling rate which was 3.9kg/capita in 2014 to 6kg/capita by 2018.

c.Taiwan

With the e-waste per capita generation of 18.6 kg/inhabitant in 2014, Taiwan becomes the third-highest per capita e-waste arising in East and Southeast Asia at, after Hong Kong and Singapore (Honda, et.al, 2016). A large domestic market for EEE contributes to over 20 percent increase from 2009 to 2014. According to the UNU Global E-waste Monitor, 436,000 tonnes were generated in 2014 across all EEE product categories. Taiwan has no an e-waste specific laws. In 1997, the Environmental Protection Administration Taiwan (EPAT) introduced the "4-in-1 Recycling Program", regulating the Recycling Management Fund, into which manufacturers and importers pay recycling fees. Currently, e-waste is managed using the Waste Disposal Act 1998 Article 15 to Article 23.

d.Singapore

According to the National Environment Agency (NEA), about 60,000 tons of e-waste is generated in Singapore every year. The rate is increasing from 17.5 kg per capita in 2009 to nearly 19.5 kg per capita in 2014. The amount is expected to be 21 kg per capita by 2018. However, specific legislation for e-waste management does not exist in Singapore although Singapore has a basic act on Environment, "Environmental Protection and Management Act, 2002" as well as regulations on air, water and waste management (UNEP, 2017). E-waste is managed under the Hazardous Waste (Control of Export, Import, and Transit) Act (1998).

It regulates the control of export, import, and transit of hazardous waste in accordance with the principles and provisions of the Basel Convention. Industry involves in e-waste collection, take-back, and recycling in a voluntary way (Honda et al. 2016).

7.2 WEEE in Gulf countries

The Gulf Cooperation Council (GCC) countries (i.e., Saudi Arabia, United Arab Emirates, Qatar, Bahrain, and Oman) experiences WEEE increase as standards of living is increasing over the last four decades (Alameer, 2014; Nizami et al, 2016; Ouda et al, 2013; Ouda et al, 2016). In 2014, total WEEE in GCC was 641 thousand tons (Blade et al, 2015). This amount is predicted to increase. Most of GCC countries have no WEEE specific laws or policies according to Hassanin (2016) and Alameer (2014).

a. Qatar

Among the GCC nations, Qatar has been at the forefront in terms of national legislation on WEEE management because it has had a law governing end-of-life mobile phone recycling since 2009 which came into force in 2010 (Hassanin, 2010). The law establishes regulations for collection of WEEE in the form of discarded and end-of-life products by EnviroServe and its shipment to Singapore for recycling. Totally, WEEE generation was about 32 thousand tons in 2014 with the per capita WEEE generation was at 16.3 kg (Blade et al, 2015).

b. Kuwait

The per capita E-waste generation in Kuwait is estimated at 17.2 kg per year with a total countrywide annual generation of about 68.8 thousand tons (Blade et al, 2015). An Environmental Public Authority (EPA) was established in 1995 and disseminated a new 10-year strategy in 2005. However, WEEE management did not include in its new comprehensive strategy. WEEE has not been any of the components or targets for the future (Hassanin, 2010). Kuwait as one of the biggest per capita e-waste producers among the GCC nations uses the same landfills for both conventional and e-waste.

c. UEA

Some waste management centers in UAE has equipped with facilities where WEEE is classified and sorted out specifically. The UAE government is developing regulation and facilities for comprehensive WEEE recycling. Currently, small recyclers have increased in the UAE and involve in WEEE collecting and recycling e-waste and make a small profit from the recycled products. To increase the current recycle rate, the government is constructing a facility which will serve as the region's largest center of expertise for WEEE management in the Middle East to change the current practice of throwing potentially hazardous phones, computers and other electronic products out with regular garbage (Khaleej Times, 2017). The facility should be in operation at the end of 2017 with the processing capacity of 39 kt WEEE (Almeer, 2014). The per capita E-waste generation in UAE is estimated at 17.2 kg per year with a total countrywide annual generation of about 101 thousand tons (Blade et al, 2015).

d. Arab Saudi

WEEE generation in Saudi Arabia is the biggest amount among the GCC countries. According to Blade et al. (2015), total annual WEEE generation is about 378 thousand tons and the per capita WEEE generation is estimated at 12.5 kg annually (Alameer, 2014).

Private companies, initiatives and Non-Profit-Organizations working on WEEE recycling exist in Saudi Arabia. However, there is no regulated system in place. In 2012, the Kingdom of Saudi Arabia (KSA) initiated the efforts to respond to increasing and compounding WEEE by announcing a collaboration with a company, EXITCOM, to establish the EXITCOM KSA recycling company (Alameer, 2014). The company was intended to work specifically in WEEE recycling.

