The Global E-waste Monitor 2017

Quantities, Flows, and Resources

Authored by Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P.

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Foreword

It is our pleasure to present to you the 2017 Global E-waste Monitor, a joint effort of the United Nations University (UNU), the International Telecommunication Union (ITU), and the International Solid Waste Association (ISWA) to increase awareness and draw attention to the growing issue of electronic-waste.

More and more people are joining the global information society and digital economy, and are benefiting from the opportunities they offer. More and faster networks, and new applications and services delivered at increasingly high speeds, have brought new opportunities to many people, particularly in the areas of health, education, government, entertainment, and commerce. In parallel, higher levels of disposable incomes, urbanization, and industrialization in many developing countries are leading to growing amounts of electrical and electronic equipment and, consequently, to greater amounts of e-waste.

Discarded equipment, such as phones, laptops, fridges, sensors, and TVs contain substances that pose considerable environmental and health risks, especially if treated inadequately. Most e-waste is not properly documented and not treated through appropriate recycling chains and methods. At the same time, e-waste streams challenge the efforts towards a circular economy as valuable and scarce resources are wasted. This report represents an important step to identify current challenges and solutions.

Indeed, this report shows that the amounts of e-waste continue to grow, while too little is recycled. By 2016, the world generated 44.7 million metric tonnes (Mt) of e-waste and only 20% was recycled through appropriate channels. Although 66% of the world's population is covered by e-waste legislation, more efforts must be made to enforce, implement, and encourage more countries to develop e-waste policies.

The report also highlights the lack of reliable e-waste data at the country level. Often, merely anecdotal evidence is available on the production, management, and recycling of e-waste, and only 41 countries in the world collect international statistics on e-waste.

To address these challenges, UNU, ITU, and ISWA joined forces, and in January 2017 launched the Global Partnership for E-waste Statistics. Its objective is to help countries produce e-waste statistics and to build a global e-waste database to track developments over time. Better data is an important step towards addressing the e-waste challenge. Statistics help to evaluate developments over time, set and assess targets, and identify best practices of policies. Better e-waste data will eventually contribute to minimizing e-waste generation, prevent illegal dumping and improper treatment of e-waste, promote recycling, and create jobs in the refurbishment and recycling sector.

This 2017 edition of the Global E-waste Monitor is an important achievement of the Partnership and will inform policy makers, industries, and businesses to enhance the understanding and interpretation of global e-waste data, thus communicating the data to the general public and relevant stakeholders. The Partnership further aims to map recycling opportunities from e-waste, pollutants, and e-waste related health effects, along with building national and regional capacities to help countries produce reliable and comparable e-waste statistics that can identify best practices of global e-waste management. Ultimately, its work will contribute to the achievement of Sustainable Development Goals (SDG) 11.6 and 12.5 by monitoring relevant waste streams and tracking the ITU Connect 2020 target 3.2 on e-waste.

We would like to thank all authors and contributors to this report, and would like to invite you to support the Global Partnership for E-waste Statistics and its continuous efforts to improve global e-waste management.

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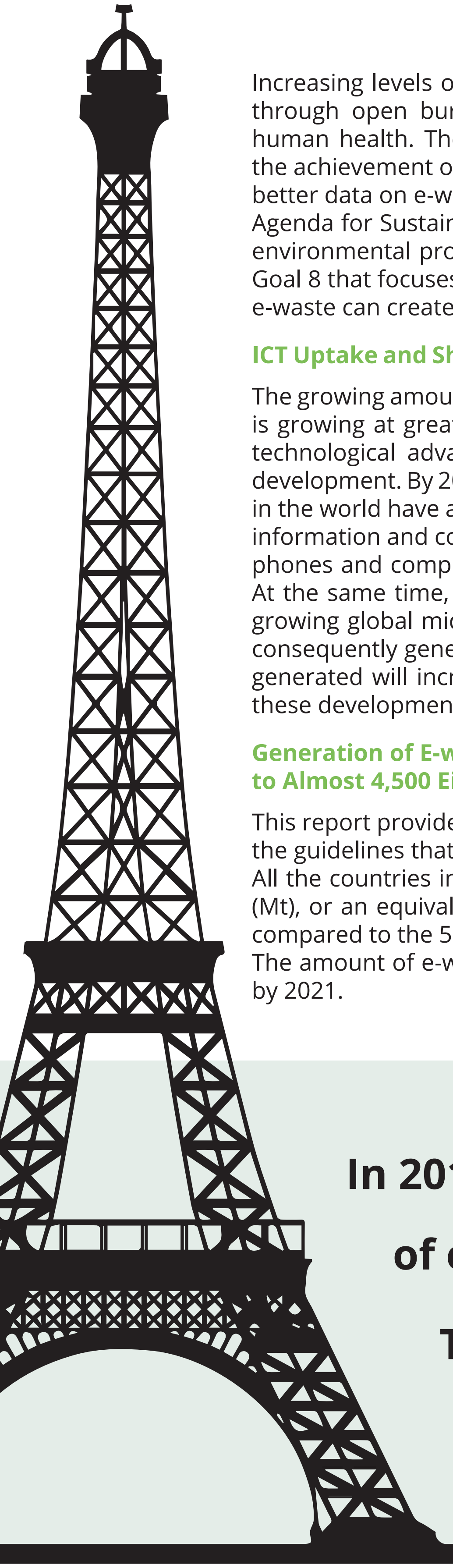
Geneva, Bonn, Vienna - November 2017

Executive Summary



Increasing levels of electronic waste, and its improper and unsafe treatment and disposal through open burning or in dumpsites, pose significant risks to the environment and human health. They also present several challenges to sustainable development, and to the achievement of the Sustainable Development Goals (SDGs). A better understanding and better data on e-waste will contribute towards the achievement of several goals of the 2030 Agenda for Sustainable Development. In particular, it will help address the SDGs related to environmental protection (Goals 6, 11, 12, and 14) and health (Goal 3). It will also address Goal 8 that focuses on employment and economic growth, since the sound management of e-waste can create new areas of employment and drive entrepreneurship.

ICT Uptake and Shorter Replacement Cycles Are Contributing to the Growth of E-waste

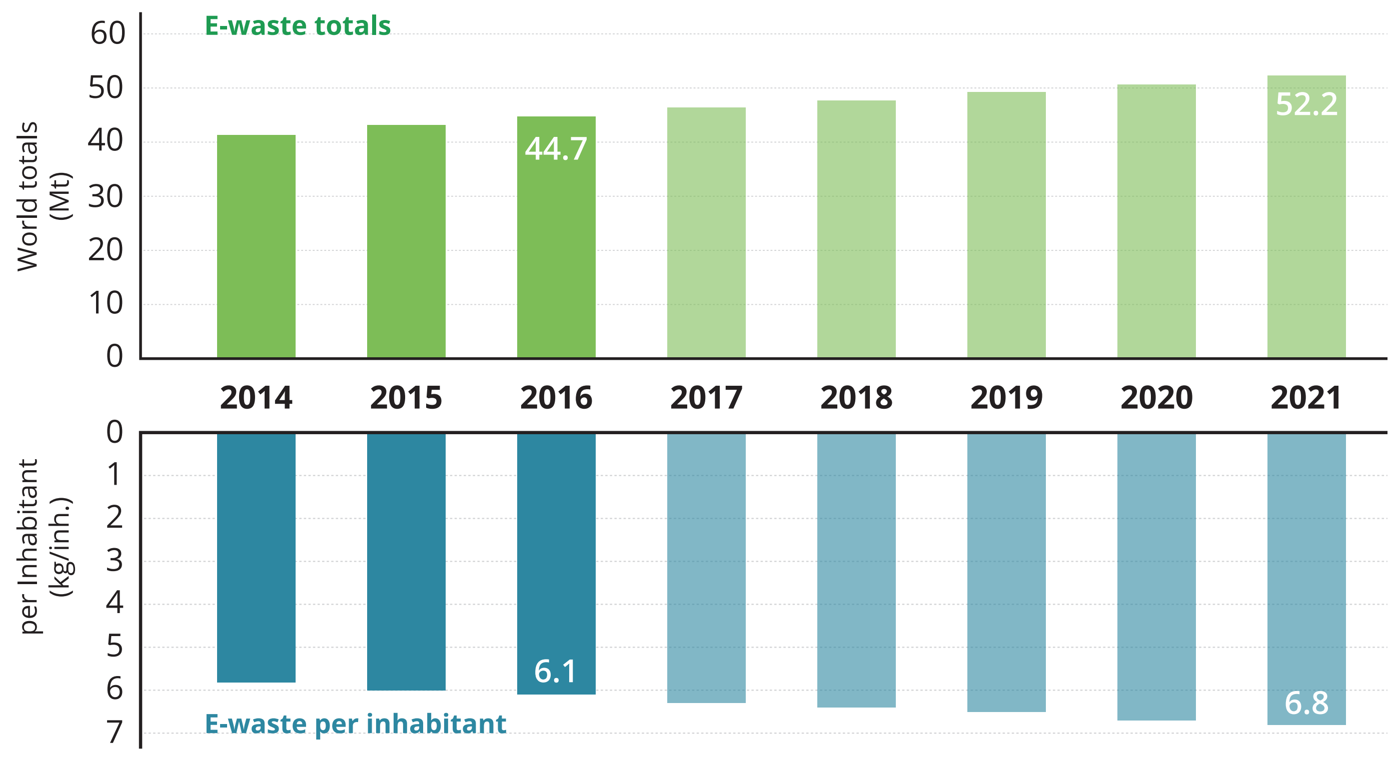
The growing amount of e-waste is the result of several trends. The global information society is growing at great speed. It is characterized by an increasing number of users and rapid technological advances that are driving innovation, efficiency, and social and economic development. By 2017, close to half the world's population uses the internet and most people in the world have access to mobile networks and services. Many people own more than one information and communication technology (ICT) device, and replacement cycles for mobile phones and computers, and also for other devices and equipment, are becoming shorter. At the same time, disposable incomes in many developing countries are increasing and a growing global middle-class is able to spend more on electrical and electronic equipment, consequently generating more e-waste. Current trends suggest that the amount of e-waste generated will increase substantially over the next decades, and that better data to track these developments are needed.

Generation of E-waste Has Grown to 44.7 Million Metric Tonnes Annually – Equivalent to Almost 4,500 Eiffel Towers

This report provides the most comprehensive overview of global e-waste statistics following the guidelines that were developed by the Partnership on Measuring ICT for Development[1]. All the countries in the world combined generated a staggering 44.7 million metric tonnes (Mt), or an equivalent of 6.1 kilogram per inhabitant (kg/inh), of e-waste annually in 2016, compared to the 5.8 kg/inh generated in 2014. This is close to 4,500 Eiffel Towers each year. The amount of e-waste is expected to increase to 52.2 million metric tonnes, or 6.8 kg/inh, by 2021.

In 2016, 44.7 million metric tonnes of e-waste were generated. This is an equivalent of almost 4,500 Eiffel towers.

Global e-waste generated

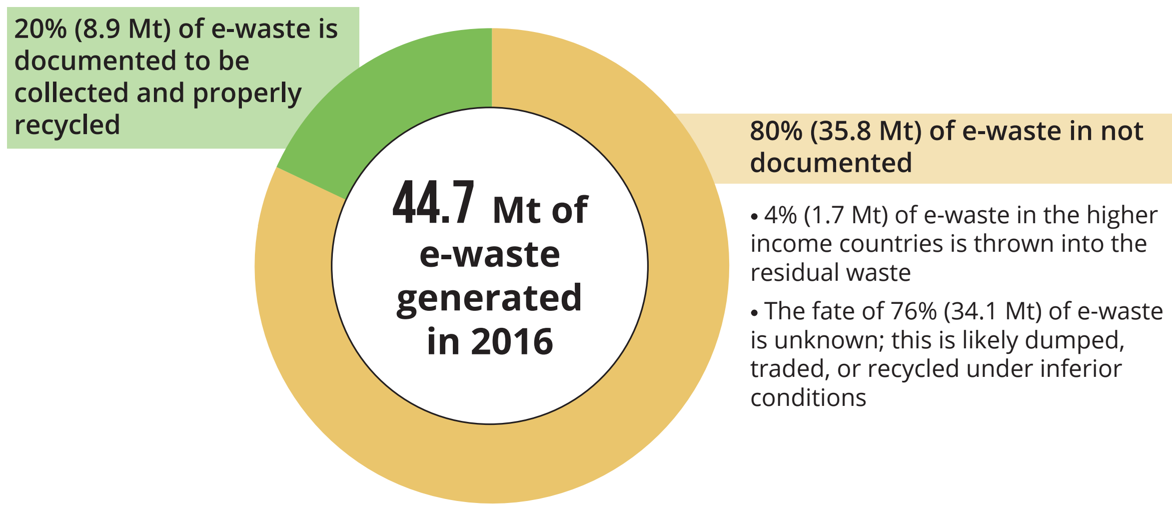


Note: 2017-2021 are estimates

Only 20% of E-waste Generated Is Documented To Be Collected and Recycled

Of those 44.7 Mt, approximately 1.7 Mt are thrown into the residual waste in higher-income countries, and are likely to be incinerated or land-filled. Globally, only 8.9 Mt of e-waste are documented to be collected and recycled, which corresponds to 20% of all the e-waste generated.

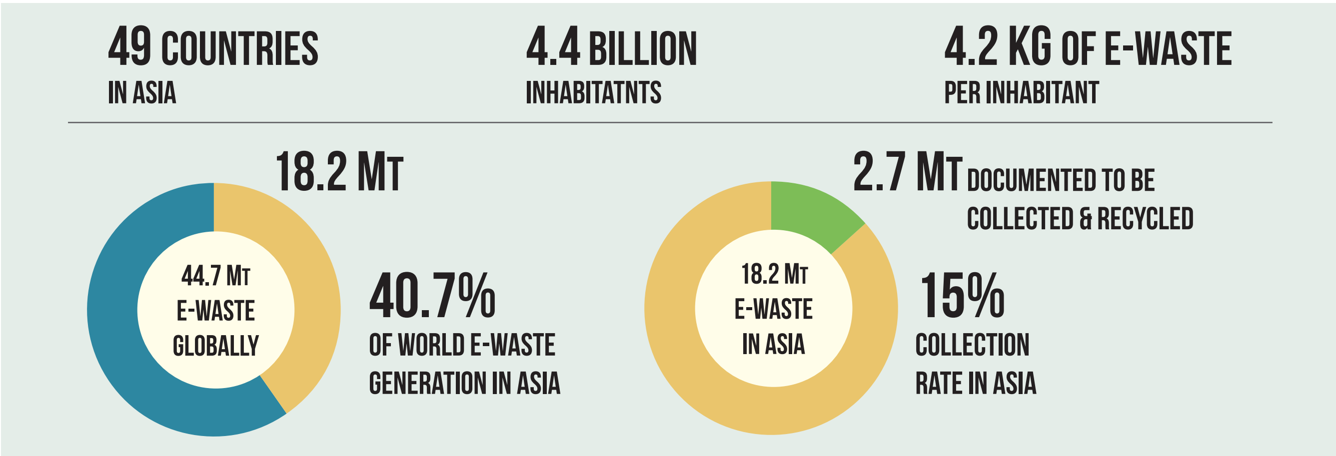
Collection methods of e-waste in 2016



Asia Generates the Greatest Amounts of E-waste; Africa the Least, Both in Total and Per Inhabitant

In 2016, Asia was the region that generated by far the largest amount of e-waste (18.2 Mt), followed by Europe (12.3 Mt), the Americas (11.3 Mt), Africa (2.2 Mt), and Oceania (0.7 Mt). While the smallest in terms of total e-waste generated, Oceania was the highest generator of e-waste per inhabitant (17.3 kg/inh), with only 6% of e-waste documented to be collected and recycled. Europe is the second largest generator of e-waste per inhabitant with an average of 16.6 kg/inh; however, Europe has the highest collection rate (35%). The Americas generate 11.6 kg/inh and collect only 17% of the e-waste generated in the countries, which is comparable to the collection rate in Asia (15%). However, Asia generates less e-waste per inhabitant (4,2 kg/inh). Africa generates only 1.9 kg/inh and little information is available on its collection rate. The report provides regional breakdowns for Africa, Americas, Asia, Europe, and Oceania.

E-waste snapshot: Asia



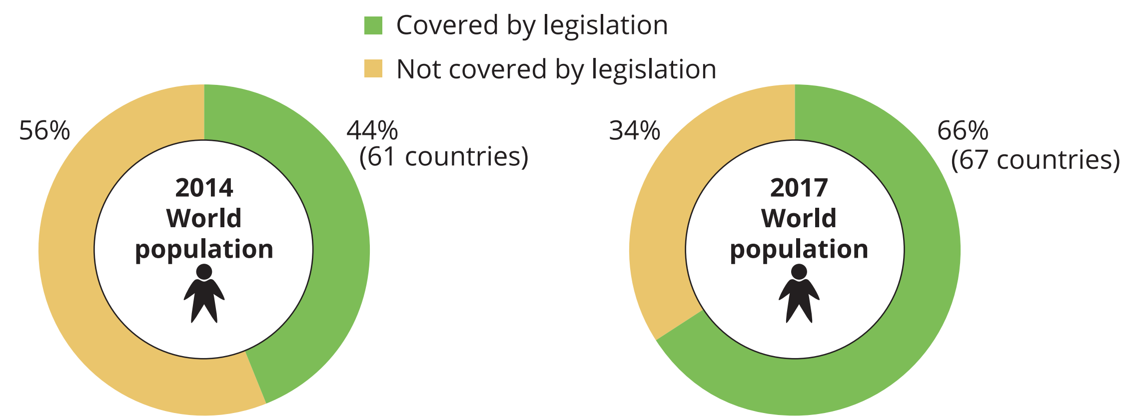
Only 41 Countries Have Official E-waste Statistics

The low collection rate compared to the total amount of e-waste generated is partly explained by the fact that only 41 countries have official e-waste statistics. For 16 other countries, e-waste quantities were gathered from research and estimated. The fate of a large majority of the e-waste (34.1 Mt) is simply unknown. In countries where there is no national e-waste legislation in place, e-waste is likely treated as other or general waste. This is either land-filled or recycled, along with other metal or plastic wastes. There is the high risk that the pollutants are not taken care of properly, or they are taken care of by an informal sector and recycled without properly protecting the workers, while emitting the toxins contained in e-waste.

More Countries Adopt E-waste Legislation

Although the e-waste challenge is on the rise, a growing number of countries are adopting e-waste legislation. Currently, 66% of the world population is covered by national e-waste management laws, an increase from 44% that were covered in 2014.

World population (and number of countries) covered by e-waste legislation in 2014 and 2017



The large increase was mainly attributed to India, where legislation was adopted in 2016. The most populous countries in Asia currently have e-waste rules, whereas only a handful of countries in Africa have enacted e-waste-specific policies and legislations. However, it must also be noted that countries with national e-waste management laws do not always enforce the law. Many countries lack measureable collection and recycling targets that are essential for effective policies.

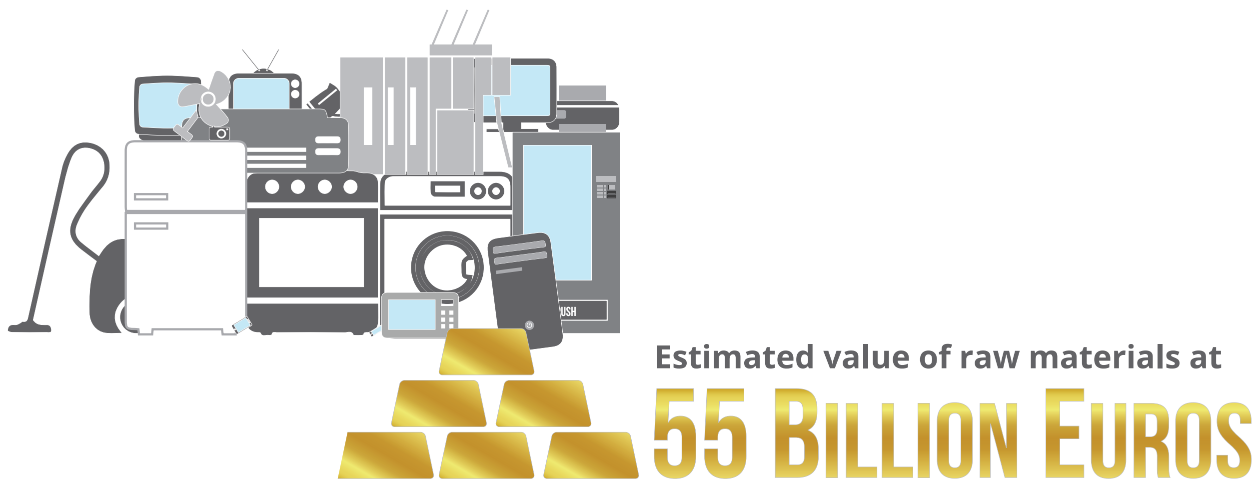
Currently available statistics are not able to track the amount of e-waste or used electronics shipped from richer to poor sub-regions in the world. One case study on Nigeria showed that in 2015/2016, EU member states were the origin of around 77% of Used Electric and Electronic Equipment (UEEE) imported into Nigeria. Sometimes, used equipment is actually broken upon arrival and should be considered e-waste. Even if parts may be repairable or directly usable as a second-hand goods, they are likely to become e-waste as well. Since low-income countries generally have less e-waste management infrastructure than higher income economies, these are alarming trends that need to be addressed.

The type of e-waste covered by legislation differs considerably throughout countries, causing difficulties in coordinating collected and recycled e-waste amounts. Without better statistics on e-waste, and closing the main data gaps of current e-waste statistics, it is impossible to measure the effectiveness of existing and new legislation to show any potential improvements in the future. It is also difficult to provide data that guides business developments.

Huge Amounts of Raw Materials Are Wasted

E-waste statistics are not only relevant in terms of the environmental impact; there is also an important economic component to the debate. The total value of all raw materials present in e-waste is estimated at approximately 55 Billion Euros in 2016, which is more than the 2016 Gross Domestic Product of most countries in the world. The value of secondary raw materials after waste management is just a fraction of the value of its components or the price of used appliances. Circular economy models need to be adopted to encourage closing the loop of materials through better design of components, recycling, reusing, etc., while mitigating the environmental pollution. Therefore, the circular economy concept offers huge economic and employment opportunities for e-waste management; the presented 55 Billion Euros of secondary materials is an underestimate of those economic opportunities. This calls for the development of proper legislation to manage e-waste that's supported by data to show both the environmental and economic benefits the the better management of e-waste.

Potential value of raw materials in e-waste in 2016



Chapter 1

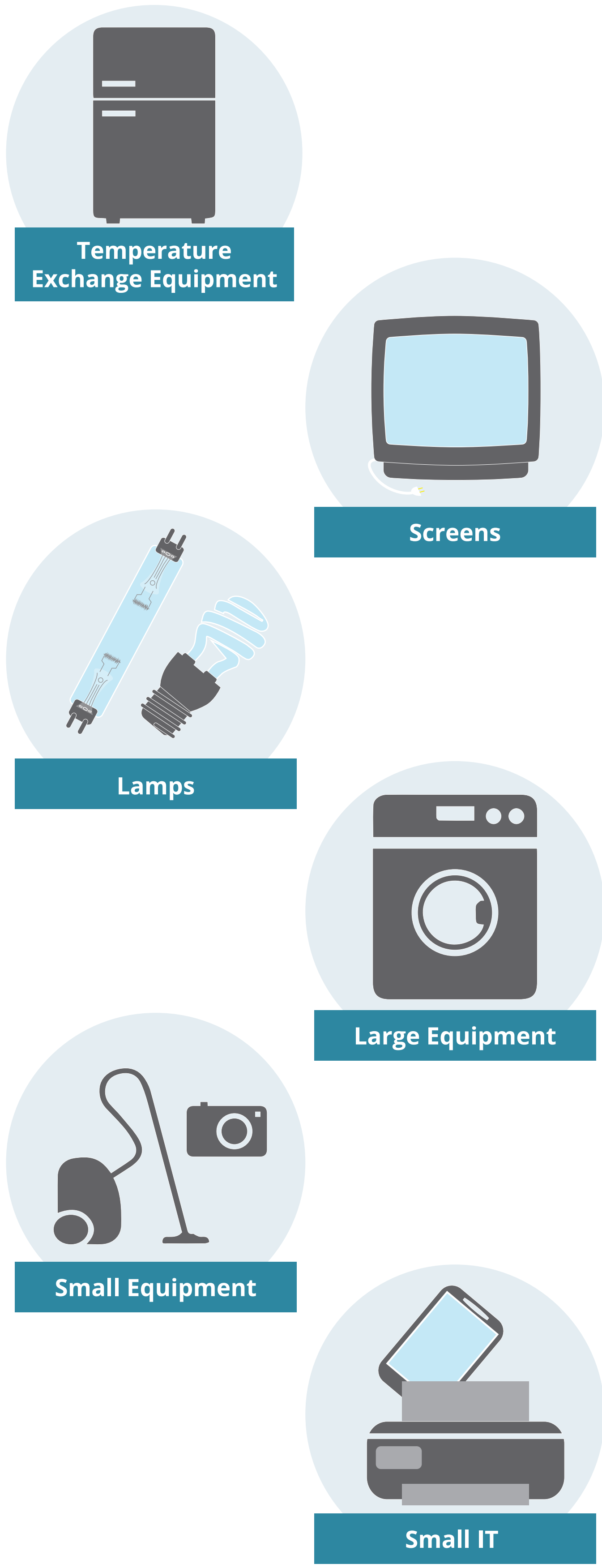
What is E-waste?

Electronic waste, or e-waste, refers to all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of re-use (Step Initiative 2014). E-waste is also referred to as WEEE (Waste Electrical and Electronic Equipment), electronic waste or e-scrap in different regions and under different circumstances in the world. It includes a wide range of products – almost any household or business item with circuitry or electrical components with power or battery supply. In this methodology, defined by the Partnership on Measuring ICT for Development (Baldé et al., 2015a), the definition of e-waste is very broad. It covers six waste categories:

1. Temperature exchange equipment, more commonly referred to as cooling and freezing equipment. Typical equipment includes refrigerators, freezers, air conditioners, heat pumps.
2. Screens, monitors. Typical equipment includes televisions, monitors, laptops, notebooks, and tablets.
3. Lamps. Typical equipment includes fluorescent lamps, high intensity discharge lamps, and LED lamps.
4. Large equipment. Typical equipment includes washing machines, clothes dryers, dish-washing machines, electric stoves, large printing machines, copying equipment, and photovoltaic panels.
5. Small equipment. Typical equipment includes vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, electrical and electronic toys, small electrical and electronic tools, small medical devices, small monitoring and control instruments.
6. Small IT and telecommunication equipment. Typical equipment includes mobile phones, Global Positioning Systems (GPS), pocket calculators, routers, personal computers, printers, telephones.

Each product of the six e-waste categories has a different lifetime profile, which means that each category has different waste quantities, economic values, as well as potential environmental and health impacts, if recycled inappropriately. Consequently, the collection and logistical processes and recycling technology differ for each category, in the same way as the consumers' attitudes when disposing of the electrical and electronic equipment also vary.

Illustration 1.1: The six e-waste categories



Source: Baldé et al., 2015a

Chapter 2

E-waste and Its Relation to the Sustainable Development Goals

In September 2015, the United Nations and all Member States adopted the ambitious 2030 Agenda for Sustainable Development. This new agenda identified 17 Sustainable Development Goals (SDGs) and 169 targets to end poverty, protect the planet, and ensure prosperity for all over the next 15 years. Increasing levels of e-waste, and improper and unsafe treatment, and disposal through incineration or in landfills pose significant challenges to the environment and human health, and to the achievement of the SGDs.

A better understanding and more data on e-waste will contribute to the achievement of several goals of the 2030 Agenda for Sustainable Development. It will help address the SDGs related to environmental protection and health. It will also address employment and economic growth, since the sound management of e-waste can create new areas of employment and drive entrepreneurship.

A better understanding and management of e-waste is closely linked to Goal 3 (Good health and Well-being), Goal 6 (Clean water and Sanitation), Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), Goal 14 (Life Below Water), and Goal 8 (Decent Work and Economic Growth).

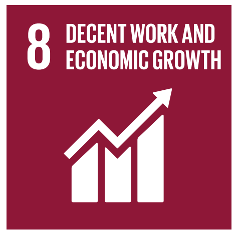
E-waste, when treated inadequately, poses serious health issues since it contains hazardous components, including contaminating air, water, and soil, and putting people's health at risk. Dismantling processes that do not utilize adequate means, facilities, and trained people pose additional threats to people and the planet. These issues are addressed in the following SDGs:

Target 3.9 refers to the reduction of the number of deaths and illnesses caused by hazardous chemicals and air, water, and soil pollution and contamination. Target 6.1 seeks to achieve universal and equitable access to safe and affordable drinking water for all, and Target 6.3 aims to reduce pollution, eliminate dumping, and minimize release of hazardous chemicals and materials. Goal 14 refers to marine pollution and the protection of the marine ecosystem (Targets 14.1 and 14.2).

Target 11.6 aims to reduce the adverse per capita environmental impact of cities, by paying special attention to air quality and to municipal and other waste management. Since over half of the world's population lives in cities, rapid urbanization requires new solutions to address rising environmental and human health risks, especially in densely populated areas. Most e-waste will be generated in cities and it is particularly important to properly manage e-waste in urban areas, improve collection and recycling rates, and to reduce the amount of e-waste that ends up in dumpsites. The move towards smart cities and the use of ICTs for waste management offer new and exciting opportunities.

Similarly, Target 12.4 aims to achieve the environmentally sound management of chemicals and all waste throughout the life cycle, in accordance with agreed international frameworks, and to significantly reduce their release into air, water, and soil in order to minimize their adverse impacts on human health and the environment.

Target 12.5 aims to substantially reduce waste generation through prevention, reduction, repair, recycling, and reuse. An increasing number of people on the planet are consuming growing amounts of goods, and it is critical to make production and consumption more sustainable by raising awareness levels of producers and consumers, specifically in the area of electrical and electronic equipment.



SDG Target 8.3 aims to promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity, and innovation, and to encourage the formalization and growth of micro-, small-, and medium-sized enterprises.

Target 8.8 calls for the protection of labour rights and promotes safe and secure working environments for all workers, including migrant workers, particularly women migrants, and those in precarious employment. The sound management of e-waste can create new employment and contribute to economic growth in the recycling and refurbishing sector. Now, e-waste is often processed in the informal sector, and many e-waste disposal and recycling jobs are unsafe and not protected by formal regulation (Brett et al. 2009; Leung, et al. 2008). It is therefore necessary for countries to formalize the environmentally sound management of e-waste and to take advantage of the business opportunities it offers.

Chapter 3

Information and Communication Technology (ICT) and EEE Consumption Trends

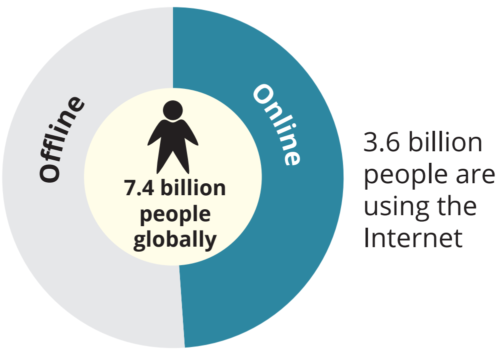
The global information society is growing at great speed. More and faster networks, and new applications and services delivered at increasingly high speeds, have brought new opportunities to many people, particularly in the areas of health, education, government, entertainment, and commerce. At the same time, higher levels of disposable income, urbanization, and industrialization in many developing countries are leading to growing amounts of electrical and electronic equipment, and consequently to e-waste.

Expanding Networks, More Internet Users, and Online Businesses

Mobile-cellular and broadband networks and services have expanded rapidly, and allow more people, especially in rural and previously unconnected areas, to have access to the internet.

- Some 3.6 billion people - close to half the world's population - are using the Internet.

Chart 3.1: Half the world's population is online



- The world counts 7.7 billion mobile-cellular subscriptions and 4.2 billion active mobile-broadband subscriptions[2].
- Over 80% of the world's population is covered by a mobile broadband signal.
- 54% of households have Internet access at home and 48% have a computer.

In parallel, an increasing number of enterprises have websites, receive orders over the internet, and cater to an online population. The United Nations Conference on Trade and Development (UNCTAD) estimates that in 2015:

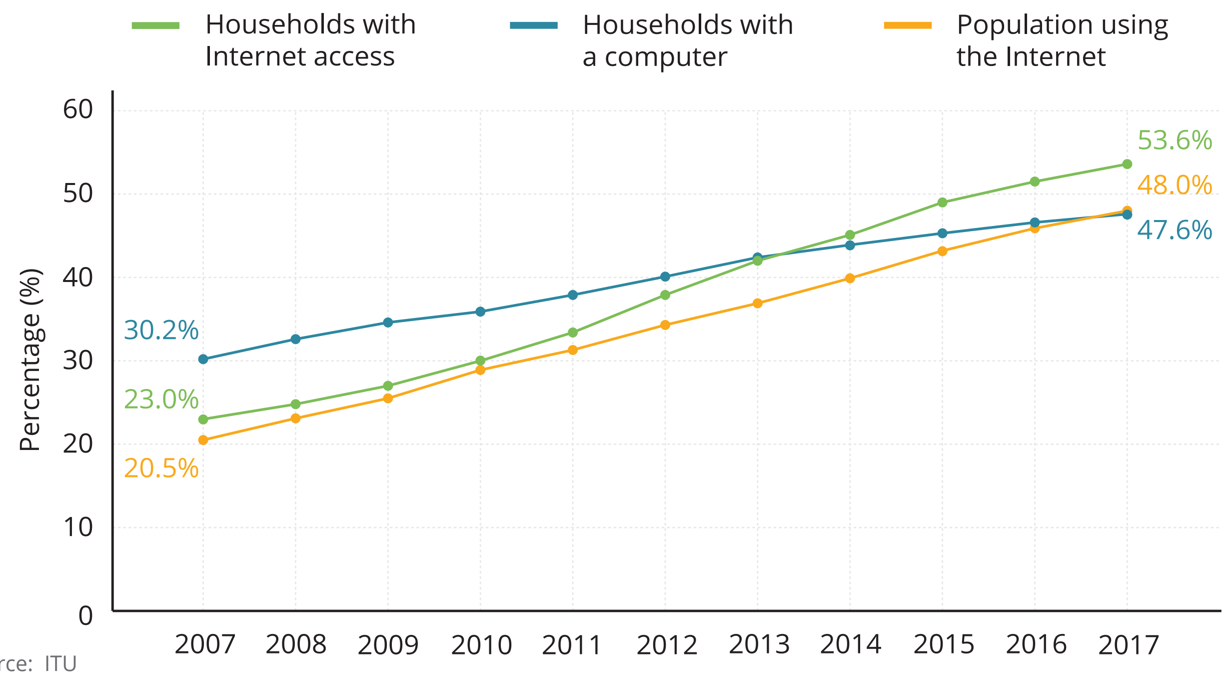
- The value of global business-to-business (B2B) e-commerce exceeded US$22 trillion and business-to-consumer (B2C) value accounted for about US$3 trillion.
- In the EU, on average 40% of large enterprises were receiving orders over the Internet.

Growth Rates of EEE

The consumption of EEE in general has also shown rapid growth over the period of 2000 to 2016.

This indicates that the emerging economies with a low Purchasing Power Parity (PPP) have shown the fastest annual growth rates in EEE consumption. The products that had the largest absolute growth of consumption in terms of weight were fridges, washing machines, electric furnaces, electric centralized heating units, and flat panel TVs. The demand for EEE goods, which for many people represents a higher standard of living, is expected to grow further.

Chart 3.2: Percentage of households with Internet access and a computer, and percentage of the population using the Internet, 2007-2017



Source: ITU

Table 3.1: Average annual growth rate of EEE per group of countries, by Purchasing Power Parity

Purchasing Power Parity range (USD/inh. in 2016)		Average growth rate per year
Highest PPP	> 34000	1.6%
High PPP	34000 - 15280	5.2%
Mid PPP	15280 - 6740	13%
Low PPP	6740 - 1700	23%
Lowest PPP	< 1700	15%

Over the same time period, some technologies became obsolete. The largest declines in sales were found for portable audio, portable video, the bulky cathode ray tube (CRT) monitors, and CRT televisions. This is because the technology is old and replaced by new technology. This is the case in the shift of the CRT monitors being replaced by flat panel displays. In some cases, a single device with single functionality is being replaced by items with multiple functionality, such as a mobile phone or laptop.

Prices Are Falling

Key factors for the success and spread of EEE and the Internet include a high degree of competition in the telecommunication market, technological advances, particularly in computing power and mobile broadband technologies, and decreases in the price of services and devices. Basic prepaid mobile-cellular services have especially become relatively affordable in the majority of countries, and prices of mobile-broadband services also continue to fall.

Illustration 3.1: ICT devices are becoming more affordable

At the same time, the price of IT equipment, such as computers, peripheral equipment, TVs, laptops, printers, and mobile handsets are dropping. Lower handset prices in developing regions are the result of manufacturers' efforts to offer increasingly affordable entry-level smartphones for low-income users. Many budget, but still smart phones, are on sale for less than USD 200, and producers in India and China are promising even lower prices (ITU 2016). This means that more people will be able to afford purchasing new equipment, and that more equipment will eventually be discarded.

Other Trends Driving the Generation of E-Waste

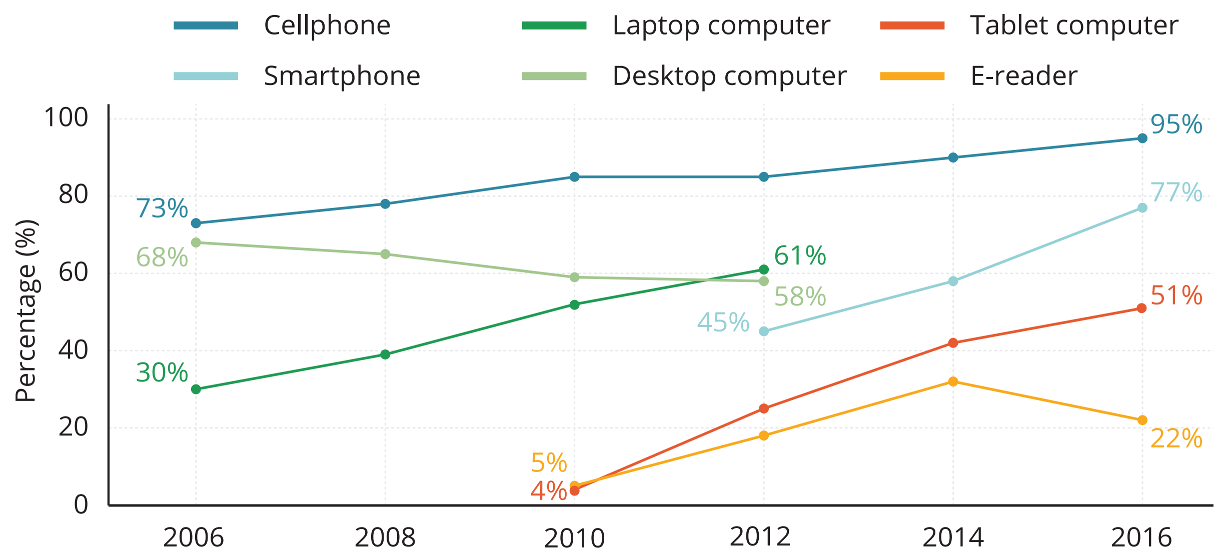
There are a number of other trends that are driving the generation of e-waste. These include growing multiple device ownership, the tendency to electrify non-electrical equipment, growth in cloud computing services, a growing number of data centres, and shorter replacement cycles.

First, more people own more connected devices. In many countries, people own more than one phone and the number of people who own multiple devices, including phones, laptops, and e-readers, is growing. By 2016, almost every person in the United States owned a phone and every second person also owned a tablet computer. Close to 25% also owned an e-book reader (Chart 3.2). Between 2012 and 2015, the number of Americans who owned a smartphone, a computer, and a tablet doubled to 36% of adults (Anderson 2015).

Although cloud computing trends can lead to fewer devices because all services can be accessed from one device, more cloud computing also means more data centres and more e-waste. The amount of traffic, in particular from cloud services, and the number of data centres are increasing and will continue to grow in the coming years, according to the Cisco Global Cloud Index (GCI, Chart 3.4).

Illustration 3.2: Many people own multiple devices

Chart 3.3: Pecentage of American adults who own different ICT devices

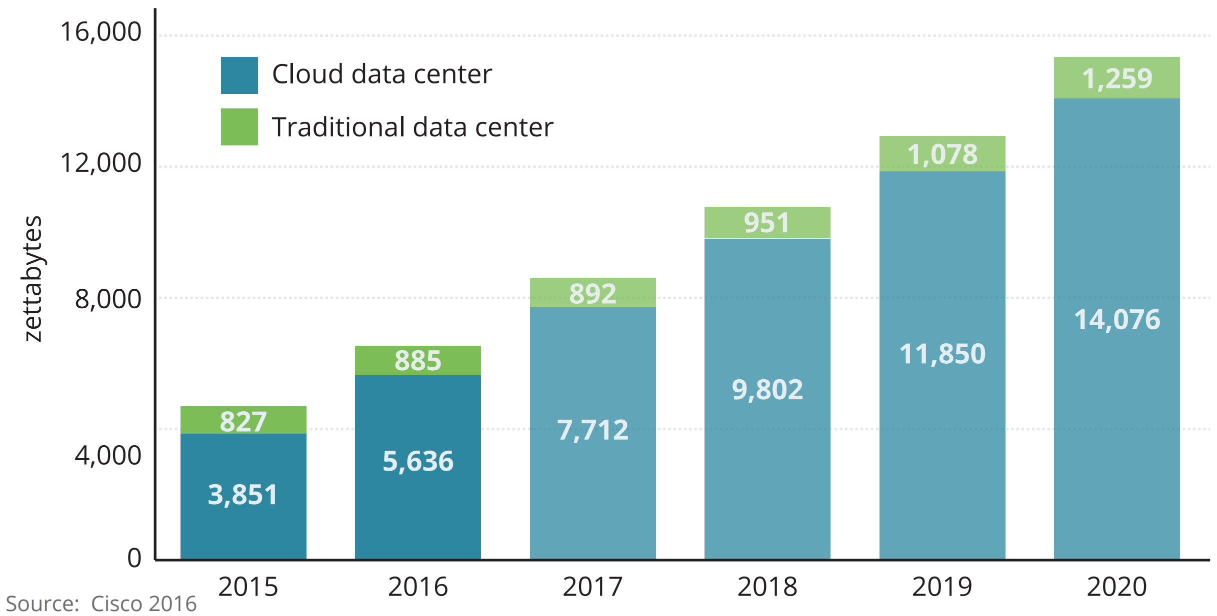


Source: Pew Research Center 2016

The amount of obsolete equipment is further driven by relatively short replacement cycles. Since technologies change quickly, many users change device, such as their mobile phone, regularly and often before it actually breaks. While the smartphone lifecycle is used as a measure of how close the average consumer's device is to the technical state–of-the-art version, it is also an indication of the growing amount of e-waste. Although data collected by Kantar World Panel indicates that between 2013 and 2015, smartphone users started to delay their phone upgrades, the average smartphone lifecycle in the USA, China, and major EU economies does not usually exceed 18 months to 2 years (Table 3.2).

Smartphones are not the only devices that many consumers change frequently. To benefit from the latest upgrades, higher speeds, and the latest technologies, consumers and businesses regularly change their laptops, PCs, routers, TV sets, and other devices. In many cases, older equipment is replaced even if it is not broken or obsolete, but simply regarded as outdated. In the recent switchover, or conversion, from analogue to digital TV broadcasting, for example, many TV sets were unnecessarily discarded. While analogue televisions can receive digital signals simply by using a digital box, many consumers chose to upgrade to new TVs, and the switchover had an important environmental impact that left the world with a mountain of Carbon-Ray-Tube TVs (ITU 2015; ITU 2017a)[3].

Chart 3.4: Global data center traffic in zettabytes



Source: Cisco 2016

Table 3.2: Smartphone life cycles by countries, in months, for 2013 - 2015

	USA	China	EU5	France	Germany	Great Britain	Italy	Spain
2015	21.6	19.5	20.4	21.6	18.8	23.5	17.7	20.0
2014	20.9	21.8	19.5	19.4	18.2	22.0	18.7	18.2
2013	20.5	18.6	18.3	18.0	17.1	20.0	18.6	16.6

Source: Kantar World Panel 2016

Additionally, there has been much debate and criticism of the growing 'throwaway society', characterized by consumerism and the trend to throw away and buy something new rather than keep and repair. A growing global middle-class with higher incomes often prefers to purchase a new product or device, since in many cases this holds a status symbol and provides social recognition. Some users may decide to buy new products to avoid any hassle due to warranty and data security issues of repaired products.

There are many efforts underway to limit the amount of obsolete devices and equipment and to reduce the amount of energy needed for EEE and especially ICT devices. This includes the development of universal power adapters and chargers (ITU 2012; ITU 2016b; ITU 2017b). The amount of e-waste will continue to grow, though, and clear policies, solutions for recycling, and better data is needed.

Illustration 3.3: Users change their devices more often to keep up with technological changes

Box 3.1: How Universal Power Adapters and Chargers Reduce E-waste

One million tons of external power supplies are manufactured each year. This highlights the importance of efforts to reduce the number of such power supplies, and to make them more sustainable. In this regard, environmentally friendly standards for power adapters by the International Telecommunication Union (ITU) are an important step towards reducing greenhouse gas emissions, increasing energy efficiency, and reducing the amount of e-waste generation. In one of its latest eco-standards, ITU identifies specific principles for the eco-design of laptop chargers to reduce power consumptions, and to make them compatible with more devices. This will help increase a charger's lifetime and reduce the amount of e-waste resulting from their disposal.[4]

Source: ITU 2012 and ITU 2016b

Chapter 4

Availability of International E-waste Statistics

At the international level, monitoring of e-waste quantities is essential to track developments, set and monitor targets, and identify policies. Statistics should be collected at the international level and organised for comparison to ensure that data is frequently updated, published, and interpreted. Despite growing international interest, very little official statistics can be used to date. Only 41 countries in the world collect statistics on e-waste.

Measuring e-waste is an important step towards addressing the e-waste challenge. Statistics help to evaluate developments over time, set and assess targets, and identify best practices of policies. Better e-waste data will help to minimize its generation, prevent illegal dumping and emissions, promote recycling, and create jobs in the reuse, refurbishment, and recycling sectors.

The International Telecommunication Union (ITU), the UN specialized agency for information and communication technologies, set a target in the Connect 2020 agenda to reduce the volume of redundant e-waste by 50% by 2020. Through the Connect 2020 Agenda, ITU Member States committed to work towards the shared vision of "an information society, empowered by the interconnected world, where telecommunication/ICT enables and accelerates socially, economically, and environmentally sustainable growth and development for everyone." All stakeholders were invited to contribute with their initiatives, experience, qualifications, and expertise to successfully implement the Connect 2020 Agenda.

In 2015, the Partnership for Measuring ICT for Development (Baldé et al., 2015a)[5] published a document of guidelines on e-waste statistics. These guidelines identified a set of indicators to track e-waste that included methodologies and classifications. The guidelines benefitted from the broader input of the Partnership for Measuring ICT for Development and other environment statistics experts.

So far, only 41 countries in the world collect international statistics on e-waste. Currently, only Europe has regular and harmonized statistics on e-waste. This includes the EU countries, plus Iceland, Liechtenstein, Norway, and Switzerland. In order to improve regional coverage of e-waste statistics, the UNU has done policy work and joined forces with various international agencies that have contact with Member States throughout the world. Upon the request of UNU to improve the regional data coverage, United Nations Economic Commission for Europe (UNECE, Joint Task Force on Environmental Indicators, CIS countries) and Organisation for Economic Co-operation and Development (OECD, Working Party on Environmental Information, non-EU OECD Member States) sent out a pilot questionnaire in 2015. In 2017, United Nations Statistics Division (UNSD, Environment Statistics Section) sent out a pilot questionnaire to 40 countries. The results of the OECD, UNSD, and UNECE pilot questionnaire were used to compile the global totals on e-waste collection and recycling in this report.

Illustration 4.1: Response to pilot questionnaires carried out by OECD, UNECE, and UNSD.

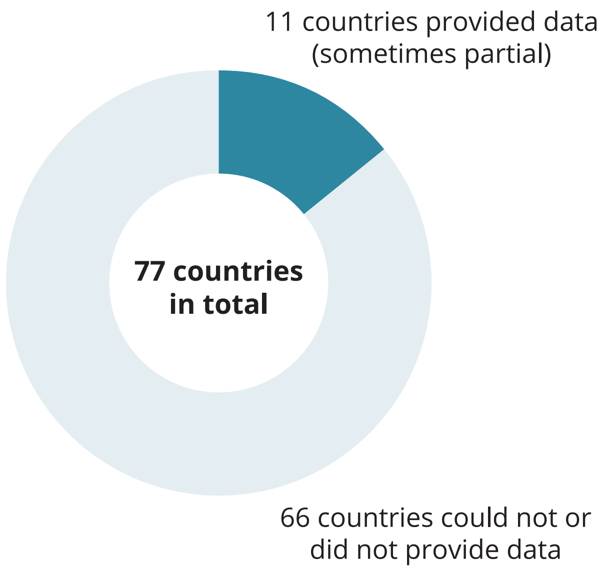


Illustration 4.2: Why e-waste statistics are needed

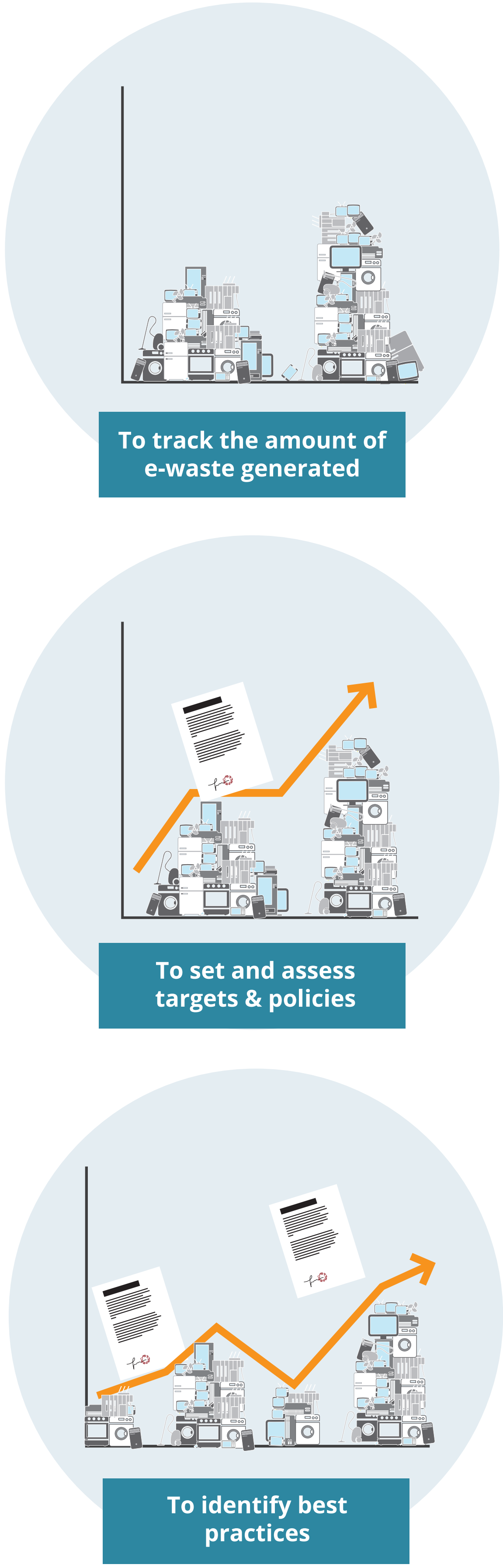
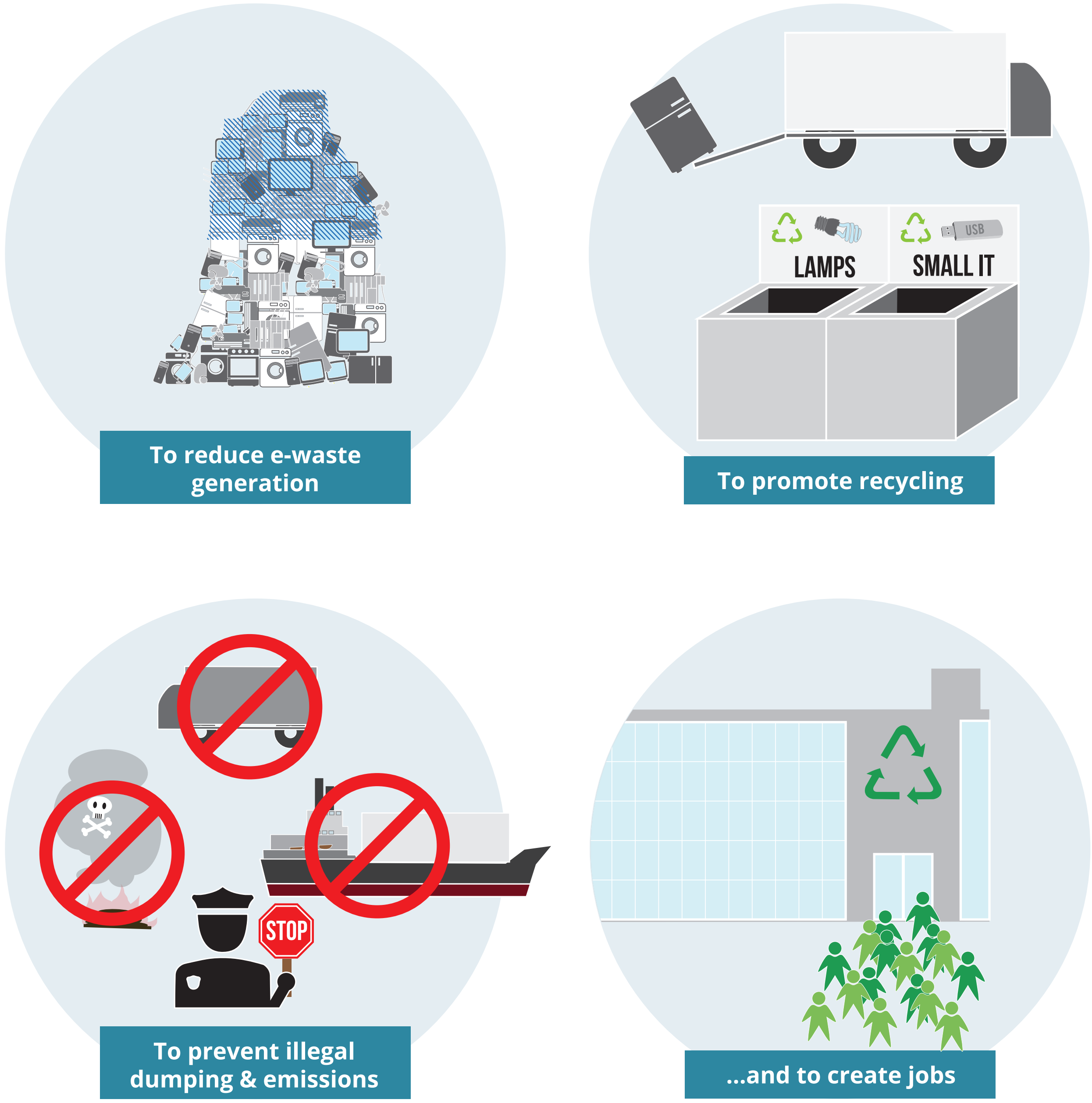


Illustration 4.3: What better e-waste data is used for



UNECE

Since February 2016, UNECE runs the Secretariat of the Task Force on Waste Statistics, which was established under the auspices of the Conference of European Statisticians. The main objective of the Task Force is to develop a conceptual framework on waste statistics, which should be the future basis for a systematic production of statistics on waste, and to help solve the most important conceptual problems that currently exist in waste data collections. This framework will also provide the foundation for further integration of important emerging issues, such as e-waste, into official statistics.