8. WEEE management in Oceania

Based on the study by United Nations University, e-waste generation in Oceania, the region comprising 13 countries including Melanesia, Micronesia, Polynesia, and Australasia is 17.3 kg per capita generating totally 0.7 million tons of e-waste in 2016 (Balde et al. 2017). This is one of many effects caused by EEE sale booming in the last decade. The amount is predicted will increase if there is no sustainable solution. Australia and New Zealand is the country with the highest e-waste generation amounting to 0.57 Mt/year and 95 kt/year respectively. Every year, Australian and New Zealander create an average of 23.6 kg/cap and 20.1 kg/cap respectively. There are no WEEE specific laws and WEEE management is regulated under recently adopted Pacific Regional Waste Pollution Management Strategy 2016-25 (Cleaner Pacific 2025). The document details the current situation and the future strategy for managing all the waste streams, including WEEE(SERP, 2016).

Across the Pacific Island countries, WEEE is mostly landfilled and the official collection and recycle rate is 0%. WEEE management practices are predominantly informal since WEEE is separated at the disposal sites by waste pickers and sold to recyclers. The amount of WEEE in government institutions and commercial establishments are relatively unknown. As far as regulations are concerned, New Caledonia is the only country implementing an Extended Producer Responsibility (EPR) scheme for WEEE. New Caledonia's EPR scheme is managed by a non-profit environmental organization (TRECODEC). It collects WEEE through voluntary drop-off receptacles and from authorized dumps (Balde e.al, 2017).

a. Papua New Guinea

The per capita E-Waste generation in Papua New Guinea1.2 kg/year. There is no available data about the WEEE quantities and flows in this country. However, getting the description of the current SWM in Papua New Guinea, especially in Port Moresby, which is incapable of serving the needs of this rapidly expanding international capital city, the WEEE management is inferior. Moreover, its residents have little awareness of, and engagement in, environmental protection. It is a challenge to practices sustainable waste segregation. Recycling is a virtually unknown concept and waste collection is sporadic and inefficient. Although a regulatory framework exists, it is insufficient to properly guide and regulate the SWM sector. Institutions lack funding, and there is a crucial need to modify and regulate the practices of waste collection contractors active in the sector.

b Fiji

Fiji, and Suva City, in particular, have attained important improvements in SWM in recent years. The construction of new landfill inNaboro has significantly decreased environmental and public health risks. Waste collection services provided by the SCC are reasonably efficient, well-managed, and financially self-sustaining. Yet, illegal dumping and waste open burning is still practiced due to inadequate enforcement.

c. Solomon Islands

The Solomon Islands has a population of approximately 552,000. Lack of funding for adequate management of solid wastes causes ineffective waste management. There is no available information about the WEEE flows and treatment practices.

d. Micronesia

WEEE is a growing problem for FSM, and an assessment was completed in 2009 [FSM Department of Health and Social Affairs, 2009]. However, none of the four FSM states currently have WEEE specific laws to enforce related stakeholder to properly handle e-waste and none of the three levels of government in FSM(national, state, municipal) have plans to initiate actions to address the e-waste situation

CONCLUSIONS

A sound weee management system requires complex activities including technical, legislative, public policy, governance and socio-economic issues within a multi-level framework (local-regional-national-global) This chapter points out the geographical disparities and regional challenges concerning the e-waste flows and their management issues. African countries face huge challenges in the management of WEEE as a result of a near absence of required infrastructure. As such a two-pronged strategy necessitating, rigorous enforcement of the Basel and Bamako conventions on E-waste management is advocated, so as to reduce illegal E-waste imports alongside a significant increase in investment for E-waste management infrastructure development in the continent. This situation is also valid for Asian countries where imported e-waste is treated in rudimentary conditions with direct impact on public health and environment. Reliable e-waste statistics with a global coverage is critical towards a proper monitoring process of e-waste flows. Major disparities are identified at the global level and within each major geographical area concerning the per-capita e-waste generation rates. Unfortunately, unsound e-waste management systems still prevail in most of the transition and developing countries. Lack of proper legislation from several countries across the globe lead to improper disposal practices despite recent improvement in this sector. Even high-income countries are characterized by low levels of collection and recycling levels and it is mainly due to its fragmented legislation.

Development of special waste collection schemes for this fraction starting to be implemented in Central and Eastern Europe under EU regulations, and it is imperative across Central and South America, Africa, Asia and Oceania where such wastes end into urban landfills or dumpsites. Both urban and rural areas of a country must be part of regional integrated weee management systems. The role of informal sector in recycling activities of e-waste fraction from developing countries must be further investigated and to seek solutions for their integration with formal waste management sector. WEEE stream poses serious environmental and public health risks associated with open dumping and open burning practices or rudimentary treatment activities performed by the informal sector.

International cooperation is essential to mitigate illegal traffic of e-waste stream and to avoid poorer countries of Africa and Asia to become notorious ewaste disposal destinations. Better WEEE statistics available across all continents is crucial to understand and monitor the global e-waste flows and the geography behind it.

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