United Nations Statistics Division

In 2017, following the request of UNU, UNSD conducted a pilot questionnaire on e-waste statistics. UNSD selected a sample of 40 countries based on their communications with UNSD for the regular biennial UNSD/UNEP Questionnaire on Environment Statistics, and their English language proficiency, since the pilot was only administered in English. Given the fact that an assessment of the data provided by countries to UNSD via this pilot in 2017 is still pending, variables on e-waste are to be considered included in the regular biennial UNSD/UNEP Questionnaire on Environment Statistics. If data becomes available in the near future, they will be disseminated on UNSD's website.

OECD

E-waste and its management are integrated in the OECD programme of work on waste, material resources, and circular economy. They are covered in several OECD guidance documents, including on Extended Producer Responsibility, Environmentally Sound Management of Waste, and Strategic Waste Prevention. Data on e-waste has also long been covered in the OECD questionnaire on the state of the environment, although in a basic way (i.e. only the generation of e-waste). They are used in the OECD country Environmental Performance Reviews (EPRs) when an in-depth evaluation of waste and materials management is carried out. Questionnaires were sent to the OECD countries other than those covered by EU. Although the response rate to the 2015 ad-hoc data request sent to the WPEI in partnership with UNU was low and comparability across countries weak, the data compiled helped fill some gaps and was used in recent EPRs. However, further efforts are required to produce data of better quality, aligned with standardized definitions and concepts, and with a better understanding of recovery operations. To support the further development of e-waste statistics, the OECD intends to regularly update and validate related data with its member countries in cooperation with the global e-waste statistics partnership.

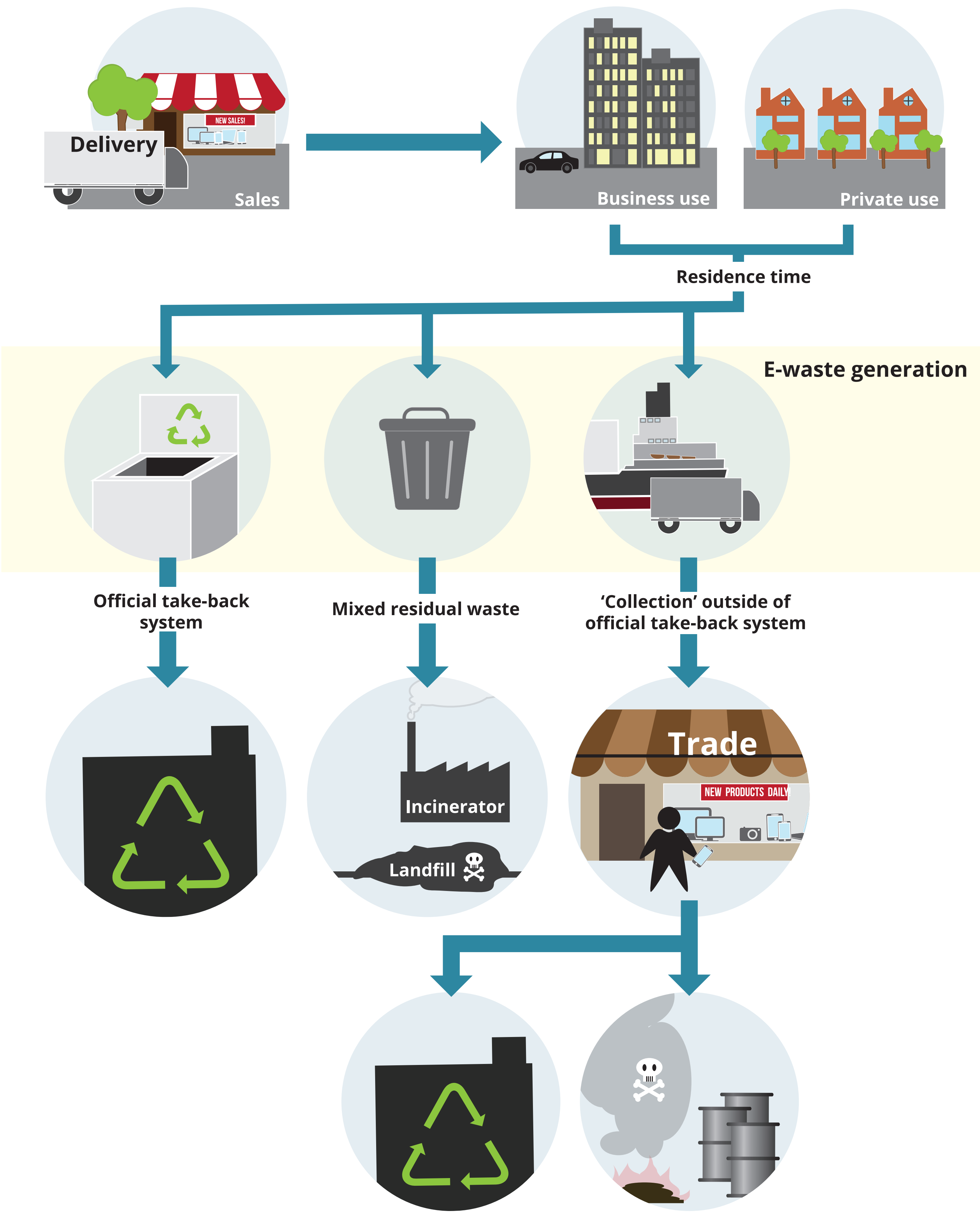
To address continuity and improve the quality of global data on e-waste statistics, the International Telecommunication Union, the United Nations University, and the International Solid Waste Association have joined forces to create the Global E-waste Statistics Partnership. Its main objective is to improve, collect, analyse, and publish worldwide e-waste statistics. Statistics on e-waste and other important types of waste (such as food waste, textiles waste, etc.) should gradually become part of official statistics. This initiative endeavours to coordinate its work closely with other ongoing work in the area of e-waste statistics, and to work closely with other partners. It will make an important contribution to addressing the global e-waste challenges by raising awareness, encouraging more governments to track e-waste, and by carrying out workshops to build national and regional capacity.

The long-term goal is to establish an organizational structure to ensure that there is a sustainable mechanism within the UN that collects and validates statistics on used electronics/e-waste collection and recycling, and the import and export of used electronics. To this end, and to help facilitate data collection at the national level, UNU is currently developing a tool kit that countries can use to collect and share information about used electronic imports and exports, which will be the basis for statistical capacity-building workshops.

Chapter 5

Standards and Methodologies to Measure E-waste

Illustration 5.1: Life cycle of EEE into e-waste, and the most common e-waste management scenarios



The most common disposal scenarios around the world are measured in a standardized framework developed by the Partnership on Measuring ICT for Development (Baldé et al., 2015a), which captures and measures the most essential features of the e-waste dynamics in a consistent manner. Four indicators have been identified and discussed in this publication:

Indicator 1: Total EEE Put on the Market

Indicator 2: Total E-waste Generated

Indicator 3: E-waste Officially Collected and Recycled

Indicator 4: E-waste Collection Rate

Additional data was gathered for populations that are covered under national e-waste laws, and for e-waste disposed of in waste bins.

In e-waste statistics, definitions and concepts help to classify e-waste, and tracing the flow from consumption to final disposal is central. Both are defined in a statistical measuring framework on e-waste as described by the Partnership of Measuring ICT for Development (Baldé et al., 2015a). The same concepts formed the basis for the first Global E-waste Monitor (Baldé et al., 2015b), and they are also used in the European Union as the common methodology to calculate the collection target of the recast EU-WEEE Directive (European Union, 2012).

5.1 Classifications for E-waste

For each electrical or electronic product, its original function, environmental relevancy, weight, size, and material composition differ considerably. Taking these differences into account, the categorization of EEE, and thus e-waste, can be grouped into roughly 54 homogeneous product types, referred to as the UNU-KEYS (See Annex 1). Each UNU-KEY corresponds to one or more codes in The Harmonized Commodity Description and Coding System (HS). This detailed correspondence table is published in the statistical guidelines from the Partnership on Measuring ICT for Development (Baldé et al., 2015a). The 54 UNU-KEYS can be grouped into six and ten categories of the recast of the WEEE Directive (See Annex 1 for the respective categories and links). The six categories of the WEEE Directive reflect the main groups in which e-waste is managed after collection, and will be used in this publication. Those are:

- Temperature exchange equipment.
- Screens, monitors.
- Lamps.
- Large equipment.
- Small equipment.
- Small IT and telecommunication equipment.

5.2 Measuring Framework of E-waste Statistics

The main lifecycle of EEE into e-waste, and the waste management that generally occurs, can be summarized into four distinct phases. The four phases describe market entry, stock, e-waste generated, and waste management.

Phase 1: Market Entry

The first phase occurs when an EEE product is sold to a consumer or a business and enters the market. Data can come from statistics on sales from a national e-waste registry for compliance with the Extended Producer Responsibility, or if not available, it can be measured with the 'apparent consumption method[6].

Phase 2: Stock

After a product has been sold, it enters a household, enterprise, or institution, called "the stock phase". The stock of EEE can be determined using household or business surveys on a national level. If that data is not available, it can be calculated using the sales information and the time the equipment spends in the stock phase, called the "product's residence time". This residence time includes the dormant time in sheds and exchange of second-hand equipment between households and businesses within the country. When a second-hand functioning product is exported, the 'residence time' in that country also comes to an end, and the product enters the stock phase market again in another country.

Phase 3: E-waste Generated

The third phase is when the product becomes obsolete to its final owner, is disposed of, and turns to waste, referred to as "e-waste generated". It is the annual supply of domestically generated e-waste prior to collection, without imports of externally generated EEE waste. The outcomes of e-waste generated are an important indicator for e-waste statistics.

Phase 4: E-waste Management

The e-waste generated is usually collected in either one of the four following scenarios:

E-waste Collection Scenario 1: The Official Take-Back System

In this scenario, usually under the requirement of national e-waste legislation, e-waste is collected by designated organizations, producers, and/or the government. This happens via retailers, municipal collection points, and/or pick-up services. The final destination for the e-waste that's collected is a state-of-the-art treatment facility, which recovers the valuable materials in an environmentally-sound way. This is the ideal scenario, aimed to reduce the environmental impact.

Typically, data is collected from the treatment facility, and there are laws that enable monitoring with recycling and collection targets. To assess its progress, data on the amount of domestic e-waste collected and recycled was gathered from countries.

E-waste Collection Scenario 2: Mixed Residual Waste

In this scenario, consumers directly dispose of e-waste through normal dustbins with other types of household waste. As a consequence, the disposed of e-waste is then treated with the regular mixed-waste from households. Depending on the region, it can be either sent to a landfill or municipal solid waste incinerator with a low chance of separation prior to its final destination. Neither option is regarded as an appropriate technique to treat e-waste because they lead to resource loss, and have the potential to negatively impact the environment. Landfilling leads to toxins leaching into the environment and incineration leads to emissions into the air. This disposal scenario exists in both developed and developing countries. Products commonly thrown away in dustbins include small equipment, small IT equipment, and lamps.

Scenarios 3+4: The Collection Outside the Official Take-Back System

The collection outside the official take-back system and management of e-waste is very different in countries that have developed waste management practices for their municipal waste recycling versus countries that have not. As a rule of thumb, this is divided into developed and developing countries by the Basel convention. Therefore, two scenarios are described: for countries that have a developed waste management system, and for countries that do not.

Countries with Developed Waste Management

In countries that have developed waste management laws, e-waste is collected by individual waste dealers or companies and then traded through various channels. Possible destinations for e-waste in this scenario include metal recycling, plastic recycling, specialized e-waste recycling, and also exportation.

To avoid double counting, e-waste handled in this scenario is not reported to the official take-back system (Scenario 1). E-waste categories typically handled by informal collection are temperature exchange equipment, large equipment, and IT products.

In this scenario, e-waste is often not treated in a specialized recycling facility for e-waste management, and there is the potential for e-waste to be shipped to developing countries.

Countries With No Developed Waste Management Infrastructure

In most developing countries, there is an enormous number of self-employed people who are engaged in the collection and recycling of e-waste. They usually work door-to-door to buy e-waste from consumers at home, and then sell it to be refurbished and recycled. These types of informal collection activities provide the basic means for many unskilled workers to make a living. Apart from the collection of domestically generated e-waste, the domestic demand for imported, inexpensive second-hand goods and secondary materials leads to the import of used EEE or e-waste from developed countries.

After informal collection, when electronic products do not have any reuse value, they are mostly recycled through "backyard recycling" or substandard methods, which can cause severe damage to the environment and human health. Such substandard treatment techniques include open burning to extract metals, acid leaching for precious metals, unprotected melting of plastics, and direct dumping of hazardous residuals. The lacks of legislation, treatment standards, environmental protection measures, and recycling infrastructure are the main reasons that e-waste is recycled in a crude manner.

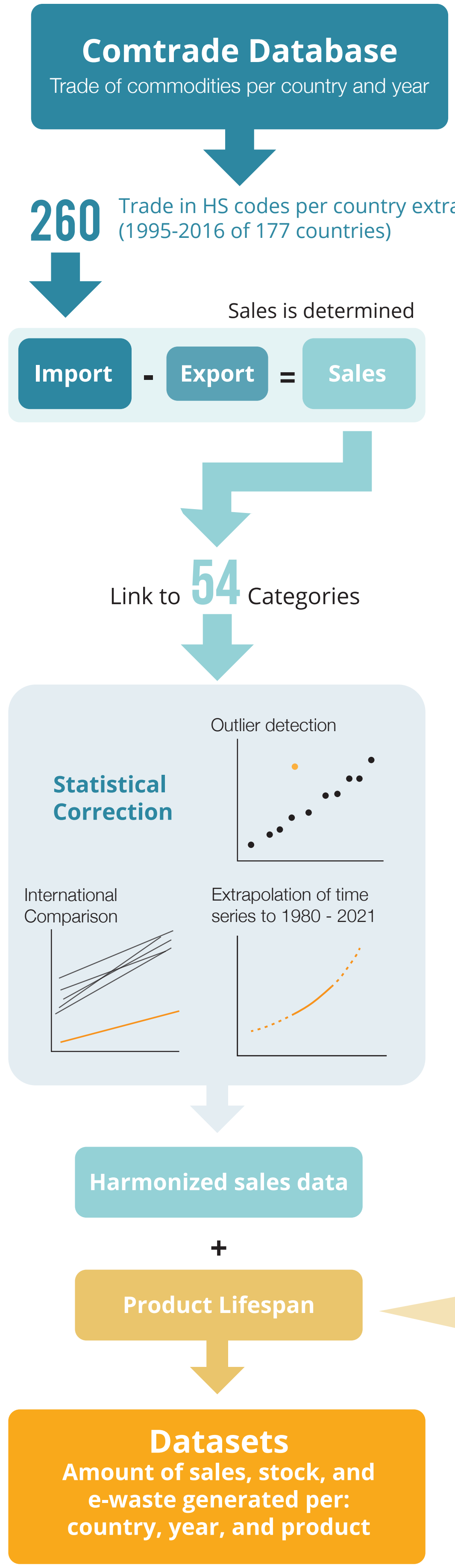
5.3 Data Sources Used for the Data in this Report

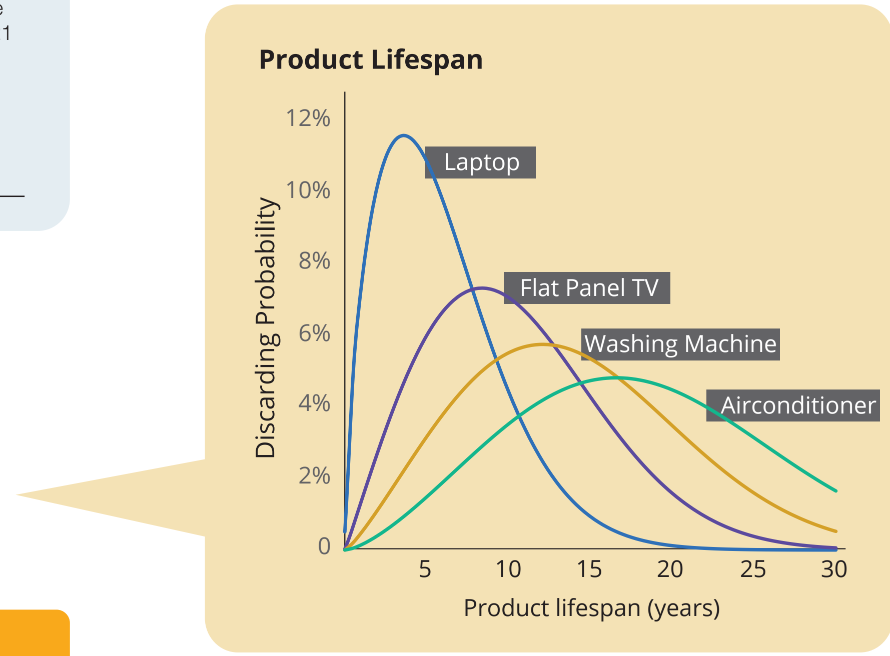
Calculation of Sales, E-waste Generated, and Stocks

Nowadays, there are no harmonized datasets available for sales at a global level that cover all countries in the world over a period of more than a decade. Thus, the apparent consumption method has been used in this report to calculate sales, as it provided the highest quality of market entry data currently available. The calculation of e-waste generated is based on empirical data from the apparent consumption method, a sales-lifespan model. In this model, lifespan data for each product is subtracted from the sales (using a Weibull function) to calculate the e-waste generated. The input data, modelling steps, and statistical routines are published in the open source script on github (https://github.com/Statistics-Netherlands/wot-world). The data in this report was obtained and treated using the following steps:

1. Selecting the relevant codes that describe EEE in the Harmonized Commodity Description and Coding System (HS)[7]. The product scope is published in the guidelines on e-waste statistics (Baldé et al. 2015a).
2. Extracting the statistical data on imports and exports from the UN Comtrade database. This was done for 177 countries, 260 HS codes for a time series of 1995 to 2016. Countries have then been classified into five groups according to the Purchasing Power Parity[8] (PPP). 1. This procedure has been repeated for each year, since the Country's PPP changes over the years, especially for developing countries. This was useful to make statistics comparable between countries, and to calculate trends between groups. A specific number of countries was used to for each group:
   - Group 1: highest PPP (higher than 34000 USD/inh in 2016): 40 countries

Illustration 5.2: Methodology for the calculation of sales, e-waste generated, and stocks





• Group 2: high PPP (34000 – 15280 USD/inh in 2016): 43 countries

• Group 3: mid PPP (15280 – 6740 USD/inh in 2016): 43 countries

• Group 4: low PPP (6740 – 1700 USD/inh in 2016): 46 countries

• Group 5: lowest PPP (lower than 1700 USD/inh in 2016): 13 countries

3. For the European Union, the international trade statistical data was extracted from Eurostat in the eight-digit combined nomenclature (CN) codes. Domestic production data was also extracted from Eurostat.

4. Converting the units to weight using the average weight data per appliance type. The average weights are published in the previously mentioned github publication.

5. Calculating the weight of sales for 54 grouped product categories (UNU-KEYs, see Annex 1) by using the apparent consumption approach: Sales = Import – Export. For 28 EU Member States: Sales = Domestic Production + Import – Export was used (European Commission, 2017). In this report, outcomes for countries other than EU-28 are not available for UNU-Keys 0002 (Photovoltaic Panels), 0502 (Compact Fluorescent Lamps) and 0505 (Led Lamps) because data was not available in UN Comtrade database.

6. Performing automatic corrections for outliers on the sales data. This is needed to detect values that were too low (due to the lack of domestic production data in some countries where domestic production is relatively large) or too high (due to misreporting of codes or units). Those detected entries are replaced with more realistic sales values either from the time series of the origin country or from comparable countries. These statistical routines lead to a harmonized dataset with a similar scope and consistent sales for a country based on their own trade statistics. The steps are published in the previously mentioned github publication.

7. Performing manual corrections resulting from the analysis of the automatic corrections. This is needed to correct unreliable data using knowledge of the market. For instance, CRT TVs have not been sold in recent years.

8. Extending the time series of sales. Past sales are calculated back to 1980 based on the trends of the available data and the market entry of the appliance. Future sales are predicted until 2021 using sophisticated extrapolation methods, the principle takes into account the ratio between the sales and the PPP per county, and uses that ratio to estimate the sales with the forecast of the PPP from the World Economic Outlook from the IMF (IMF, 2017).

9. Determining the e-waste generated by country by using the sales and lifespan distributions. Lifespan data is obtained from the 28 EU Member States using the Weibull distribution (Magalini et al. 2014; Baldé et al. 2015a). The residence times of each product is ideally determined empirically per product per type of country. At this stage, only harmonized European residence times of EEE were available from extensive studies performed for the EU, and were found to be quite homogeneous across Europe, leading to a ±10% deviation in final outcomes (Magalini et al. 2014). Due to the absence of data, it was assumed that the higher residence times per product in the EU were approximately applicable for non-EU countries as well. In some cases, this would lead to an overestimation, since a product could last longer in developing countries than in developed countries because people repair products more often. However, it can also lead to an underestimation, since the quality of products is often lower in developing countries because reused equipment or more cheaply produced versions that don't last as long might enter the domestic market. Deviations in final outcomes for some countries may be also caused by inaccuracies in the sales data or by the shortening or extension of the life span of products. In the latter case, the actual life span might be longer than what is estimated because products are stored at home for a longer period, or because items are sold as second-hand goods in other countries. But in general, it is assumed that this process leads to estimates that are relatively accurate.

10. Determining the stock quantities as the difference between the historical sales and the e-waste generated over the years.

The full overview of the methodology is published for the EU in R programming language. The whole methodology is stored in the scripts, which ensures transparency of the calculations performed (Van Straalen, Roskam and Baldé, 2016). For the global calculations, the methodology is also published on github (Van Straalen, Forti and Baldé, 2017). The method differed slightly from the previous Global E-waste Monitor (Baldé et al., 2015b). In here, both the methodology and the statistical calculations have been improved and updated data sources have been used; therefore the presented results are slightly different than in the previous Global E-waste Monitor.

E-waste in Waste Bins

The source data for the calculations of the e-waste in waste bins was based on studies of residual waste that's available in the literature for various countries. The content of e-waste was determined from the sorting analysis studies. This data was the sample of that part of the analysis. In the sample group, 600 kilotons (kt) of e-waste was found in the residual waste (the sorting analysis studies taken into account are all referenced in the references section). This was on average 5.8% compared to the total e-waste generated. This average was then multiplied with the e-waste generated from the countries with a purchasing power higher than 15260 US$/inh (in 2016) that were not present in the sample.

Officially Collected Amounts of E-waste

For the EU, data on the collected and recycled e-waste was extracted from the Eurostat database for 30 countries. For 77 other countries in the world, data was collected from a pilot questionnaire that UNU conducted with UNECE, OECD, and UNSD. From those countries, only 11 countries could provide data, sometimes only partial data. If data was not available, relevant information was searched for in pre-existing literature. Data was collected from 58 countries in total, but the datasets were far from complete and harmonized. The publicly available data is summarized in Annex 2. Missing collection and recycling amounts from the countries that did not respond to the questionnaire, or did not receive a questionnaire, were left zero in the published totals on e-waste that was collected through the official take-back systems. The collection rates were calculated as the percentage of the e-waste collected (Annex 2) over the total e-waste generated in the reference country (Annex 3).

Unknown Flows

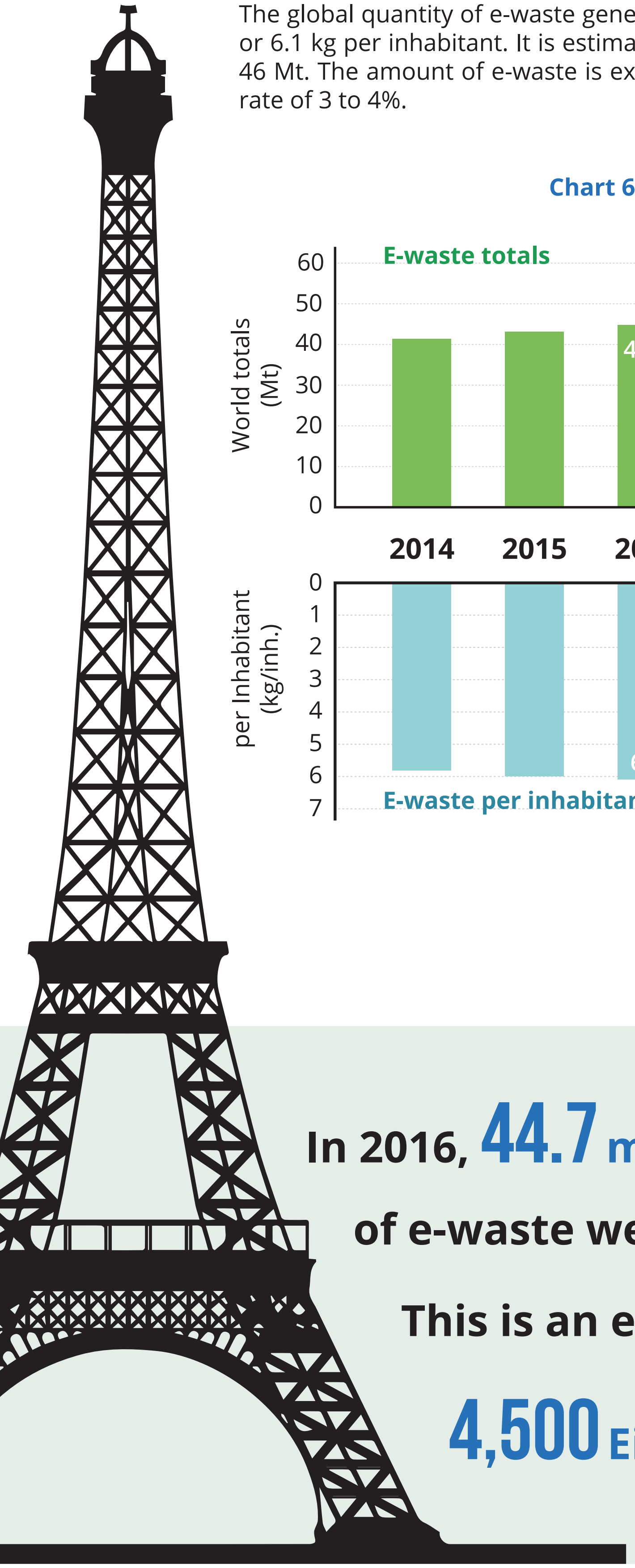
By subtracting the e-waste quantities officially collected and the e-waste found in waste bins from the total amount of e-waste generated, the quantities for which the treatment method is unknown were derived.

Population Exposure with National E-waste Legislation

The development of national e-waste policies was evaluated in this report to assess whether a country has had national e-waste management regulations in effect, until the end of 2016. Population data was obtained from the World Economic Outlook (IMF, 2017). The e-waste legislation status in countries were derived from a database that was kindly provided by C2P database[9]. The results are published in Annex 3.

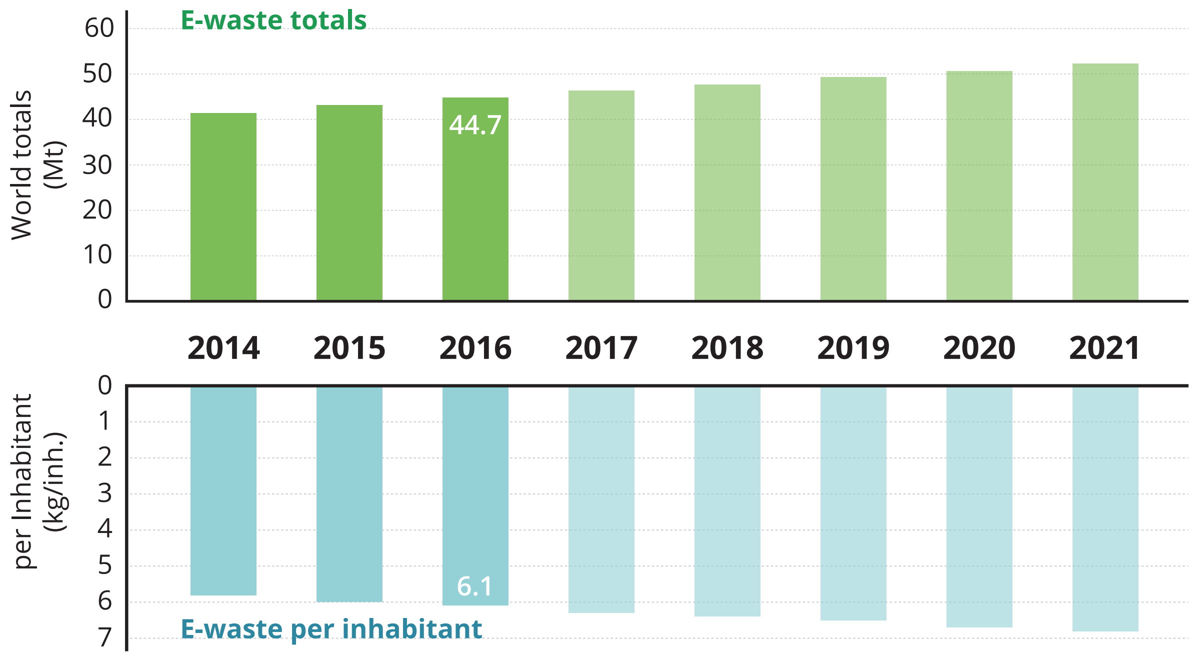
Chapter 6

Global E-waste Status and Trends



The global quantity of e-waste generation in 2016 was around 44.7 million metric tonnes (Mt), or 6.1 kg per inhabitant. It is estimated that in 2017, the world e-waste generation will exceed 46 Mt. The amount of e-waste is expected to grow to 52.2 Mt in 2021, with an annual growth rate of 3 to 4%.

Chart 6.1: Global e-waste generated



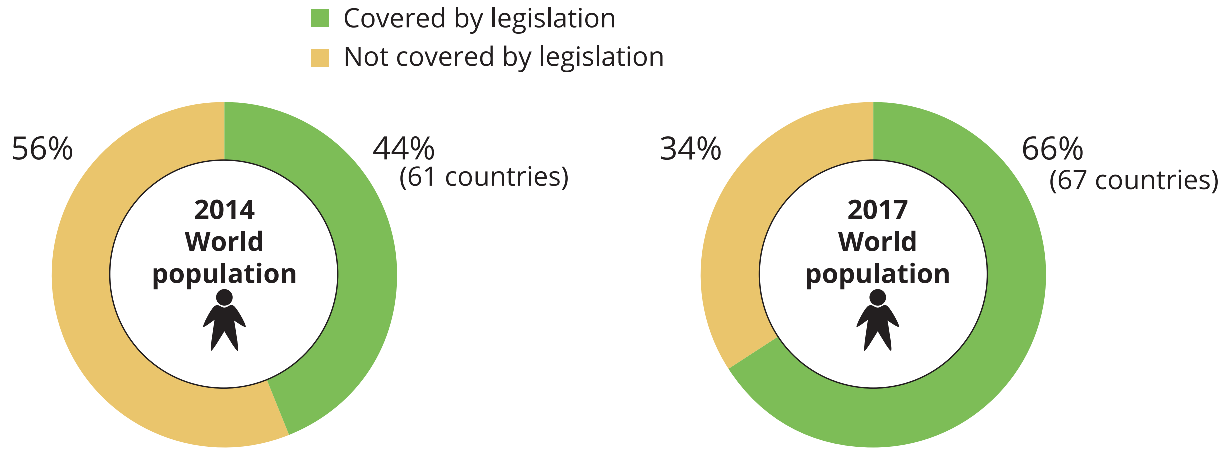
Note: 2017-2021 are estimates

In 2016, 44.7 million metric tonnes of e-waste were generated.

This is an equivalent of almost 4,500 Eiffel towers.

In January 2017, approximately 4.8 billion people were covered by national legislation, which is 66% (67 countries) of the world population. Improvements have been made since 2014, when only 44% (61 countries) was covered. However, national legislation does not always translate to concrete action. In addition, the scope of products covered and targeted by e-waste laws may differ from the more comprehensive scope of products used in this report.

Chart 6.2: World population (and number of countries) covered by e-waste legislation in 2014 and 2017



Under the requirements of the legislation, at least 8.9 Mt of e-waste was reported as formally collected and recycled by an official take-back system. It is estimated that a total of 1.7 Mt of e-waste ends up in waste bins from the richest countries in the world.

A large majority of the e-waste is managed outside the official take-back system. Those flows are not documented in a consistent or systematic manner. This, together with unreported data for the transboundary movement of e-waste (mostly from developed to developing countries), is likely to be the gap between e-waste generated that's officially collected and the e-waste in the waste bin. It is estimated that approximately 34.1 Mt of e-waste generated worldwide in 2016 is untraced and unreported.

Chart 6.3: Collection methods of e-waste in 2016

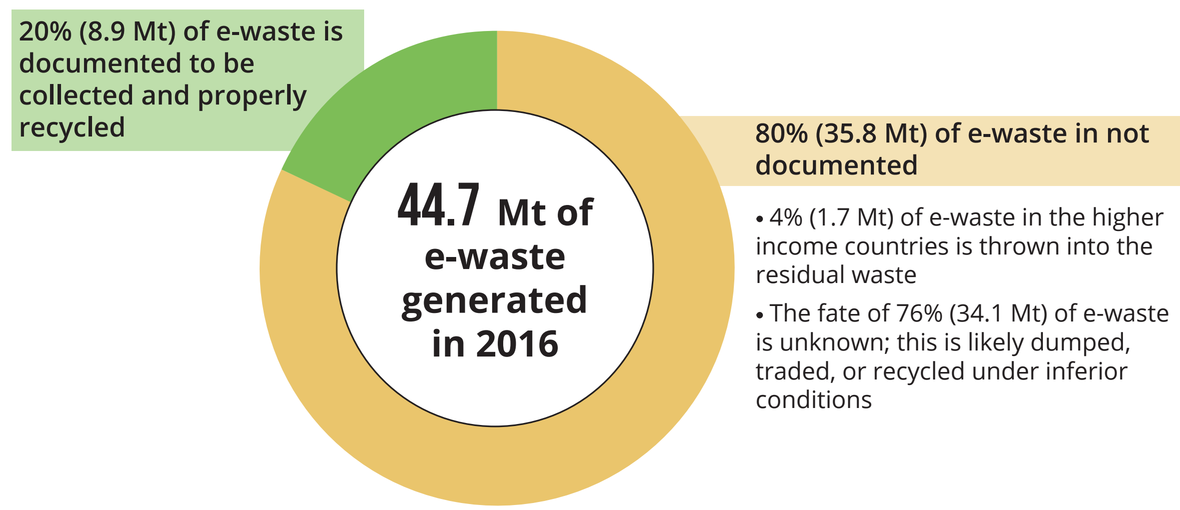
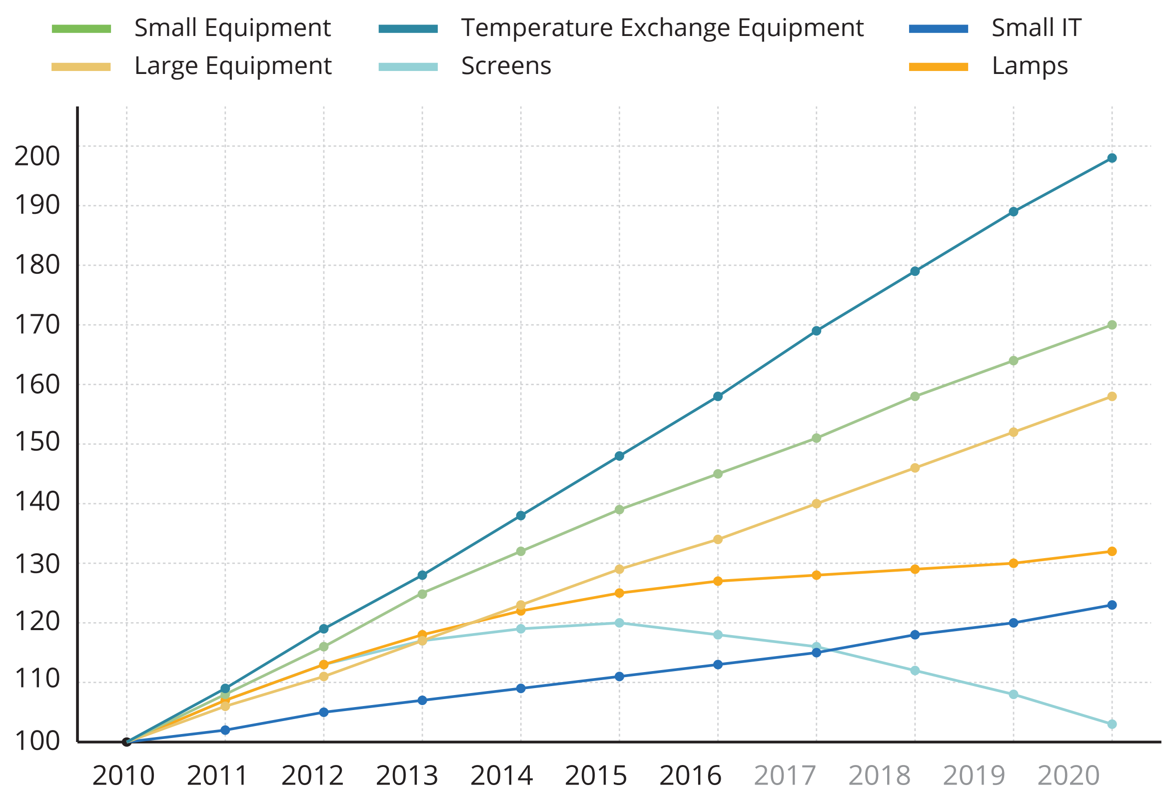
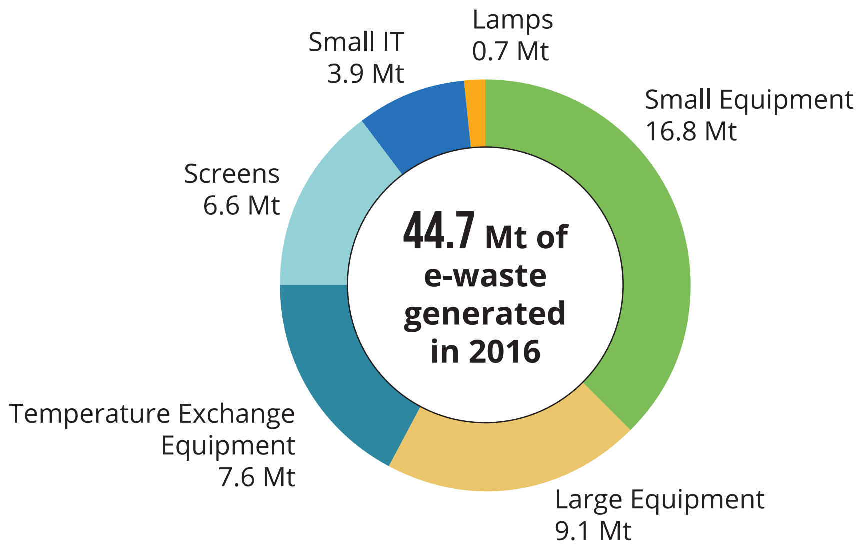


Chart 6.4: E-waste growth rates per category



Overall, the amount of e-waste generated per category is expected to grow in future years. However, the annual growth rate differs per category. It is expected that waste from temperature exchange equipment and small and large equipment will have the largest growth rates. As this is driven by growing consumption of those products, it will improve the living standards in parts of the world. It is expected that waste from screens will decline in the years to come, due to the replacement of heavy CRT screens to flat panel displays. IT waste is expected to grow less quickly, due to the effects of miniaturisation.

Chart 6.5: Estimates of e-waste totals per category in 2016



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). Lamps and Small IT represent a smaller share of the global quantity of e-waste generated in 2016, 0.7 Mt and 3.9 Mt respectively.

Table 6.1: E-waste generation and collection per continent

Indicator	Africa	Americas	Asia	Europe	Oceania
Countries in region	53	35	49	40	13
Population in region (millions)	1,174	977	4,364	738	39
WG (kg/inh)	1.9	11.6	4.2	16.6	17.3
Indication WG (Mt)	2.2	11.3	18.2	12.3	0.7
Documented to be collected and recycled (Mt)	0.004	1.9	2.7	4.3	0.04
Collection Rate (in region)	0%	17%	15%	35%	6%

In 2016, most of the e-waste was generated in Asia; around 18.2 Mt, or 4.2 kg per inhabitant. Approximately 2.7 Mt were documented to be collected and recycled.

Oceania generated the highest quantity for each inhabitant: 17.3 Kg/inh. However, Oceania generated the lowest quantity of e-waste in the world in 2016 at 0.7 Mt, and could only document 6% of its e-waste that was documented to be collected and recycled (43 kilotons (kt)). The European continent, including Russia, generated an amount of e-waste per inhabitant comparable to Oceania (16.6 Kg/inh). In total, the e-waste generation for the whole region is 12.3 Mt. Around 4.3 Mt of e-waste was collected to be recycled in Europe, showing the highest regional collection rate of 35% compared to e-waste generated. The lowest amount of e-waste per inhabitant was generated in Africa; 1.9 kg/inh. The whole continent generated 2.2 Mt of e-waste, and with current data, only 4 kt were documented as collected and recycled; this is less than 1%. In 2016, the Americas generated 11.3 Mt of e-waste: 7 Mt for North America, 3 Mt for South America, 1.2 Mt for Central America. The whole continent generated 11.6 kg/inh. of e-waste in 2016, and approximately 1.9 Mt of e-waste documented was collected and recycled.

The difference of e-waste generated in developed versus developing countries is quite large. The richest country in the world in 2016 generated an average of 19.6 kg/inh, whereas the poorest generated only 0.6 kg/inh.

Chapter 7

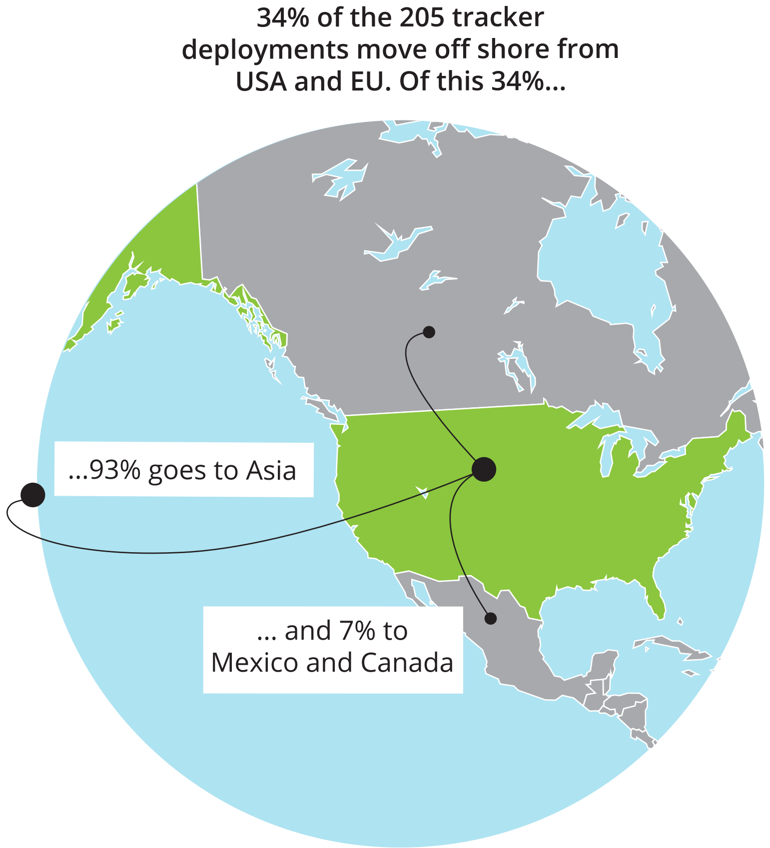
Transboundary Movement of E-waste

Countries measure import and exports flows with international trade statistics, which are usually based on trade from customs. Such statistics use the global Harmonized Trade System (HS) codes. However, the HS codes do not distinguish between new and used electronics. Though there have been some attempts and dialogue between the US and EU to create indicators for used electronics and e-waste within national export systems, the inclusion of used electronics within the trade code systems remains elusive. Countries are providing the Basel Convention Secretariat with statistics on e-waste imports and exports. However, countries do not cover the complete scope of e-waste, and countries are only partly, if at all, fulfilling their reporting obligations. Secondly, the statistics also do not cover trade of equipment that's wasted though functional. Therefore, statistics on imports and exports of used equipment and e-waste are non-existent or of low quality for most countries.

However, over the last decade, it has become clear that oftentimes "e-waste" is classified as "used electronics" because of a potential for reuse, refurbishment, and recycling. It is currently difficult to determine whether the classification of used electronics is correct. This is not only related to the technical status of the product, but also to the market of the importing country. For example, the interest in reusable CRT is globally decreasing at a fast rate. For this reason, it may be too difficult to have countries assess whether their exports and imports are "e-waste", and should turn attention toward collecting information on used electronics.

Methods to quantify a complete overview of imports and exports of used-EEE and e-waste therefore still need to be developed and tested. One potential method is to identify used or waste equipment based on a price threshold of the shipment. Although the method is applicable, it often yields estimates that are too low (Duan et al. 2016) (Baldé et al. 2016).

Illustration 7.2: Percentages of obsolete EEE exported from USA



Source: Hopson, et al. 2016

There are alternative methods to assess these flows, and two recent examples will be demonstrated. One was performed by a number of journalists and the Basel Action Network (BAN), which placed GPS trackers in obsolete equipment in the EU and USA (Hopson et al. 2016). One of BAN's main findings showed that 34% of the 205 tracker deployments moved off shore, almost all to developing countries. Of those exported, 93% went to developing countries in Asia where no proper recycling is performed. 7% moved to countries such as Mexico and Canada. One of these studies showed that around one-third of the e-waste tracked by the 200 GPS trackers in the US ended up in developing countries.

Illustration 7.1: Methods to assess import and export flows

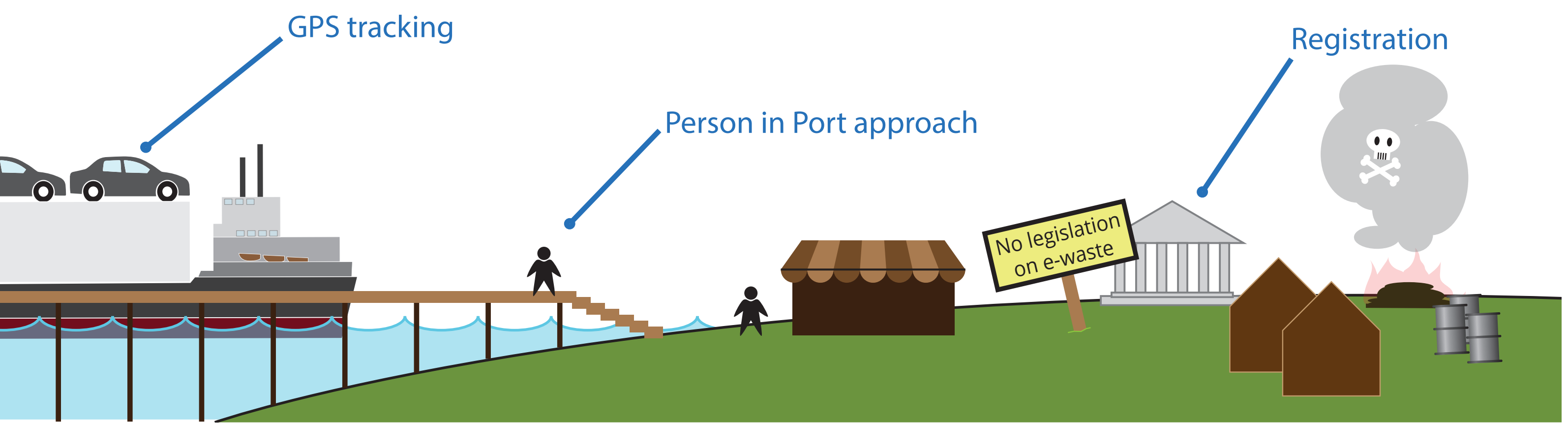
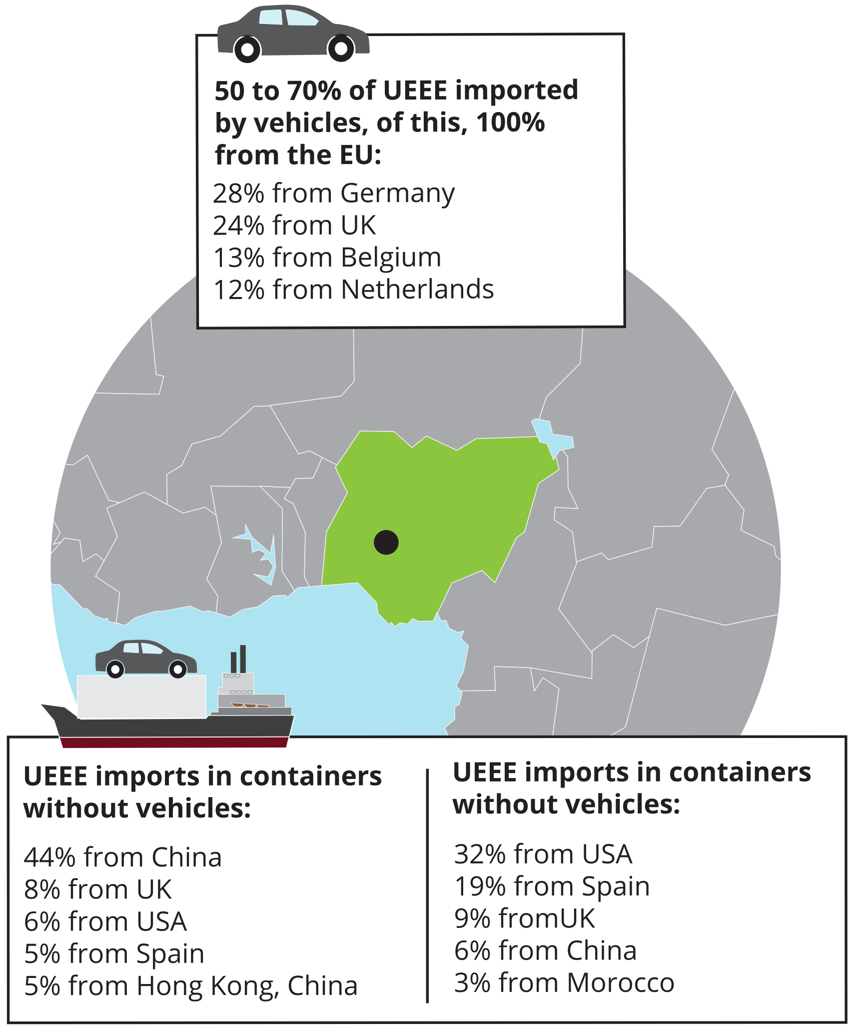


Illustration 7.3: Percentages of imported EEE into Nigeria by means of transport



Another alternative way to measure imports of used EEE and e-waste is to place a researcher in the receiving port. The approach is typically called 'Person in the Port'. In the following report, we mention the highlights from the most recent Person in the Port study.

Case study: Person-in-the-Port Project in Nigeria

This was conducted in 2015 / 2016 in Nigeria. In 2015/2016, around 71,000 t of UEEE were imported annually into Nigeria through the two main ports in Lagos. Around 69 % were stuffed in cars, buses, and trucks imported via roll-on/roll-off mode. UEEE imported in containers, with and without vehicles, contributed around 18,300 t of UEEE per year with 52% imported in containers with vehicles.

Almost 100% of the roll-on/roll-off imported vehicles were exported from ports located in the EU, mainly from Germany (28%), the UK (24%), Belgium (13%), and The Netherlands (12%). Around 44% (based on weight) of the imported UEEE in containers without vehicles originated from ports in China, the UK (8%), USA (6%), Spain and Hong Kong, China* (each 5%). The EU Member States are the source of around 25% of these imports. UEEE imports in containers with vehicles came from ports located in the USA (32%), Spain (19%), UK (9%), China (6%), and Morocco (5%). The EU Member States are responsible for around 35% of such imports into Nigeria.

In total, most imported UEEE originated from ports in Germany (around 20%) followed by the UK (around 19.5%), and Belgium (around 9.4%). The Netherlands (8.2%) and Spain (7.35%), followed by China and the USA (7.33% each), are next in the ranking of main exporters, followed by Ireland (6.2%). Overall, these eight countries account for around 85% of UEEE imports into Nigeria. EU member states were the origin of around 77% of UEEE imported into Nigeria.

Although the Nigerian Government banned the import of CRT-devices, around 260 t were found to be imported annually. The main sources of these CRT-TVs were China (23%), USA (15%), UK and Spain (14%), Italy (8%), Hong Kong, China, and the Netherlands (4%). These six countries accounted for about 80% of the total CRT imports.

Around 80% of the UEEE imported in containers was clean and undamaged, but only around 40% was properly packaged. Basic functionality tests showed that, on average, at least around 19% of devices were non-functional, and among those with the highest non-functionality and import rates were LCD-TVs and displays, refrigerators, and air conditions, which may contain mercury and (H) CFCs.

* Special Administrative Region of Hong Kong, China

Chapter 8

Status of E-waste Legislations

When establishing a new e-waste take-back and recycling system, it is vital to consider who will retain overall control and ultimately be responsible for the successful operation of the system. An entity must therefore be responsible for coordinating the specific actions of the stakeholders who have various roles and responsibilities within the system. In addition, an entity must also ensure that the system rules are enforced and compliance is ensured.

National e-waste policies and legislation play an important role because they set standards and controls to govern the actions of stakeholders who are associated with e-waste in the public and private spheres. Moreover, these policies and legislation shall frame the setting of a workable and fair financial and economic model, which must be sustainable and function properly. It is therefore vital that policymakers, together with stakeholders, establish a financial model to cover the collection sites and logistics along with the physical recycling itself. In addition, there is the need to raise awareness of the proposed system, and ensure that stakeholders are complying with their obligations, as well as setting up IT systems to receive and process the data.

Policy development was evaluated using the C2P database[9] with the purpose of assessing whether a country has national e-waste management regulations in force until January 2017. This is illustrated in Annex 3. Because of the large population in both India and China (both of which have national e-waste regulations in place), official policies and legislation currently cover around 4.8 billion people, which is 66% of the world population as opposed to 44% in 2014. However, the existence of policies or legislation does not necessarily imply successful enforcement or the existence of sufficient e-waste management systems.

Additionally, the types of e-waste covered by legislation differs considerably across the countries. This also explains the difficulties in coordinating collected and recycled e-waste amounts. Many of the countries that have already adopted e-waste legislation can still increase the coverage to include all products. For example, in the US, the 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 (U.S. Environmental Protection Agency, 2016). Therefore, many electric and electronic appliances are out of scope in the USA, such as all cooling and freezing equipment, most large equipment like dishwashers, dryers etc, some small equipment and lamps.

Table 8.1: Percentage of population covered by legislation per sub-region, in 2014 and 2017

	2014	2017
World	44%	66%
East Africa	10%	31%
Middle Africa	14%	15%
Northern Africa	0%	0%
Southern Africa	0%	0%
Western Africa	49%	53%
Caribbean	12%	12%
Central America	74%	76%
Northern America	98%	100%
South America	29%	30%
Central Asia	0%	0%
Eastern Asia	99%	100%
South-Eastern Asia	14%	17%
Southern Asia	0%	73%
Western Asia	37%	38%
Eastern Europe	46%	99%
Northern Europe	99%	100%
Southern Europe	100%	100%
Western Europe	99%	100%
Australian & New Zealand	81%	85%
Melanesia	0%	0%
Micronesia	0%	0%
Polynesia	0%	0%

The sub-regions where e-waste legislation is most developed are found in Europe. In Europe, the e-waste amounts documented to be collected and recycled are also highest. Other countries with developed e-waste recycling and collection are in Northern America, Eastern Asia, and Southern Asia. In several regions, national e-waste legislation is completely absent, such as in large parts of Africa, Caribbean, Central Asia, Eastern Asia and Melanesia, Polynesia, and Micronesia.

In addition, e-waste policies that are already present should contribute to the development of circular economy models through policy measures that don't only favour collection and recycling. Concrete actions are needed to change the direction of policy measures towards reusing, refurbishing, and remanufacturing the end-of-life of EEE. Legislation on e-waste should encourage a better product design at the production stage. This is the key to facilitate recycling and to produce products that are easier to repair or more durable. In addition, policies should point towards both a more efficient use of resources to improve production processes and to the recovery of valuable materials incorporated in EEE.

Most legislation and policies currently refer to the principle of "Extend Producer Responsibility", which emerged in academic circles in the early 1990s. It is generally seen as a policy principle that requires manufacturers to accept responsibility for all stages in a product's lifecycle, including end-of-life management.

There are three primary objectives of the EPR principle:

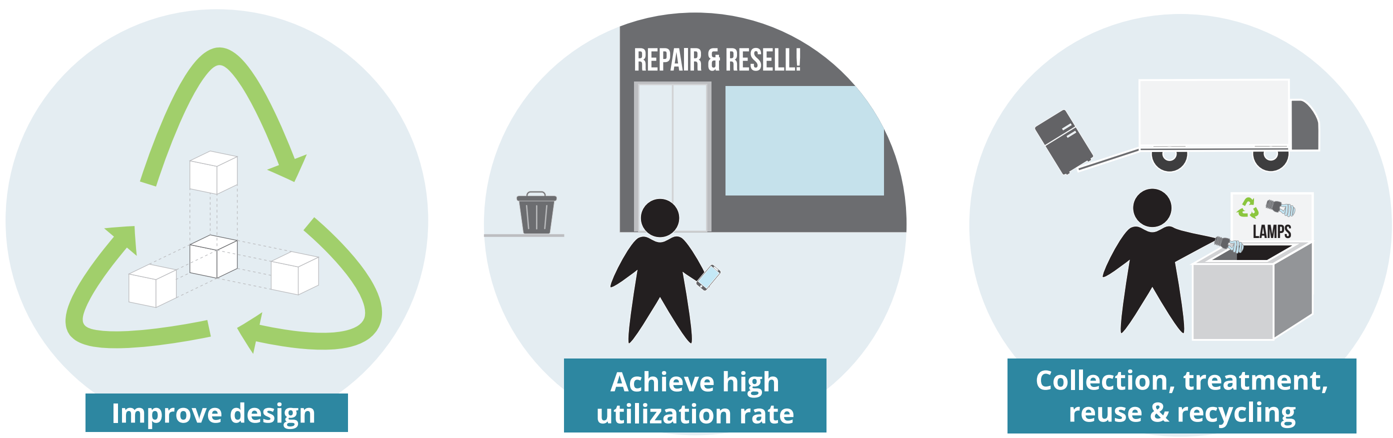
- Manufacturers shall be incentivised to improve the environmental design of their products and the environmental performance of supplying those products.
- Products should achieve a high utilisation rate.
- Materials should be preserved through effective and environmentally-sound collection, treatment, reuse, and recycling.

The key principle behind the reasoning that producers or manufacturers should be primarily responsible for this post-consumer phase is that most of the environmental impacts are predetermined in the design phase.

The EPR principle is implemented in a variety of legislations and policies. Under an EPR principle, responsibility can be assigned either individually, where producers are responsible for their own products, or collectively, where producers in the same product type or category fulfil the responsibility for EoL management together. A system as close as possible to Individual Producer Responsibility (IPR) can more easily stimulate the improvements in the design phase because the producer is interested in the benefits obtained by the improved design. However, the complexity of such a system has so far prevented its development, resulting in policies and legislation that refer to collective responsibility rather than individual.

However, in developing countries, a major hurdle to the producer adopting responsibility results from the lack of treatment facilities (TF) that are compliant with international standards and a lack of collection infrastructure that channels e-waste to these sites. This can be addressed by harnessing government support directed at ramping up compliant TFs or by market-orientated approaches that aim to leverage compliant recyclers to create their business case.

Illustration 8.1: The primary objectives of the EPR principle



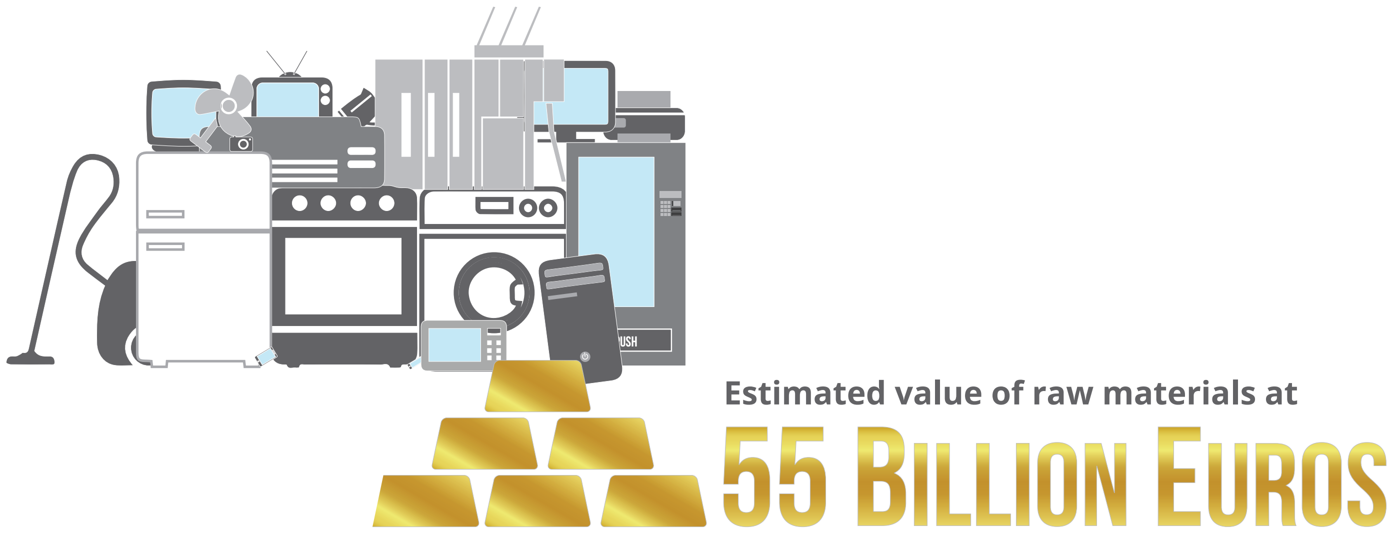
Box 8.1: International Laws on E-waste

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal is a multilateral treaty aimed at suppressing environmentally and socially detrimental hazardous waste trading patterns. The convention was signed by 186 countries[10]. E-waste, due to its constitution, often contains hazardous elements. Therefore, the Convention affirms that in order to protect human health and the environment, hazardous waste should not be traded freely like ordinary commercial goods, and thus it establishes a written notification and approval process for all cross-border movements of hazardous wastes. But the Basel Convention's regulatory exemption on equipment that's destined for reuse is entirely compatible with its prime environmental objective to prevent waste generation, as reuse extends the lifecycle of EEE and therefore mitigates the generation of hazardous waste. By prolonging the functionality of electronics, reuse promotes natural resource conservation and at least temporarily diverts the need for recycling or disposal. However, the distinction of whether something is waste or not, and therefore intended for re-use, is a long-standing discussion under the Basel Convention. The most recent Conference-of-Parties (COP13) could not reach a final consensus.

Chapter 9

Urban Mining of E-waste

Illustration 9.1: Potential value of raw materials in e-waste in 2016



A large variety of valuable materials and plastics are contained in electric and electronic appliances. Up to 60 elements from the periodic table can be found in complex electronics, and many of them are technically recoverable, though there are economic limits set by the market. E-waste contains precious metals including gold, silver, copper, platinum, and palladium, but it also contains valuable bulky materials such as iron and aluminium, along with plastics that can be recycled. Overall, UNU estimates that the resource perspective for secondary raw materials of e-waste is worth 55 Billion € of raw materials.

EEE also contains rare earth, hazardous, and scarce metals. Common hazardous materials found in e-waste are: heavy metals (such as mercury, lead, cadmium etc.) and chemicals (such as CFCs/ chlorofluorocarbon or various flame retardants).

Table 9.1: Potential value of raw materials in e-waste in 2016

Material	kilotons (kt)	Million €
Fe	16,283	3,582
Cu	2,164	9,524
Al	2,472	3,585
Ag	1.6	884
Au	0.5	18,840
Pd	0.2	3,369
Plastics	12,230	15,043

It is extremely important to treat e-waste adequately in order to prevent the health and environmental risks that the hazardous substances contained in e-waste can pose. Proper management systems of e-waste also need to be established to allow for the recovery of the impressive value of precious and valuable materials contained in discarded equipment. In order to exploit this opportunity and simultaneously mitigate pollution, good policies are needed to facilitate the creation of an infrastructure and encourage the recovery of valuable materials.

One might think that the selling price of new EEE reflects the intrinsic value of the materials from which EEE are made. However, this is not fully true. For instance, the average selling price for a new smartphone worldwide in 2016 was around € 200 (ITU, 2016a). The average selling price for a used smartphone in the same year was € 118 (McCollum, 2017). However, based on UNU estimates, the intrinsic value of precious metals and plastics contained in a mobile phone of an average weight of 90 grams is € 2 per piece. Thus, the raw material value is a relatively small amount compared to the second-hand or new price. In 2016, around 435 kiloton (kt) of wasted mobile phones were generated across the globe. This means that the value of raw materials in wasted mobile phones was 9.4 Billion €. However, if all phones had a longer life span and could enter a second-hand market, the value could be even higher.

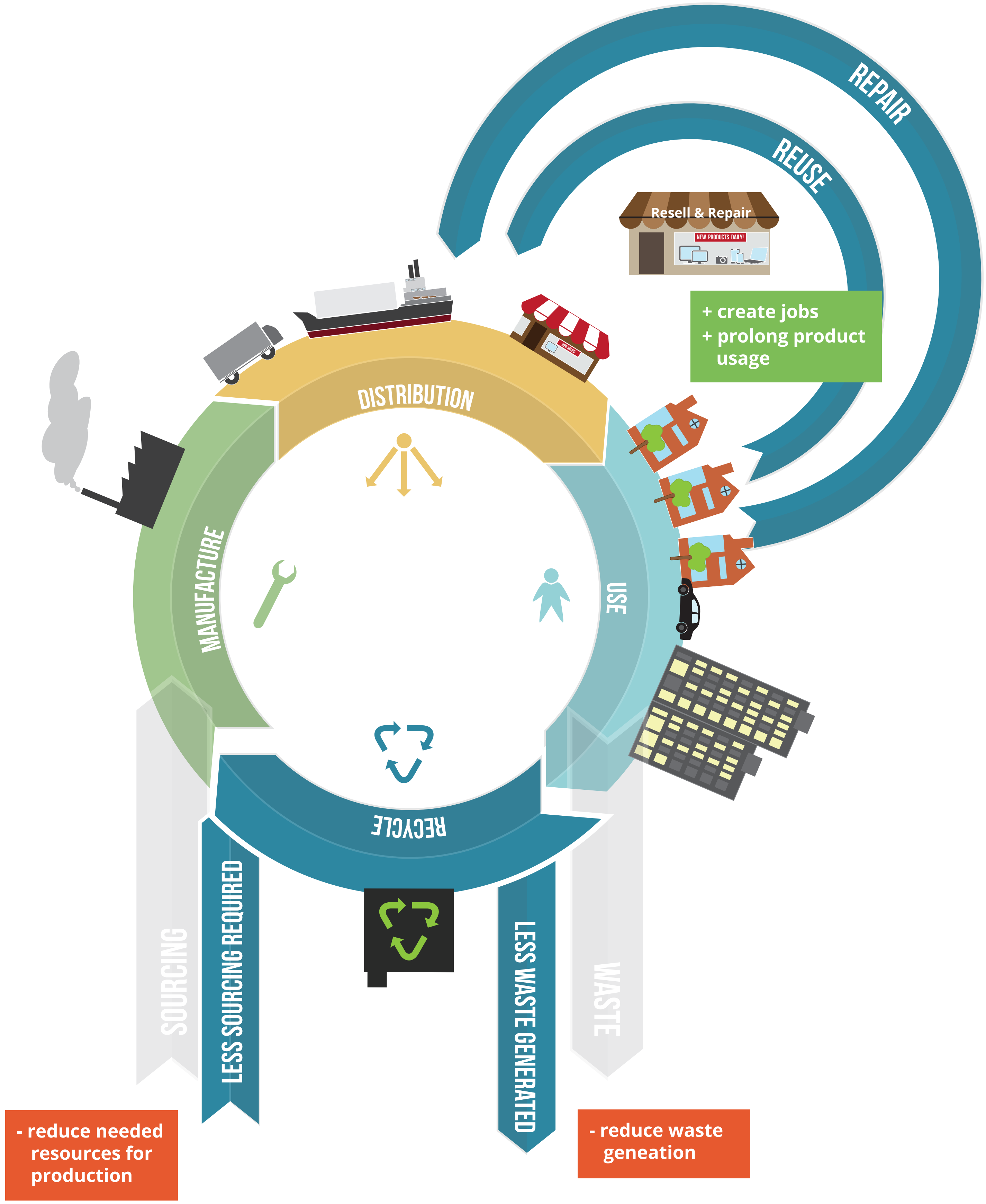
The current e-waste recycling indicators focus on percentages of recycled materials. However, in the previously illustrated result, a mass-based recycling indicator might show only a part of the resource efficiency story. In this regard, an indicator based on the monetary value of resources could be preferred over the indicators based on mass development that are used so far (Di Maio et al., 2017). If the recycling targets referred to the value of the materials, the whole recycling waste management cycle would be incentivised to recover valuable and precious materials incorporated in the discarded electric and electronic equipment. This would easily trigger a market mechanism that might facilitate improvements on the e-waste management worldwide.

Illustration 9.2: Potential value of raw materials in mobile phone waste

In order to efficiently harvest resources through this "urban mine", it is necessary to overcome the inefficient "take-make-dispose" economic model and adopt the circular economy system which aims to keep the value in products for as long as possible and eliminate waste. In this regard, countries should come up with legislation to promote circular economy models in which the e-waste is treated as resource rather than waste. They should promote the reusing, repairing, redistributing, refurbishing, remanufacturing prior to recycling of materials. In addition, an efficient management system is required to divert the formal take-back system and avoid e-waste entering other channels, such dustbins or substandard recycling. Valuable materials are easily lost due to imperfect separation and treatment processes. These solutions should be coupled with an optimized design of the electric and electronic equipment to enable the disassembly and reuse of components, or the recovery of valuable and precious materials. Very often it is more expensive to repair an item (such as mobile phones or laptops) than to buy a new one. In addition, the material used and the design of EEE make recycling challenging, as they are designed using hazardous compounds such as mercury lamps in LCD screens, PVC, flame retardants, and other toxic additives in plastic components.

Circular economy models should allow the increase in value of EEE when wasted, while reducing the environmental pressures that are linked to resource extraction, emissions, and waste. Closing the loop of materials implies the reduction in the need for new raw materials, waste disposal, and energy, while creating economic growth, new "green" jobs, and business opportunities.

Illustration 9.3: A simplified model of the Circular Economy



Chapter 10

Regional E-waste Status and Trends

Africa

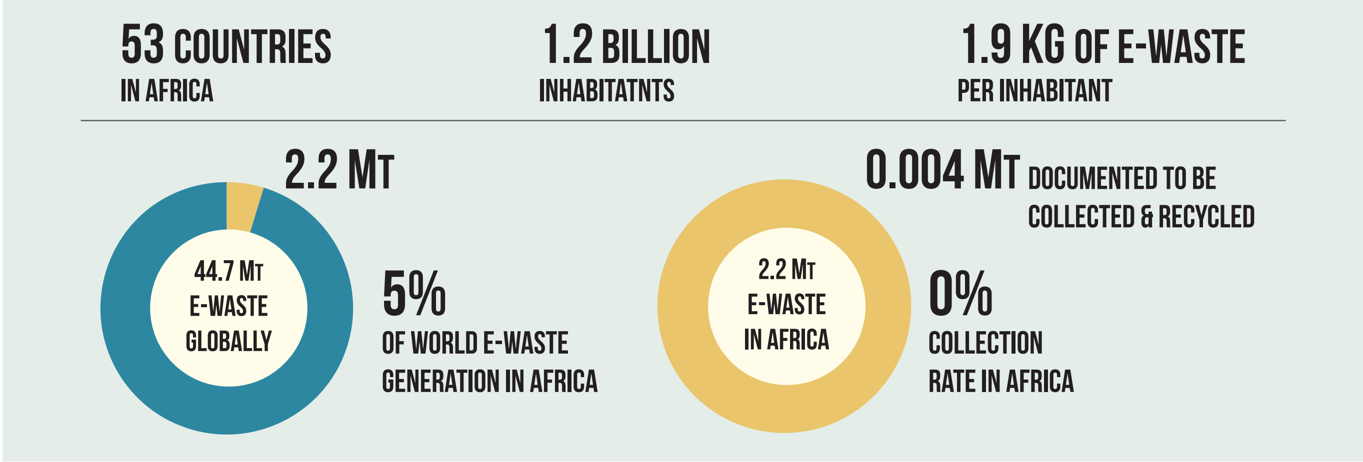
UNU estimates that in 2016, domestic e-waste generation in Africa was approximately 2.2 Mt, with contributions from Egypt (0.5 Mt), South Africa and Algeria (each 0.3 Mt) ranking highest. The top three African countries that have the highest e-waste generation per inhabitant are: Seychelles (11.5 kg/inh), Libya (11 kg/inh), and Mauritius (8.6 kg/inh). Currently, little information is available on the amount of e-waste documented that is collected and recycled by the formal sector in Africa. Only a handful of countries in the continent have enacted e-waste-specific policies and legislation. Recycling activities are dominated by ill-equipped informal sectors, with related inefficient resource recovery and environmental pollution. Most African countries are currently developing various models of EPR schemes as part of their solution to the e-waste problem.

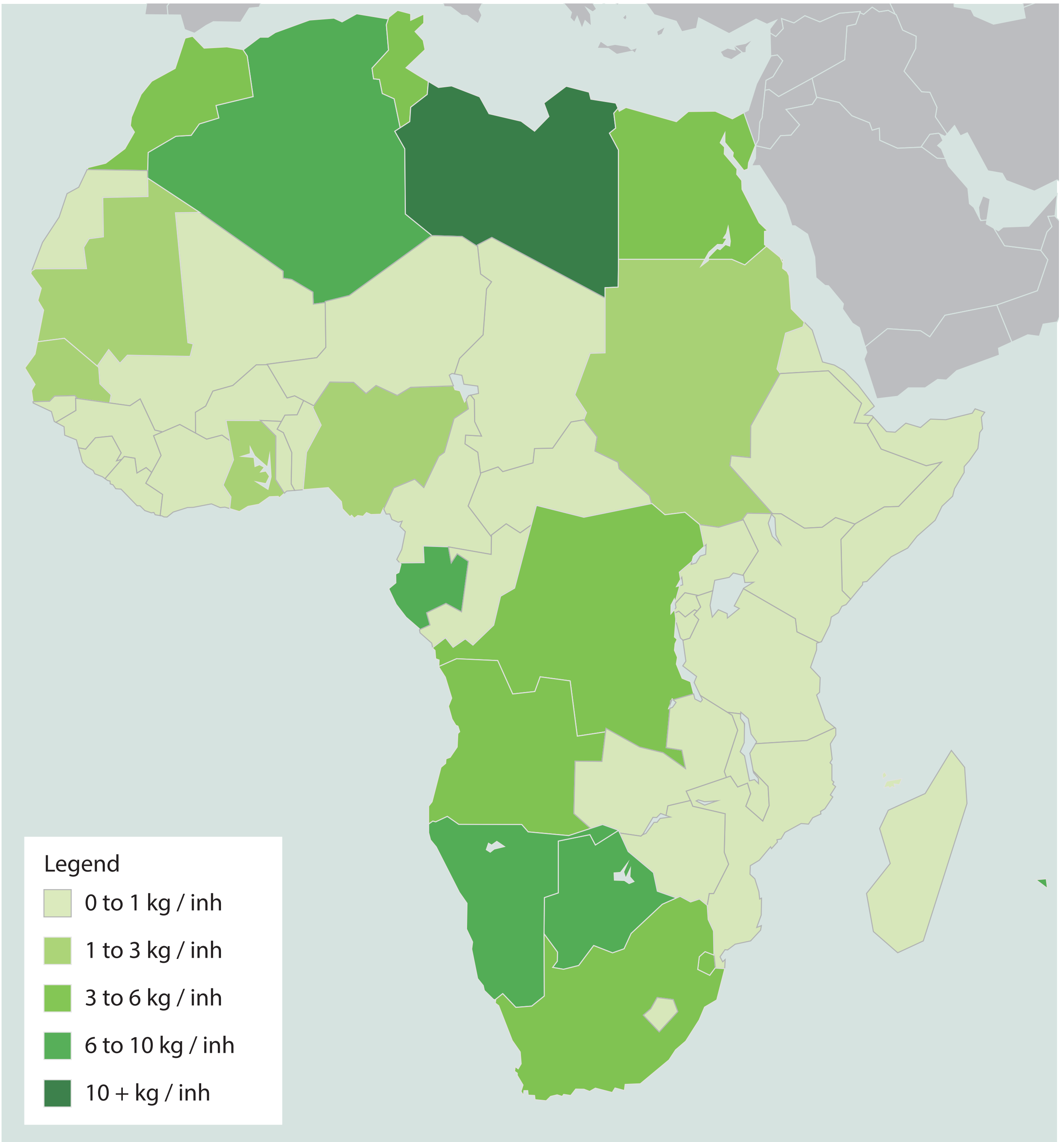
The African continent hosts the least number of direct manufacturers of EEEs, yet it carries a significant burden of contribution to the global e-waste problem, generating about 2.2 Mt annually from domestic output. Most of this is derived from imports of new and used equipment, and a few local assembly plants. Locally derived generation is believed to constitute about 50% to 85% of total e-waste generation, the rest being from the transboundary illegal import from developed countries in the Americas and Europe, and from China (Secretariat of the Basel Convention, 2011). Annual domestic generation in Egypt (0.5 Mt), South Africa and Algeria (each 0.3 Mt) rank highest in the region. However, some of the continent's smaller but richer countries (Seychelles, Mauritius) generate 11.5 kg/inh and 8.6 kg/inh respectively, in comparison to the African average of 1.9 kg/inh and world average of 6.1 kg/inh. Local generation of e-waste is expected to rise in the future with the penchant for consumption of foreign goods and the quest for comfort associated with consumer goods.

Most African countries are now aware of and concerned with the dangers inherent to poor management of e-waste. However, the legal and infrastructural framework for achieving sound management still remains far from realised in the majority of countries. Only very few countries (including Uganda and Rwanda) have any formal official government policy documents specific to e-waste management. In addition, despite the fact that almost all African countries have ratified the Basel Convention, most have not domesticated this in the form of appropriate legislations for various waste streams. As yet, only Madagascar (2015), Kenya (2016), and Ghana (2016) have formally passed a draft of e-waste bills into law. Several other countries (South Africa, Zambia, Cameroon, and Nigeria) are still working to achieve this in parliament. In Nigeria, the draft is already officially being enforced for e-waste control by the country's environment regulatory agency. E-waste imports are prohibited by this regulation, and its enforcement has resulted in the repatriation of several illegal e-waste shipments that arrived in Nigeria stuffed in second-hand vehicles or other containers; for more information, see the chapter on transboundary movement in this report[11]. The Kenya E-waste Act, which still awaits official approval before public dissemination, has as one of its highlights that no company will manufacture or import any EEE without indicating where its e-waste will be treated at end-of-life. The Ghana legislation prohibits imports and exports of e-waste, phases out the inclusion of printed circuit boards in electronic equipment, provides for the registration of manufacturers, importers, and distributors, as well as the establishment of an e-waste management fund to be achieved through payment of an advance eco-fund by manufacturers, importers, and distributors. Draft bills and regulations of many other African countries incorporate several of these features.

Based on these previous mentioned initiatives, governments in many African countries have begun showing increasing concerns and interest in adopting comprehensive and integrated approaches to solving the e-waste problem. Such approaches will integrate the informal sector into the official management structures, establish take-back schemes, Extended Producer Responsibility (EPR), and Producer Responsibility Organisations (PROs) schemes. In this regard, many countries are currently receiving advisory, technical, and financial support from several UN agencies, other development agencies, the private sector, and especially from the alliance of Original Equipment Manufacturers (OEMs) in Africa.

The government of Egypt partnered with the Sustainable Recycling Industries (SRI) in a





programme whereby an agreement was signed to build the capacity and raise awareness towards efficient, environmentally sound, and sustainable e-waste recycling. It focuses on the recycling of electronic and electric waste as a promising emerging industry. The Government of Italy has provided $4 million to implement the Third Phase of the Egyptian-Italian Environmental Cooperation Programme (EIECP), which is implemented under the supervision of UNDP. This package includes a safe health and electronic waste management programme in order to reduce emissions of harmful solid organic pollutants.

In Nigeria and Kenya, the proposed EPR schemes require manufacturers and importers to formulate their EPR procedures and obtain approvals from the government, whereas the Ghana model is based on the payment of eco-fees from such manufacturers and importers to a fund to be managed by government and the industry, and used for managing e-waste. The draft e-waste-specific EPR scheme for South Africa also features elements that are similar to the Nigerian, Kenyan, and Ghana proposals/model. The EPR scheme has good prospects in Africa but may be problematic due to several factors, including the mistrust of the scheme by an apprehensive informal sector, the lack of recycling infrastructure and standards, socio-cultural difficulties with take-back schemes, choice of appropriate EPR models, difficulty with defining who is a 'producer' in the context of a lack of real manufacturers, and generally poor financial support for the scheme.

E-waste management in Africa is dominated by thriving informal sector collectors and recyclers in most countries, as take-back schemes and modern infrastructure for recycling are non-existent or grossly limited. Government control of this sector is at present very minimal and inefficient. Handling of e-waste is thus characterised by manual stripping to remove electronic boards for resale, open burning of wires to recover few major components (copper, aluminium, iron), and the deposition of other bulk components, including CRTs, in open dumpsites. This practice by the informal sector often involves the use of illicit labour of pregnant women and minors, as well as a lack of personal protection equipment for the workers. Resulting from such practices is the severe pollution of the environment, very poor efficiencies in recovery of expensive, trace, and precious components, and the exposure of labourers and the general populace to hazardous chemical emissions and releases. The Agbogbloshie site in Ghana is the classic example that has received international attention and concern. In this context, the use of standardised modern e-waste recycling plants should have been a good solution. It is noteworthy, however, that a few modern recycling plants that were established in some east African countries (e.g. Kenya, Uganda, Tanzania) have suffered business failures and closures due, in part, to adoption of inappropriate business models. Notwithstanding such failures, there is now renewed interest by private business outfits to establish recycling plants in many parts of the continent.

E-waste management problems and attendant remedies are somewhat similar in the various sub-regions of Africa. In summary, the major problems include the lack of adequate public awareness, lack of government policy and legislation, lack of an effective take-back/collection system and EPR system, the dominance of the recycling sector by an uncontrolled, ill-equipped informal sector that pollutes the environment, lack of adequate recycling facilities, and poor financing of hazardous waste management activities.

Americas

In the Americas in 2016, the total e-waste generation was 11.3 Mt. Only 1.9 Mt is documented to be collected and recycled, mostly coming from North America. The geographical distribution and e-waste management characteristics are very different across the continent. The richer areas (USA and Canada) produce the most e-waste per inhabitant: around 20 kg/inh. USA and Canada have, respectively, state and provincial laws to manage e-waste, and the most data available. The rest of the continent is relatively well-developed, compared to the rest of the world, and generated on average 7 kg per inhabitant. For South America, there are fewer laws in effect to manage e-waste, and most of the e-waste is managed by the informal sector and private companies.

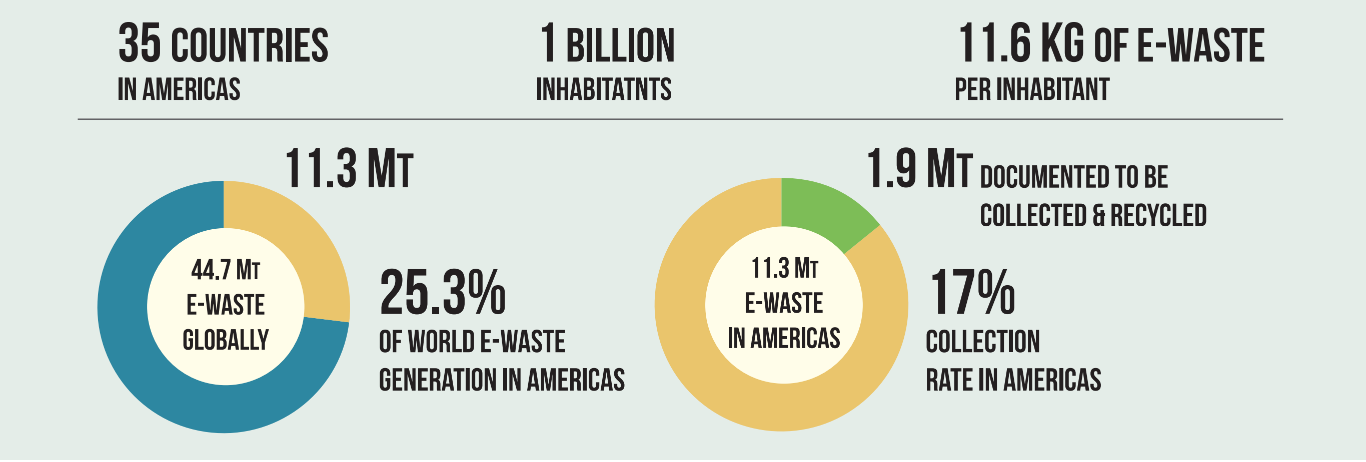
The top producer of e-waste in the Americas is the United States of America, with 6.3 Mt. The second largest producer of e-waste is Brazil, with 1.5 Mt, and the third is Mexico, with 1 Mt. UNU estimation studies show that the USA collected approximately 1.4 Mt of e-waste, which is 22% of the e-waste generated. The whereabouts of the remainder of the e-waste is largely unknown in the USA.

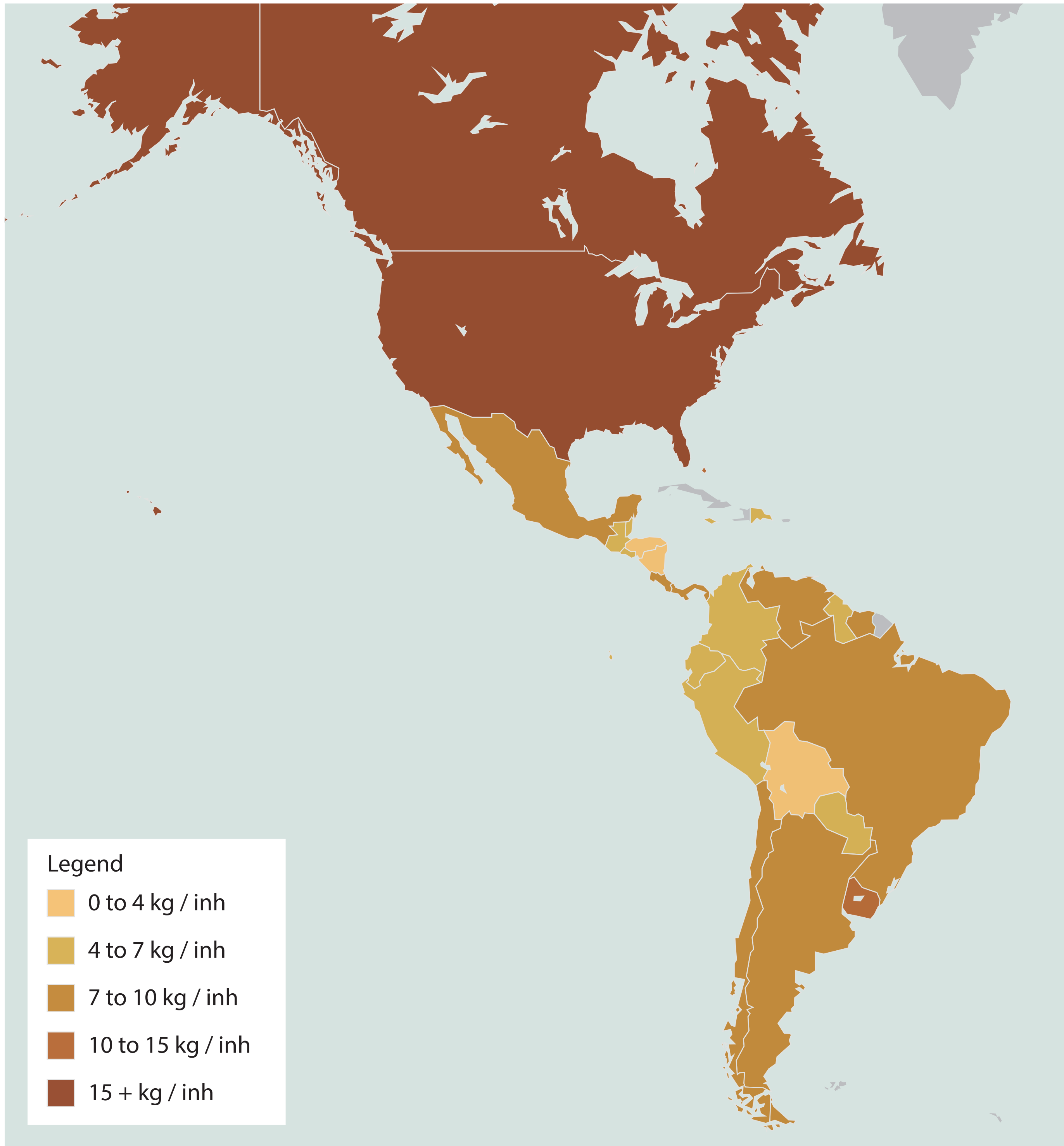
The EPA statistics show that only video products, audio products, telephones, mobile phones, fax, desktops, laptops, screens, printers, and other peripherals are included, instead of all 54 UNU-KEYS (Annex 1). Thus, the low collection rate is partially an issue of scope in the governmental statistics. Considering only the products in the EPA's scope, the collection rate for the USA rose to 70%. It is also likely that some of the e-waste is exported to other countries, since the USA did not ratify the Basel Convention that restricts the transboundary movement of international hazardous waste. In 2010, it was estimated that 8.5% of the collected units of computers, TV's, monitors, and mobile phones were exported as whole units (Duan et al, 2013). This weighed 26.5 kilotons (kt). Most larger electronic items, especially TVs and monitors, were exported over land or by sea to destinations such as Mexico, Venezuela, Paraguay, and China, while used computers, especially laptops, were more likely sent to Asian countries. The main destinations for mobile phones were Hong Kong (China), Latin American counties, and the Caribbean.

The USA still doesn't have national legislation in effect about the management of e-waste, and instead has regulations by state. 84% of the population in the USA is covered by legislation on e-waste. However, 15 states still don't have legislation in effect, including Alabama, Ohio, and Massachusetts. 25 states, plus Puerto Rico and DC, have some sort of consumer take-back law; 17 states and New York City have landfill bans (mostly CRTs).

However, the USA undertook general measures to prevent e-waste and limit the adverse effects posed by unappropriated disposal and treatment. Electronics that are proved to be hazardous must follow the Resource Conservation and Recovery Act (RCRA), and be managed accordingly. Broken and intact Cathode Ray Tubes (CRTs) have explicit regulations that set specific requirements for their management, import, and export. The USA follows the National Strategy for Electronics Stewardship framework when developing new actions on electronics. Federal agencies are mandated to purchase electronics that are Electronic Product Environmental Assessment Tool (EPEAT) registered. EPEAT products are more environmentally preferable and require Original Equipment Manufacturers (OEMs) to offer electronics take-back programs to customers. Federal agencies are directed to use electronics recyclers that are certified to either the Responsible Recycling (R2) or the e-Stewards standards. A policy regarding the certification of the recyclers is under development. To date, there are over 700 electronics recycling facilities that have been independently certified to one or both of the certification programs.

Many initiatives are undertaken by the USA Environmental Protection Agency. Within the EPA's Sustainable Materials Management (SMM) Electronics Challenge, EPA partners with electronics OEMs and retailers to collect used electronics from the American public. The partners commit to using certified electronics recyclers to manage the material collected. This EPA-managed challenge is a national effort under the EPA's SMM Program, which challenges the EPA and other federal agencies throughout the country to lead by example in reducing the federal government's environmental impact, including the area of electronics. In this regard, the Challenge promotes





electronics stewardship in the federal government by encouraging federal facilities to purchase greener electronics (EPEAT registered), reduce the impacts of electronics during use (i.e. enabling power management and default to double-side printing), and to send used electronics to certified electronics recyclers so that used electronics can be managed in an environmentally responsible way. In particular, the program requires participants send 100% of collected electronics to certified recyclers, increase nationwide collection year over year, and increase collection in states without take-back laws. In 2015, the participants recycled about 256 kt of used electronics.

In addition to the USA, Canada still doesn't have national legislation in effect on the management of e-waste. However, most of the states have local regulation except the Yukon and Nunavut. Several organizations are working in various provinces to deal with the collection and recycling of e-waste. These organizations recycled approximately 20% of the total e-waste generated in 2016 (148 kilotons (kt)). The collection rate can be boosted by increasing awareness and by creating more centers to collect all kinds of e-waste throughout the country (Kumar & Holuszko, 2016).

In Latin America, 4.2 Mt of e-waste was estimated to be generated in 2016, with an average of 7.1 kg/ inh. The Latin American countries with the highest e-waste generation are: Brazil 1.5 Mt, Mexico 1 Mt, and Argentina 0.4 Mt. The top three countries in Latin America with the highest e-waste generation in relative quantities in 2016 were Uruguay (10.8 kg/ inh), Chile (8.7 kg/ inh), and Argentina (8.4 kg/ inh).

One of the main problems in this sub-region is the lack of e-waste regulation. Only 7 countries in Latin America enforce national legislation on e-waste (Bolivia, Chile, Colombia, Costa Rica, Ecuador, Mexico, and Peru). Some countries just recently started the process of promoting e-waste legislation (Argentina, Brazil, Panama, and Uruguay). Costa Rica initiated the process with an Electronic Waste Management Executive Decree in 2010. At the same time, Colombia adopted a national system for selective collection and management of computers and/or peripheral waste resolution. Recently, Colombia enacted national policy on the management of Electrical and Electronic Waste Equipment (WEEE) (June 2017). Peru enacted an e-waste national regulation in 2012, while Ecuador adopted specific rules to regulate the take-back system for some e-waste categories. These countries all use the Extended Producer Responsibility principle as the common approach in their e-waste laws. In June 2016, Chile enacted the 20290 Bill "Framework Law on Waste Management, Extended Producer Responsibility, and Promotion of Recycling". So far, Argentina has developed legal frameworks only at the provincial level, mainly focused on the collection of e-waste. In this country, three bills projects have been presented in the congress. However, no national law has been approved.

There are only a few countries that have a defined regulatory framework and can count on formal recycling systems. However, these are often at an initial phase and improvements need to be done in the whole sub-region. Mexico collects most of the e-waste in Latin America (358 kt), which leads to a collection rate of approximately 36% compared to the e-waste generated. The collection rate in the rest of Latin America is lower than 3%. Argentina, for example, only 10.6 kt are collected and recycled compared to reported to be the 368 kt e-waste generated. In countries such as Argentina, the collection and recycling of e-waste is not regulated by a national low, therefore the e-waste is most likely treated by the informal sector or private recycling companies. The private recycling companies in Latin America mainly disassemble computers and cellular phones with the aim to recover the valuable materials contained in these items.

The main challenge with sustainable e-waste management in Latin America is the acceleration of all legislation processes. For the few countries that already have e-waste laws in effect, this is necessary to speed up their implementation. All the other countries in the sub-region have an urgent need to tackle this issue.

Improvements also need to be done in the research field. Only a few studies have been done so far to address the e-waste problem in Latin America, and all of them were conducted many years ago. The lack of a historical environmental culture in Latin America fuels the thought that the final user of EEE is not responsible for proper disposal and treatment.

Asia

In Asia, the total e-waste generation was 18.2 Mt in 2016. China generates the highest e-waste quantity both in Asia and in the world (7.2 Mt). Japan generated 2.1 Mt, and India 2 Mt. The top four Asian countries that have the highest e-waste generation in relative quantities are: Cyprus (19.1 kg/inh), Hong Kong (19 kg/inh), Brunei and Singapore (around 18 kg/inh). An average of 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 East-Asia, the official collection rate is close to 25%, whereas in other sub-regions, such as Central and South Asia, it is still 0%, likely leaving most of the e-waste managed by the informal sector.

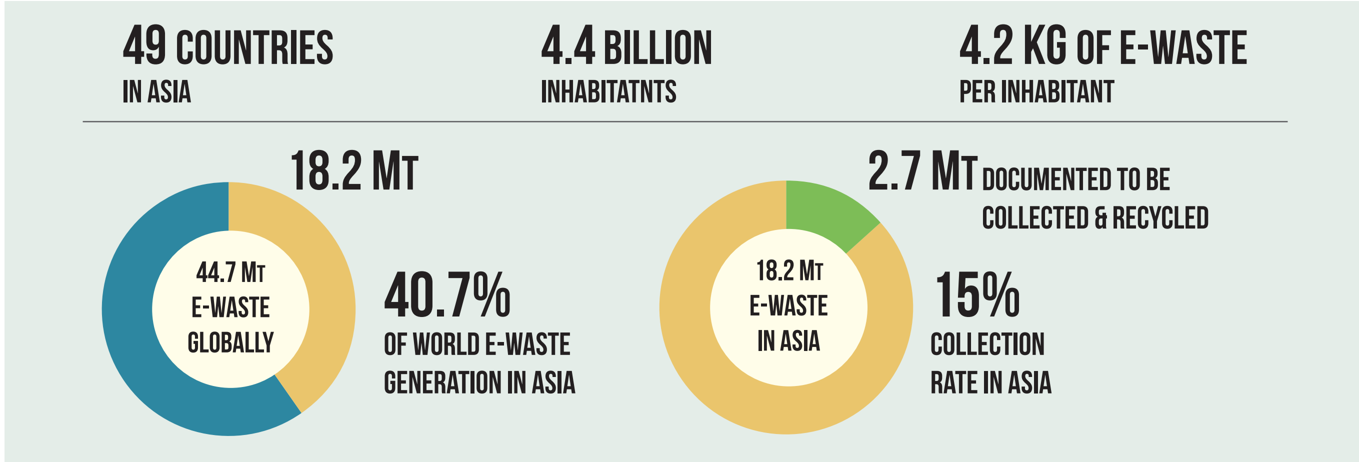
Compared to other continents, Asia is the most complicated, with many countries ranging from developing to industrial nations. This huge discrepancy has caused a highly complex e-waste management. United Arab Emirates, for example, is considered to have one of the world's lowest life expectancy of electronics and high amounts of consumption, making the country produce substantial amounts of electronic waste annually. The average resident in UAE generates 13.6 kg of e-waste, while Saudi Arabia and Kuwait produce the highest amount of e-waste per inhabitant in the Middle East (around 15.9 kg/inh). The continent also has countries that are still developing, such as Afghanistan and Nepal, and generate less than 1 kg/inh of e-waste.

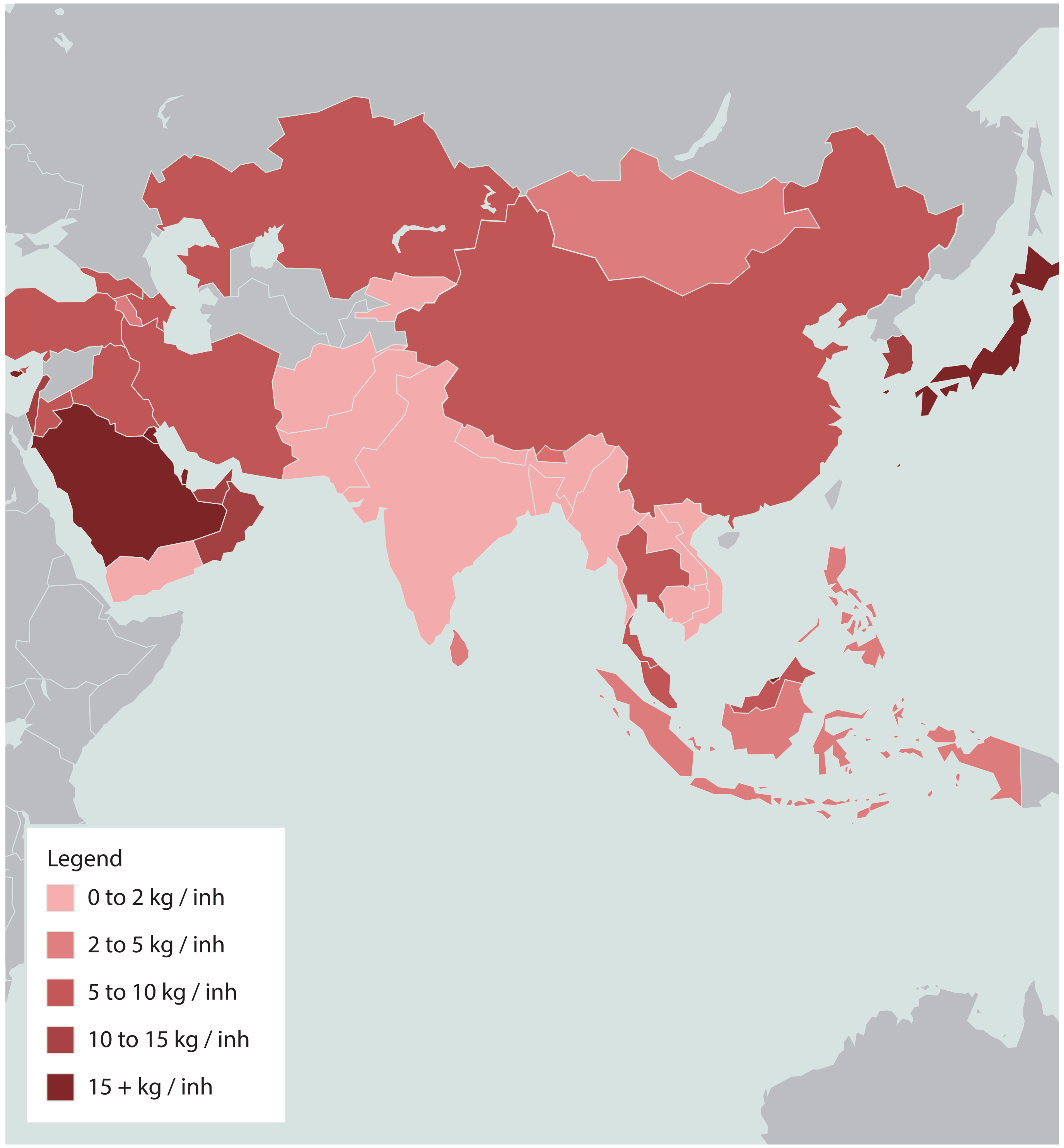
The top e-waste producer in the world is China, which generates 7.2 Mt of e-waste according to our figures. According to another study, the amount of e-waste is expected to grow to 27 Mt by 2030 (Zeng et al. 2017). China plays a key role in the global EEE industry for several reasons; it is the most populous country in the world, so the demand of EEE is very high, and it has a strong EEE manufacturing industry. China has a big role also in the refurbishment, reuse, and recycling of e-waste. The formal e-waste recycling industry has shown considerable growth in treatment capacity and quality; 18% of the e-waste generated has been documented to be collected and recycled in recent years. China has national legislation in effect that regulates the e-waste collection and treatment of TVs, refrigerators, washing machines, air conditioners, and computers (desktop and laptops). However, due to a range of social and economic factors, the informal sector is still leading the business of collecting and recycling e-waste. This very often causes detrimental effects on the environment and health. Therefore, the growth of the formal sector is important in lessening the environmental and health impacts due to improper and unsafe treatment of e-waste.

Other countries have advanced e-waste regulation, such as Japan and South Korea. In Japan, most of the UNU categories are collected and recycled under the Act on Promotion of Recycling of Small Waste Electrical and Electronic Equipment. Japan was one of the first countries in the world to implement an EPR (Extended Producer Responsibility) based system for e-waste. Japan relies on strong legal framework, an advanced take-back system, and developed processing infrastructure. In 2016, Japan collected 546.4 kilotons (kt) through official channels[12].

In the Southern and South-Eastern Asia region, India plays an important role in the domestic generation of e-waste (2 Mt in 2016) due to the large population, but the country also imports from developed countries. India's electronics industry is one of the fastest growing industries in the world. The formal e-waste recycling sector in India is currently being developed in major cities. However, informal recycling operations have been in place for a long time, with over 1 million poor people in India involved in manual recycling operations. Most of these people have very low literacy levels with little awareness of the dangers of the operations. Severe health impacts and environmental damage are widespread in India, due to the final step of the e-waste processing by the informal sector. India has had the e-waste rules in effect since 2011. The rule mandates producers to be responsible for the collection and financing of systems according to the Extended Producer Responsibility concept. Further amendment to this rule came in 2015, which resulted in the E-waste (Management) Rule in 2016. The main feature of this rule is EPR. The amended rule has provisions for Producer Responsibility Organisations (PROs) and Deposit Refund Scheme under EPR.

In Cambodia, Sub-decree on Electronic Waste Management was enforced in 2016. Vietnam also had a Prime Ministerial decision on e-waste





published in 2015, which came into effect in July 2016 and requires that enterprises manufacturing or importing electrical and electronic products to be responsible for collection, transport, and processing of e-waste. So far, Vietnam has not developed an official inventory of e-waste generated in the country. The main issue related to e-waste in Vietnam is the informal recycling activities that are undertaken in Vietnamese craft villages. Transboundary movement is another major issue in Vietnam, and there is no local capacity to deal with the recycling of all the materials in e-waste while using the best available technology. All these factors are effecting the EPR implementation in the country. Sri Lanka currently has no regulations to deal with e-waste specifically. Pakistan currently has no inventory or exact data on e-waste generation, but they have made provisions to prohibit e-waste imports to Pakistan. However, many such items are still being imported to Pakistan as second-hand items (Imran et al. 2017). One of the studies that has attempted to estimate illegal import shows an annual average import of e-waste to Pakistan of around 95,4 kt (mostly computers and related products). Bangladesh currently has no specific Environmental Policy Act or guidelines directly related to managing e-waste. However, Bangladesh has attempted to address this problem. At the moment, no inventory of e-waste in Bangladesh is available. As for end-of-life management of electrical and electronic equipment, reuse is a common practice in Bangladesh. Dismantling and recycling is also a growing business, mainly undertaken by the informal sector. Most of the e-waste in Bangladesh is dumped in open landfills, farming land, and open bodies of water, causing severe health and environmental impacts. A report states that over 50,000 children are involved in the informal e-waste collection and recycling processes, 40% of them in the ship-breaking yards. Every year, around 15% of child workers die as a result of e-waste recycling. Over 83% are exposed to toxic materials in e-waste, become sick, and are forced to live with long term illness. (Environment and Social Development Organisation, 2010). Thailand also suffers from issues such as lack of general awareness about e-waste, incomplete databases and inventories related to e-waste, lack of environmental sound management practices, and lack of specific laws and regulations on e-waste.

Central Asia is currently the only sub-region in Asia where countries still don't have national legislation enforced on e-waste. In 2016, this sub-region generated an average of 6.4 kg/inh of e-waste, accounting for 154 kt in total; an amount not comparable to the 10.2 Mt generated in Eastern Asia, but there is still an imminent need for its management to be regulated in this sub-region. In Kazakhstan, a project in collaboration with the Ministry of Energy of the Republic of Kazakhstan and the private sector has made proposals to improve the legislative foundation in e-waste management and is helping to improve efficiency of the services for collection, transportation, use, and disposal of e-waste. The questionnaires received from the countries in the sub-region reveal that both legislations and statistics on e-waste have not been defined so far, but they are under development.

Western Asia generates 2 Mt of e-waste. The sub-region includes both high-income countries, such as Qatar and Kuwait, and countries ravaged by wars and conflicts, which cannot rely on a strong legislative framework and on an efficient e-waste management system. Regardless of the economic inequality in the sub-region, only three countries have national legislation in effect (Cyprus, Israel and Turkey). In this area, only the 6% of e-waste is reported to be collected and recycled, mainly by Turkey.

However, governments of some countries in Western Asia are showing increasing interest in adopting solutions to the e-waste problem. Many countries are currently receiving support from other countries or private companies that are interested in the business of e-waste recycling. For instance, in UAE, a facility is being built that will serve as the region's largest centre of expertise for electronic waste management in the Middle East. Expected to commence operations by the end of 2017, Phase 1 of the plant will comprise state-of-the-art equipment to process 39 kt of electronic waste annually.

As a way forward, the policy makers in Asian countries need a well-defined national e-waste management strategy based upon 3R concepts. They should also create enabling conditions for relevant stakeholders and take into account the financial, institutional, political, and social aspects of e-waste management, in particular incorporating the activities of the informal e-waste recycling sector.

Europe

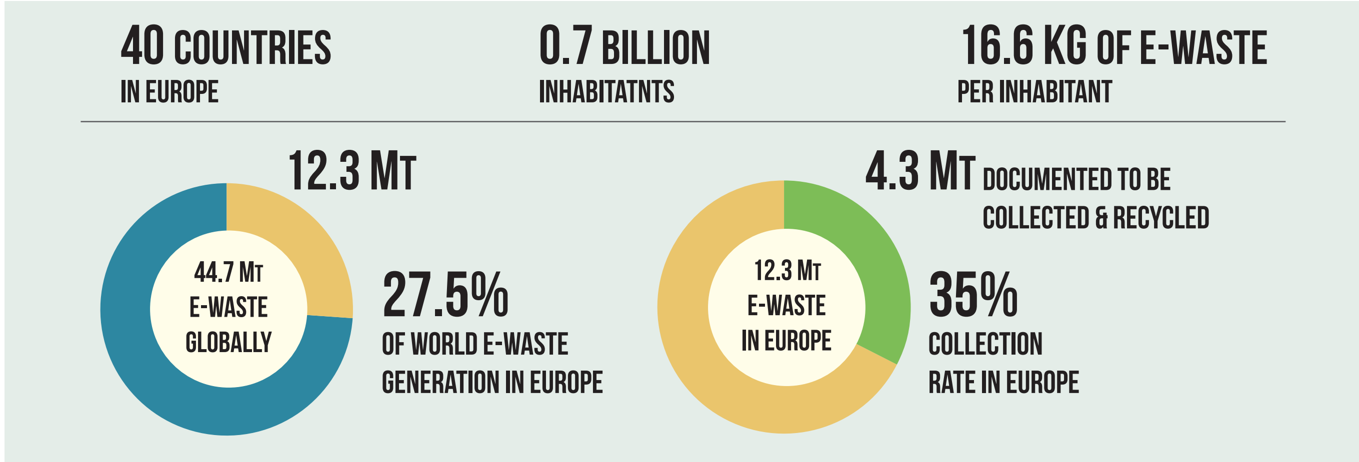
In Europe, the total e-waste generation in 2016 was 12.3 Mt, corresponding to 16.6 kg on average per inhabitant. Germany generated 1.9 Mt in 2016, which is the highest quantity in Europe, Great Britain and Russia generated 1.6 and 1.4 Mt. Norway generates the highest quantity of e-waste per inhabitant in Europe (28.5 kg/inh), followed by Great Britain and Denmark (each 24.9 kg/inh). Europe, Switzerland, Norway, and Sweden show the most advanced e-waste management practices across the globe. However, other countries are still catching up with Northern Europe, whose collection rate is 49%, the highest in the world.

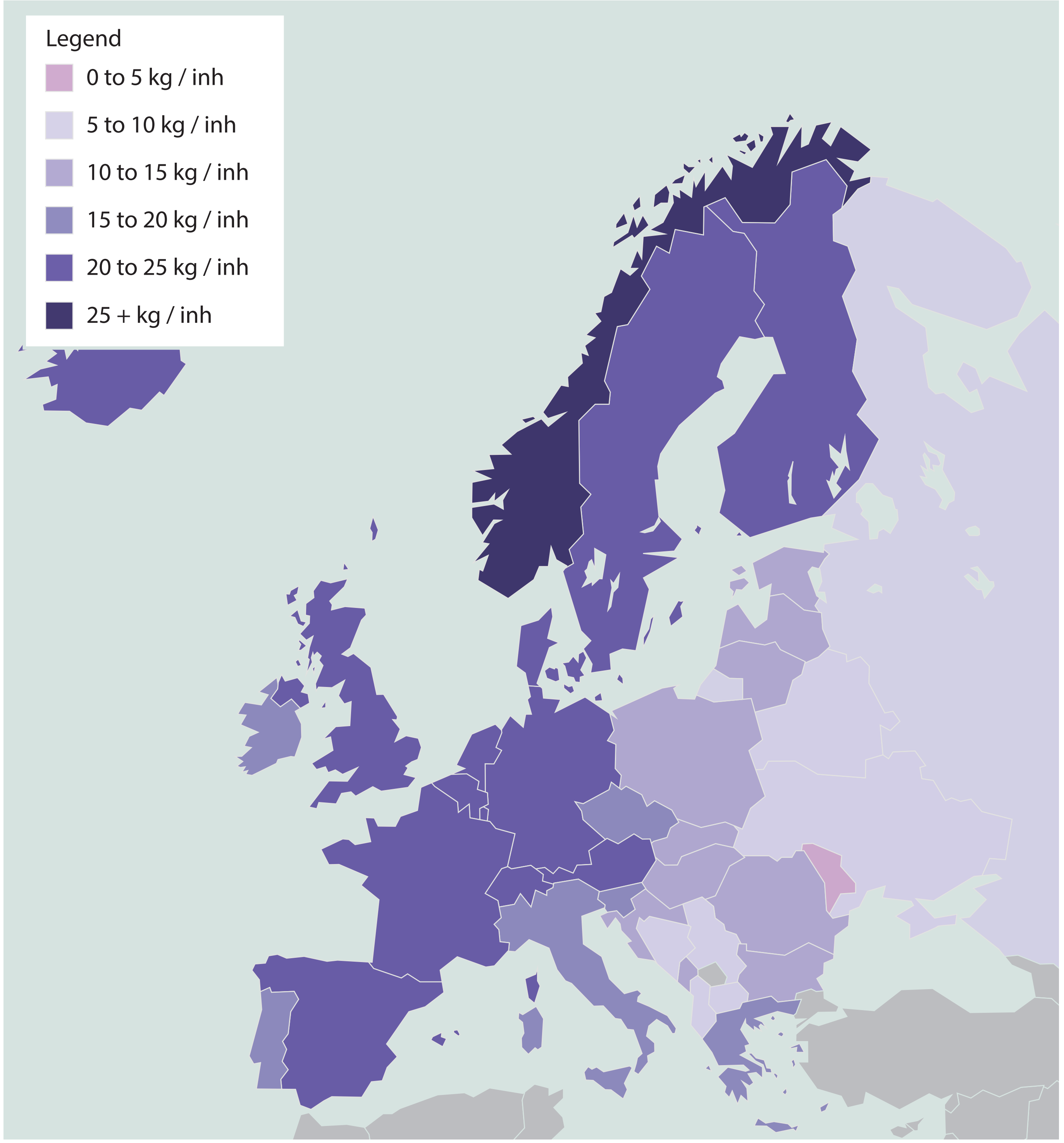
In the European Union (EU), the e-waste management is regulated uniformly by the WEEE Directive (2012/19/EU). The directive is meant to regulate the collection, recycling, and recovery of e-waste. It includes the provision of national e-waste collection points and processing systems, which enable the proper disposal and treatment of e-waste. This results in a higher quantity of processed e-waste that must be accounted for and reported to the national enforcement authority. The WEEE Directive prescribes that Member States shall encourage the design and production of electrical and electronic equipment, which accounts for and facilitates dismantling and recovery, in particular the reuse and recycling of e-waste, its components, and materials. Member States shall adopt appropriate measures in order to minimise the disposal of e-waste as unsorted municipal waste, and achieve a high level of separate collection of e-waste. The Directive requires Member States to create systems that allow final stakeholders and distributors to return e-waste free of charge. To guarantee environmentally sound treatment of the separately collected e-waste, the E-waste Directive lays down treatment requirements for specific materials and components of e-waste, and for the treatment and storage sites. This legal framework uses the principle of Extended Producer Responsibility, which requires producers to organise and/or finance the collection, treatment, and recycling of their products at end-of-life. Each Member State of the EU, Norway, Switzerland, and Iceland have implemented national legislation in accordance with the intrinsic conditions of the countries.

Since 2016, EU member states have needed to collect 45% of the amount placed on the market, with 65% by 2019, or 85% of the e-waste generated. Reaching these legal targets by 2019 will be very challenging. The official reported numbers by Eurostat have essentially not seen an increase since 2009 and remain about 37% of e-waste generated. A key issue, researched in-detail in the EU - Countering WEEE Illegal Trade Project[13], is to capture the tonnage present in multiple complementary flows, including discarding with other wastes (≈10% of waste), complementary non-reported recycling and scavenging of valuable parts and materials (≈40%), export for reuse (≈10%), and illegal exports (≈5%). The most recent country data is provided by the EU – Prospecting Secondary raw materials in the Urban Mine Project[14]. This data shows that the best performing countries in Europe, in terms of collection of e-waste, are Switzerland, which collects 74% of the waste generated, Norway (74%), followed by Sweden (69%), Finland and Ireland (each 55%). Ireland and Denmark collect 50% of the waste generated. It should be noted that the denominator of the collection rate are estimations by UNU that have an error of margin of at least ± 10% depending on the country, as already mentioned in chapter 5. Therefore, the highest mentioned collection rates indicate that these countries probably collect all or most of the e-waste, and outperform other countries in the world where collection rates are much lower.

In order to improve the official reported numbers, several countries, including France, Ireland, Portugal and the Netherlands, have been enacting the so-called 'all actors report' model. This includes metal scrap traders, recyclers operating outside the producer compliance programs, refurbishers, and second-hand shops to register volumes.

Another interesting debate relates to Critical Raw Materials in Europe, which are deemed critical to the EU economies. Here, the ProSUM project aims to prospect the amounts, concentrations, and presence of key components, materials, and vital elements to the electronics industry over time. An important ongoing effect is the increased miniaturisation of electronics. Despite a large increase in unit sales of TVs, monitors, laptops, and tablets, the total amount of 'electronics' and, thus gold content, is rapidly declining. From an





eco-design perspective, this means that more is done with less. However, recovering a larger range of more diluted materials poses future recycling challenges.

The e-waste legislation and knowledge on e-waste management in the Balkan sub-region still needs to be improved. Valid statistical data is still missing, as well as an infrastructure that provides e-waste disposal solutions. The sub-region is currently facing two major problems related to e-waste: most of the e-waste is disposed in landfills, and the current recycling and recovery activities lead to significate resource losses; both cause health and environmental damage. Given the fact that the gaps between the Union and its neighbours to the East, the Southern Caucasus, and the Mediterranean sub-region are worryingly large, the EU established the European Neighbourhood Policy (ENP) in 2003/2004 to align interests in tackling common problems, e-waste being one of them (European Commssion, 2007). The ENP Action Plans aim to assist the ENP partner- countries and Russia in addressing environmental concerns. They provide information on EU environment policy and legislation in key policy areas (including the WEEE Directive) and explain how progress can be achieved. In recent years, many initiatives have been carried out and financed by the European Union to improve the legal and institutional framework that enables proper e-waste management in the sub-region. Most of the ongoing projects aim to increase the capacities of the Balkan countries (in particular Macedonia, Serbia, Croatia, and Bulgaria) for lobbying and advocacy concerning e-waste management issues, and to raise awareness about proper e-waste management among citizens, government officials, and the private sector. Thanks to these collaborations, most of the countries in the Balkans nowadays have national legislation on e-waste in effect (Albania, Bulgaria, Bosnia and Herzegovina, Montenegro, Macedonia, Serbia, and Slovenia). Bulgaria, and Slovenia are members of the EU, and have therefore adopted the WEEE Directive. However, there is still no national legislation tackling e-waste in Kosovo. Although the Balkans sub-region has not implemented an effective e-waste take-back system like the EU Member States, initiatives are undertaken mainly by the private recycling sector. Approximately 158 kilotons (kt) of e-waste is currently collected in the Balkans comparing to the 512 kt generated in 2016. A minimum of 6.5 kg/inh was generated in Bosnia and Herzegovina and a maximum of 16.1 kg/inh in Slovenia.

The disposal structure of e-waste in Eastern European countries such as Russia, Ukraine, and Moldova is not as advanced as in the EU, and e-waste collection and recycling is insufficient despite numerous initiatives by the private sector, which doesn’t receive subsidies from the government. In this regard, many initiatives have been started to assist those countries in tackling e-waste, develop ad hoc legislation, and raise awareness. In countries such Poland, Czech Republic, Hungary, and Bulgaria, collection and recycling are mainly led by the private sector. In the recent years, the collection rate in those countries has risen to approximately 46% of the estimated e-waste generated in 2016. All countries in Eastern Europe, except Moldova, currently have national legislation that regulates e-waste. In 2017, Russia will start an Extended Producer Responsibility (EPR) programme for electrical and electronic scrap. Manufacturers and importers must help collect and process obsolete electronics in line with Russian circular economy legislation.

Oceania

In Oceania, the total e-waste generation was 0.7 Mt in 2016. The top country with the highest e-waste generation in absolute quantities is Australia (0.57 Mt). In 2016, Australia generated 23.6 kg/inh and New Zeeland 20.1 kg/inh. Only the Australian government implemented its National Television and Computer Recycling Scheme in 2011. Official data shows that only 7.5% of the e-waste generated in Australia is documented to be collected and recycled. In New Zeeland and the rest of Oceania, the official collection rate is 0%. New Zeeland is still in the process of developing a national scheme to deal with the e-waste issue. The e-waste is now mostly landfilled. Across the Pacific Island countries, e-waste management practices are predominantly informal.

Currently, there is only one law on the management of e-waste in Oceania. The National Television and Computer Recycling Scheme is one of the most significant producer responsibility schemes to be implemented in Australia under the Australian Government's Product Stewardship Act 2011. The Act came into effect on 8 August 2011. Under this Act, the Product Stewardship (Televisions and Computers) Regulations 2011 came into effect on 8 November 2011. This scheme provides Australian households and small businesses with access to industry-funded collection and recycling services for televisions and computers. The television and computer industries are required to fund collection and recycling of a proportion of the televisions and computers disposed of in Australia each year, with the aim to increase the rate of recycling of televisions and computers in Australia from an estimated 17% in 2010–11 to 80% by 2021–22 (Australian Government, 2012).

The co-regulatory aspect is a key feature of the above scheme, where the Australian Government, through the Regulations, set the outcomes to be achieved by industry, along with how it is to be implemented. The television and computer industries, operating through the approved co-regulatory arrangements (Producer Responsibility Organisation), will determine how to deliver these outcomes efficiently.

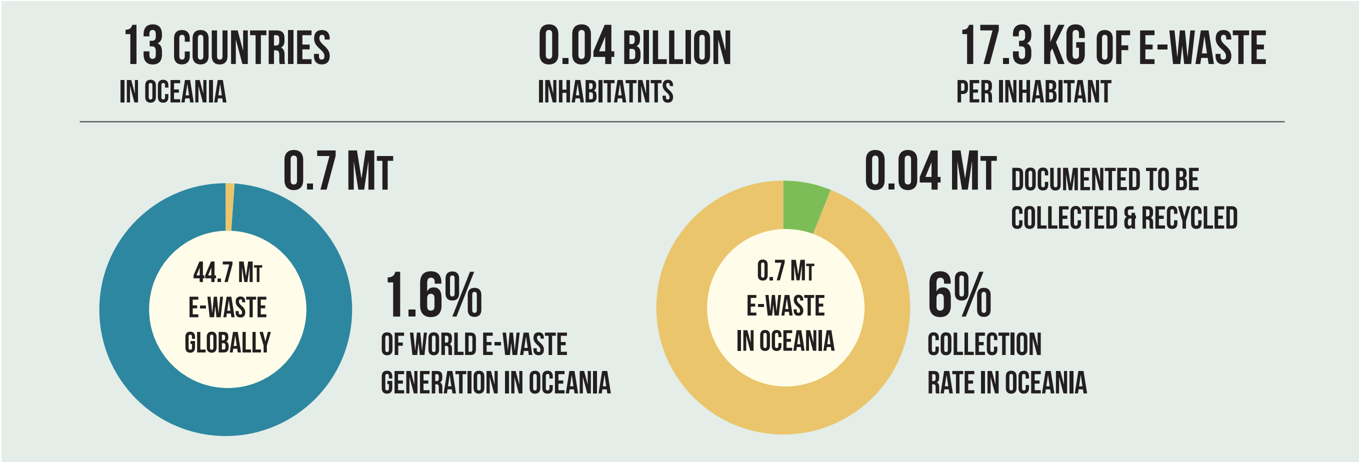
The Australian Government reports that, to date, over 1,800 collection services have been made available to consumers. An estimated total of 122 kilotons (kt) of televisions and computers reached end-of-life in Australia in 2014–15, out of which around 43 kt were recycled (35%) under this scheme. This a significant improvement from a recycling rate of only 9% in 2008 (Australian Government, 2017).

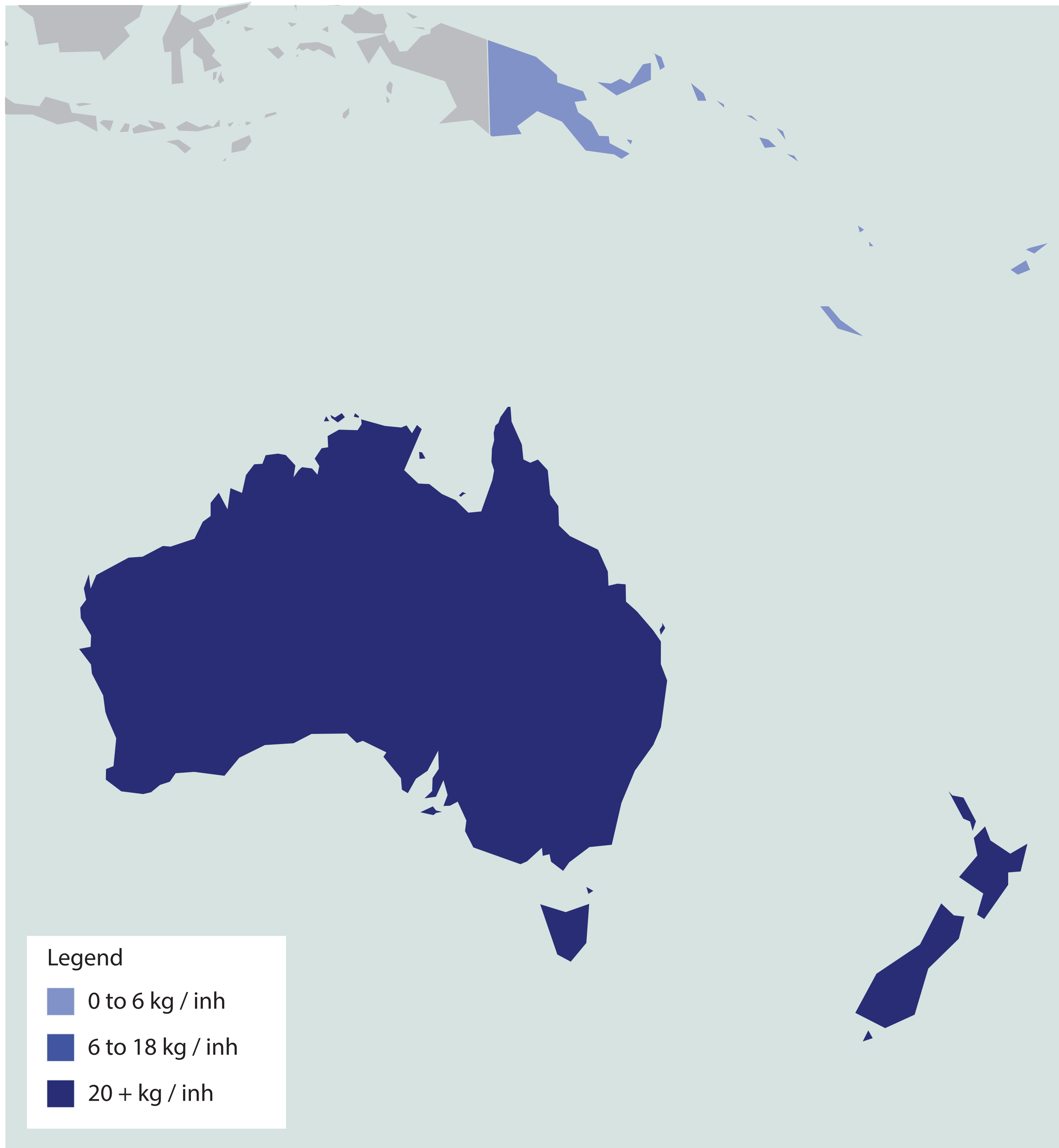
Compared to Australia, New Zealand is still in the process of developing a national scheme to deal with the e-waste issue. It is estimated that around 95 kt of e-waste is produced in New Zealand annually, no information is available on the amount of e-waste recycled, which is likely to go into landfills.

In 2014, the Ministry of Environment in New Zealand contracted a private organization to develop a product stewardship framework for managing e-waste in New Zealand. This organization undertook a comprehensive stakeholder engagement and consultation, together with collection and analysis of e-waste data, to develop recommendations for an e-waste stewardship option for New Zealand. It is understood that the New Zealand government is still considering these various options to decide on a particular scheme. They are also closely monitoring the success of the Australian scheme (SLR , 2015).

In addition to the above task, the New Zealand government has developed comprehensive guidelines for collection, reuse, and recycling of the waste of electrical and electronic equipment. These guidelines are targeted towards good management of health, safety, and environmental issues when reusing or recycling e-waste (Ministry for the Environment Manatū Mō Te Taiao, 2017).

The Pacific Island sub-region, consisting of 22 countries and territories (PICTs), faces unique challenges due to their geographical spread. The limited availability of suitable land on small islands for constructing landfills, remoteness, relatively small populations are causing issues of economies of scale for waste management technologies. Rapid urbanisation, and limited institutional and human resource capacities are among the key challenges faced by PICTs. Changing weather patterns and rising sea levels compound waste management challenges of PICTs. The waste management in the sub-region is governed by the recently adopted Pacific Regional Waste Pollution Management Strategy 2016-25 (Cleaner Pacific 2025), which





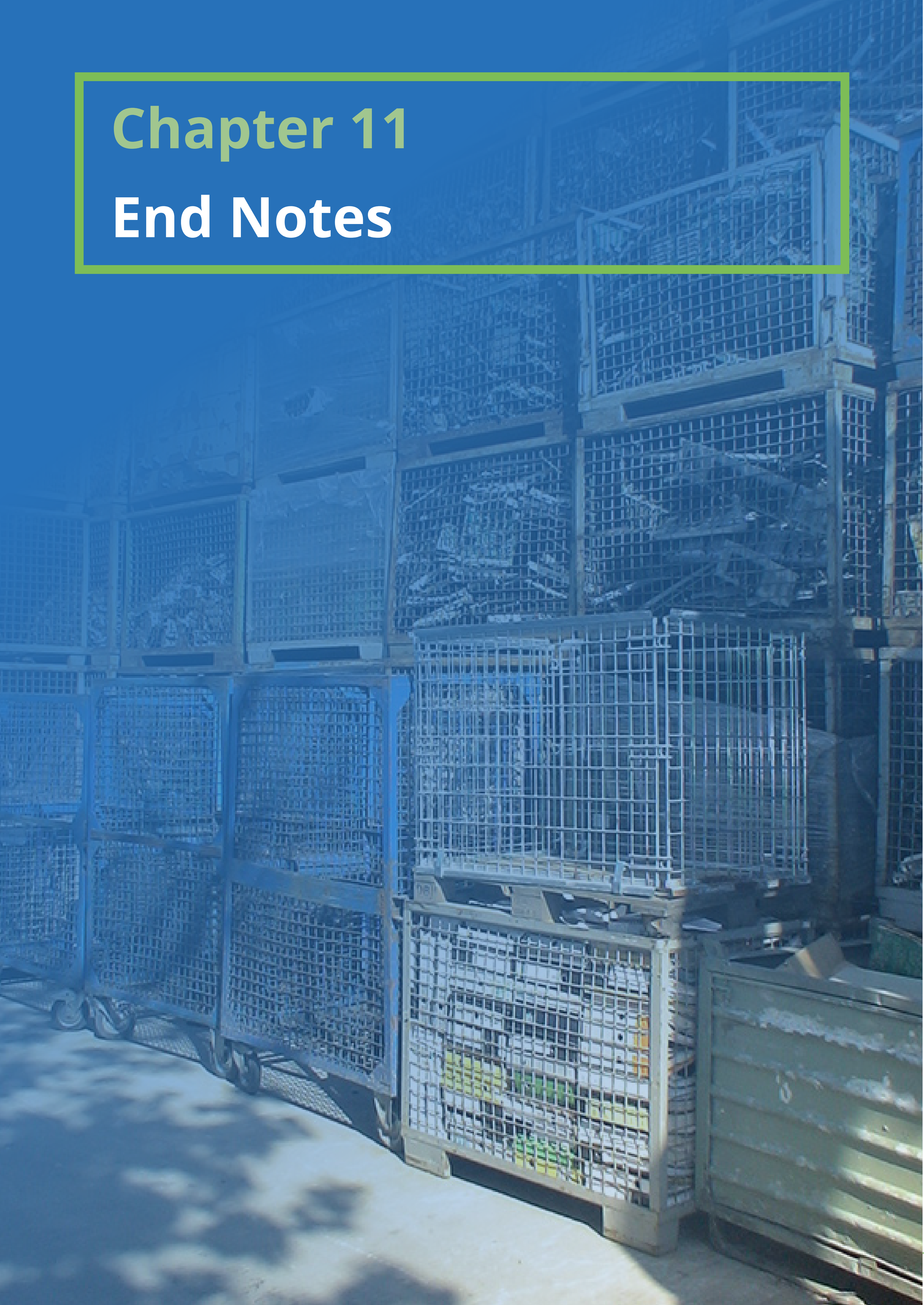
details the current situation and the future strategy for managing all the waste streams, including e-waste (SERP, 2016).

Currently in the Pacific, there are significant amounts of e-waste stockpiles awaiting disposal. The efforts to deal with this stockpile face challenges including economic, logistics, limited access to disposal points and recycling markets, and high costs in transporting e-waste out of the sub-region. To find a sustainable solution to the e-waste issues and other hazardous waste streams, the European Union funded a four-year project referred to as the PacWaste (Pacific Hazardous Waste), which is managed by the Secretariat of the Pacific Regional Environment Programme (SPREP) in Samoa. The initial aim of the project is to collect information about current e-waste management practices and stockpiles across five Pacific island countries in order to prioritize future actions that assist other Pacific islands countries to manage their e-waste stream.

The current e-waste management practices in the sub-region are predominantly informal. Most e-waste is separated at the disposal sites by waste pickers and sold to recyclers. The quantities of e-waste stockpiles in government institutions and commercial establishments are relatively unknown. As far as regulations are concerned, New Caledonia is the only place implementing an Extended Producer Responsibility (EPR) scheme for e-waste. New Caledonia's EPR scheme is managed by a non-profit environmental organisation (TRECODEC) that collects e-waste through voluntary drop-off receptacles and from authorised dumps.

Chapter 11

End Notes



1. http://www.itu.int/en/ITU-D/Statistics/Documents/partnership/E-waste_Guidelines_Partnership_2015.pdf
2. It should be noted that the number of subscriptions does not refer to unique subscribers or mobile phone users or owners. One person may have several mobile cellular or mobile-broadband subscriptions; or two or more people may share/use the same subscription.
3. This digitalization of broadcasting, which was formalized in an ITU agreement that was adopted by about 120 countries in 2006, responded to new requirements for a changing telecommunication environment and improved broadcasting experience. By mid- 2017, 55 countries had implemented the digital switchover and 66 countries were in the process of implementation. For more information, see: ITU 2015 and ITU 2017a.
4. In October 2016, for example, ITU approved Recommendation ITU-T L.1002 on “external universal power adapter solutions for portable ICT devices”. See http://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=10381.
5. The Partnership for Measuring ICT for Development is a multi-stakeholder initiative that was launched in 2004 to improve the availability and quality of ICT data and indicators. It established a task group on e-waste statistics under the leading role of the UNU and garnered support from various international agencies such as ITU, UNEP-Secretariat of Basel Convention, Eurostat, and UNCTAD.
6. For the world: Sales = Import – Export.

   For 28 EU Member States: Sales = Domestic Production + Import – Export.
7. The Harmonized Commodity Description and Coding System generally referred to as "Harmonized System" or simply "HS" is a multipurpose international product nomenclature developed by the World Customs Organization (WCO).
8. Purchasing Power Parity: PPPs are the rates of currency conversion that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, PPPs are simply price relatives that show the ratio of the prices in national currencies of the same good or service in different countries. (OECD, 2017).
9. http://www.complianceandrisks.com/c2p
10. http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx
11. http://www.step-initiative.org/news/person-in-the-port-project-to-examine-nigerias-e-waste-imports.html
12. http://www.env.go.jp/press/104201.html
13. http://www.cwitproject.eu
14. http://www.prosumproject.eu
15. The WEE Directive currently in force in the EU Member States list 10 categories for which data is collected (EU-10). However, since it lacks the ability to capture the effectiveness of waste management, the list of 10 categories has been recast to 6 categories, which are representative of the e-waste collection streams in practise (Baldé et al. 2015a).

Chapter 12

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Chapter 13

About the Authors

Kees Baldé splits his time between three employers. At the United Nations University, Kees is the Focal Point on e-waste quantifications, and statistical capacity building. At Statistics Netherlands, he is the Deputy Head of the team Environment Statistics. Next to that, Kees is a Member of the board of directors of the Dutch Waste Electronical and Electronic Appliances Register. He is an official delegate at several meetings and an experienced panelist and speaker. For Statistics Netherlands, he takes place as the chair of the Taskforce on Waste Statistics of the UNECE Conference of European Statisticians (CES), and he is in the board of the EU-H2020 Project Optimising quality of information in RAw MAterials (ORAMA Project). Kees earned his PhD at the Faculty of Chemistry at Utrecht University (Netherlands).

Vanessa Forti recently joined the SCYCLE Programme hosted by United Nations University (Vice-Rectorate in Europe) to work on e-waste related research projects, which aim to quantify both global and regional e-waste amounts and problems. She is recently involved in conducting capacity building workshops in developing countries on e-waste management and statistics in cooperation with key international organizations or United Nations institutes. Prior to this position, Vanessa worked on various projects aimed to solve the waste problems in developing countries. Vanessa is recently graduated with a Master's degree in Environmental Engineering from Università di Bologna (Italy) with a background in Civil Engineering too.

Vanessa Gray is the Head of the Division for Least Developed Countries (LDCs), Small Island Developing States (SIDS) and Emergency Telecommunications within the International Telecommunication Union's (ITU) Telecommunication Development Bureau (BDT). In this position, she is responsible for studying the ICT needs of LDCs, Landlocked Developing Countries (LLDCs) and SIDS, developing specific programs of assistance tailored to address the particular vulnerabilities of these countries, and identifying ICT for development opportunities. Vanessa coordinates the BDT's work in the area of Emergency Telecommunications, to develop ICT projects and provide assistance for disaster prevention, preparedness, mitigation, response, and recovery. She is also responsible for the BDT's work on e-waste and climate change adaptation. Vanessa holds a Master's degree in Political Science and Economics from the Graduate Institute of International and Development Studies in Geneva (Switzerland).

Ruediger Kuehr is the Head of the Sustainable Cycles (SCYCLE) Programme hosted by United Nations University Vice Rectorate in Europe. He co-founded the Step Initiative and functioned as its Executive Secretary from 2007-2017. Previously, he served as Head of UNU-IAS Operating Unit SCYCLE and as Head of the UNU Zero Emissions Forum (ZEF) – European Focal Point. A political and social scientist by education, he holds a PhD (Dr.rer.pol.) from the University of Osnabrück (Germany) and a M.A. (Magister Artium) from the University of Münster, (Germany), plus additional post-graduate studies in Tokyo (Japan) and Berlin (Germany). Ruediger has authored, co-authored and co-edited several books and regularly publishes and lectures on environmental policies.

Paul Stegmann was previously a project coordinator for the technical cooperation department at the International Solid Waste Association (ISWA). He is currently a PhD-Candidate at Utrecht University, working on projects in the fields of circular economy & waste management, bio-based economy and development cooperation.

Chapter 14

Annexes

Annex 1

A. Classification of EEE under the ten categories (EU-10) set out in Annex I to the WEEE Directive 2012/19/EU[15]

EU-10	Full name
1	Large household appliances
2	Small household appliances
3	IT and telecommunications equipment
4	Consumer equipment and photovoltaic panels
5	Lighting equipment
6	Electrical and electronic tools
7	Toys, leisure, and sports equipment
8	Medical devices
9	Monitoring and control instruments
10	Automatic dispensers

B. Classification of EEE under the six categories (EU-6) set out in Annex III to the WEEE Directive 2012/19/EU

EU-10	Full name
1	Temperature exchange equipment
2	Screens, monitors, and equipment containing screens (..)
3	Lamps
4	Large equipment
5	Small equipment
6	Small IT and telecommunication equipment

C. Classification of EEE under the UNU-KEYs and correlation of UNU-KEYs with the categories under EU-10 and EU-6 classification

UNU-KEY	Description	EEE category under EU-10	EEE category under EU-6
0001	Central Heating (household installed)	1	4
0002	Photovoltaic Panels (incl. inverters)	4	4
0101	Professional Heating & Ventilation (excl. cooling equipment)	1	4
0102	Dish washers	1	4
0103	Kitchen equipment (e.g. large furnaces, ovens, cooking equipment)	1	4
0104	Washing Machines (incl. combined dryers)	1	4
0105	Dryers (wash dryers, centrifuges)	1	4
0106	Household Heating & Ventilation (e.g. hoods, ventilators, space heaters)	1	4
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)	1	5
0201	Other small household equipment (e.g. small ventilators, irons, clocks, adapters)	2	5
0202	Equipment for food preparation(e.g. toaster, grills, food processing, frying pans)	2	5
0203	Small household equipment for hot water preparation (e.g. coffee, tea, water cookers)	2	5
0204	Vacuum Cleaners (excl. professional)	2	5
0205	Personal Care equipment(e.g. tooth brushes, hair dryers, razors)	2	5
0301	Small IT equipment (e.g. routers, mice, keyboards, external drives, and accessories)	3	6
0302	Desktop PCs (excl. monitors, accessoires)	3	6
0303	Laptops (incl. tablets)	3	2

UNU-KEY	Description	EEE category under EU-10	EEE category under EU-6
0304	Printers (e.g. scanners, multi functionals, faxes)	3	6
0305	Telecommunication equipment (e.g. (cordless) phones, answering machines)	3	6
0306	Mobile Phones (incl. smartphones, pagers)	3	6
0307	Professional IT equipment (e.g. servers, routers, data storage, copiers)	3	4
0308	Cathode Ray Tube Monitors	3	2
0309	Flat Display Panel Monitors (LCD, LED)	3	2
0401	Small Consumer Electronics (e.g. headphones, remote controls)	4	5
0402	Portable Audio & Video (e.g. MP3, e-readers, car navigation)	4	5
0403	Music Instruments, Radio, Hi-Fi (incl. audio sets)	4	5
0404	Video (e.g. Video recorders, DVD, Blue Ray, set-top boxes) and projectors	4	5
0405	Speakers	4	5
0406	Cameras (e.g. camcorders, photo, and digital still cameras)	4	5
0407	Cathode Ray Tube TVs	4	2
0408	Flat Display Panel TVs (LCD, LED, Plasma)	4	2
0501	Small lighting equipment (excl. LED and incandescent)	5	5
0502	Compact Fluorescent Lamps (incl. retrofit and non-retrofit)	5	3
0503	Straight Tube Fluorescent Lamps	5	3
0504	Special Lamps (e.g. professional mercury, high & low pressure sodium)	5	3
0505	LED Lamps (incl. retrofit LED lamps)	5	3
0506	Household Luminaires (incl. household incandescent fittings, and 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)	6	5
0602	Professional Tools (e.g. for welding, soldering, milling)	6	4

UNU-KEY	Description	EEE category under EU-10	EEE category under EU-6
0701	Toys (e.g. car racing sets, electric trains, music toys, biking computers, drones)	7	5
0702	Game Consoles	7	6
0703	Leisure equipment (e.g. sports equipment, electric bikes, juke boxes)	7	4
0801	Household Medical equipment(e.g. thermometers, blood pressure meters)	8	5
0802	Professional Medical equipment (e.g. hospital, dentist, diagnostics)	8	4
0901	Household Monitoring & Control equipment (alarm, heat, smoke, excl. screens)	9	5
0902	Professional Monitoring & Control equipment (e.g. laboratory, control panels)	9	4
1001	Non- cooled Dispensers (e.g. for vending, hot drinks, tickets, money)	10	4
1002	Cooled Dispensers (e.g. for vending, cold drinks)	10	1

Annex 2

E-waste Collection Data From Official Take-Back Systems

Data in kilotons (kt). The scope of the products that are collected and recycled do usually reflect the scope of the national legislation, and do not always match the scope of the products in Annex 3, except for data from Eurostat.

Region	Country / Economy	Year	Collection (kt)	Source
Africa	Mauritius	2011	2	Africa Institute 2012
Americas	Argentina	2013	11	Telecom Argentina
Americas	Canada	2014	148	Kumar et al., 2016
Americas	Chile	2012	0.7	Reporte de Sustentabilidad Bienal 2011-2012
Americas	El Salvador	2012	0.6	MINED
Americas	Honduras	2015	0.2	Rush Martínez et. al, 2014
Americas	Saint Lucia	2015	0.03	Roldan, 2017
Americas	United States of America	2014	1400	US EPA
Asia	China	2013	1290	China Ministry of environment
Asia	Hong Kong, Special Administrative Region of China	2013	56	Hong Kong EPD
Asia	Cyprus	2014	2.3	Eurostat
Asia	Taiwan, Province of China	2015	127	EPA Taiwan
Asia	Turkey	2015	125	EXITCOM
Europe	Austria	2015	80	Eurostat
Europe	Belgium	2015	118	Eurostat
Europe	Bulgaria	2015	62	Eurostat
Europe	Croatia	2015	24	Eurostat
Europe	Czech Republic	2015	74	Eurostat
Europe	Denmark	2015	72	Eurostat
Europe	Estonia	2015	5.7	Eurostat
Europe	Finland	2015	62	Eurostat
Europe	France	2015	596	Eurostat
Europe	Germany	2015	631	Eurostat
Europe	Greece	2015	49	Eurostat
Europe	Hungary	2015	52	Eurostat
Europe	Iceland	2014	3.4	Eurostat
Europe	Ireland	2015	49	Eurostat
Europe	Italy	2015	249	Eurostat
Europe	Latvia	2015	5.0	Eurostat
Europe	Lithuania	2015	16	Eurostat
Europe	Luxembourg	2015	5.8	Eurostat
Europe	Malta	2014	1.7	Eurostat
Europe	Netherlands	2015	145	Eurostat
Europe	Norway	2015	106	Eurostat
Europe	Poland	2015	199	Eurostat
Europe	Portugal	2015	65	Eurostat
Europe	Romania	2014	32	Eurostat
Europe	Russian Federation	2014	90	Analytical Center for the Governament of Russian Federation
Europe	Serbia	2015	13	IENE
Europe	Slovakia	2015	23	Eurostat
Europe	Slovenia	2015	11	Eurostat
Europe	Spain	2015	198	Eurostat
Europe	Sweden	2015	145	Eurostat
Europe	Switzerland	2015	134	WEEE Forum
Europe	United Kingdom of Great Britain and Northern Ireland	2015	663	Eurostat
Oceania	Australia	2014	43	Australian Ministry of Environment
Total from questionnaires		**2014 /2015**	**1063**	**UNSD, OECD, UNECE**

Annex 3

Domestic E-waste Generated Per Country in 2016

The amounts of e-waste generated are the sum of the six e-waste categories: Temperature Exchange Equipment, Screens, Monitors, Lamps. Large equipment, Small equipment, Small IT and telecommunication equipment.

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Afghanistan	Asia	32739	0.6	20	no
Albania	Europe	2885	7.1	20	yes
Algeria	Africa	40762	6.2	252	no
Angola	Africa	27360	3.3	92	no
Antigua and Barbuda	Africa	90	12.0	1.1	no
Argentina	Americas	43600	8.4	368	no
Armenia	Asia	2991	4.7	14	no
Australia	Oceania	24357	23.6	574	yes
Austria	Europe	8691	20.9	182	yes
Azerbaijan	Asia	9492	6.7	63	no
Bahamas	Americas	368	13.2	4.9	no
Bahrain	Asia	1319	15.5	20	no
Bangladesh	Asia	161513	0.9	142	no
Barbados	Americas	280	13.7	3.8	no
Belarus	Europe	9451	7.6	72	no
Belgium	Europe	11332	21.2	241	yes
Belize	Americas	377	6.0	2.3	no
Benin	Africa	11128	0.7	8.2	no
Bhutan	Asia	791	2.5	2.0	yes
Bolivia (Plurinational State of)	Americas	10896	3.3	36	yes
Bosnia and Herzegovina	Europe	3854	6.5	25	yes
Botswana	Africa	2154	7.6	16	no

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Brazil	Americas	206090	7.4	1534	no
Brunei Darussalam	Asia	423	18.3	7.7	no
Bulgaria	Europe	7114	11.1	79	yes
Burkina Faso	Africa	18420	0.6	11	no
Burundi	Africa	9648	0.5	5.0	no
Cambodia	Asia	15776	0.9	14	yes
Cameroon	Africa	23685	0.8	19	yes
Canada	Americas	36209	20.0	724	yes
Cape Verde	Africa	531	4.6	2.4	no
Central African Republic	Africa	4888	0.5	2.7	no
Chad	Africa	11855	0.7	8.8	no
Chile	Americas	18196	8.7	159	yes
China	Asia	1378984	5.2	7211	yes
Hong Kong, Special Administrative Region of China	Asia	7357	19.0	140	yes
Macao, Special Administrative Region of China	Asia	658	16.6	11	yes
Colombia	Americas	48750	5.6	275	yes
Comoros	Africa	823	0.8	0.6	no
Congo	Africa	4460	3.0	13	no
Costa Rica	Americas	4910	9.7	48	yes
Côte d'Ivoire	Africa	24327	0.9	22	no
Croatia	Europe	4204	12.6	53	yes
Cyprus	Asia	851	19.1	16	yes
Czech Republic	Europe	10561	15.9	168	yes
Denmark	Europe	5683	24.8	141	yes
Djibouti	Africa	993	0.9	0.9	no
Dominica	Americas	71	7.7	0.5	no

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Dominican Republic	Americas	10088	5.8	59	no
Ecuador	Americas	16529	5.5	90	yes
Egypt	Africa	91047	5.5	497	no
El Salvador	Americas	6146	5.8	36	no
Eritrea	Africa	6938	0.6	3.8	no
Estonia	Europe	1312	14.4	19	yes
Ethiopia	Africa	91196	0.5	49	no
Fiji	Oceania	895	5.1	4.6	no
Finland	Europe	5500	21.1	116	yes
France	Europe	64569	21.3	1373	yes
Gabon	Africa	1881	7.6	14	no
Gambia	Africa	2035	1.1	2.2	no
Georgia	Asia	3701	5.7	21	no
Germany	Europe	82571	22.8	1884	yes
Ghana	Africa	27573	1.4	39	no
Greece	Europe	10835	17.5	189	yes
Grenada	Americas	107	7.8	0.8	no
Guatemala	Americas	16673	4.0	67	no
Guinea	Africa	12654	0.6	8.0	no
Guinea-Bissau	Africa	1818	0.5	1.0	no
Guyana	Americas	769	6.1	4.7	no
Honduras	Americas	8203	2.3	19	no
Hungary	Europe	9835	13.8	136	yes
Iceland	Europe	336	22.6	7.6	yes
India	Asia	1309713	1.5	1975	yes
Indonesia	Asia	258802	4.9	1274	no
Iran (Islamic Republic of)	Asia	80460	7.8	630	no
Iraq	Asia	36067	6.1	221	no

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Ireland	Europe	4675	19.9	93	yes
Israel	Asia	8528	14.1	120	yes
Italy	Europe	61151	18.9	1156	yes
Jamaica	Americas	2829	5.9	17	no
Japan	Asia	126804	16.9	2139	yes
Jordan	Asia	7748	5.6	43	no
Kazakhstan	Asia	17947	8.2	147	no
Kenya	Africa	45451	0.8	38	yes
Kiribati	Oceania	116	0.8	0.1	no
Kuwait	Asia	4225	15.8	67	no
Kyrgyzstan	Asia	6059	1.2	7.2	no
Lao People's Democratic Republic	Asia	7163	1.0	7.5	no
Latvia	Europe	1976	11.0	22	yes
Lebanon	Asia	4597	11.1	51	no
Lesotho	Africa	1937	0.9	1.8	no
Libya	Africa	6385	11.0	70	no
Lithuania	Europe	2871	13.4	38	yes
Luxembourg	Europe	576	20.9	12	yes
Madagascar	Africa	24916	0.5	14	yes
Malawi	Africa	18632	0.5	9.5	no
Malaysia	Asia	31716	8.8	280	no
Maldives	Asia	354	6.9	2.5	no
Mali	Africa	16817	0.7	12	no
Malta	Europe	431	15.5	6.7	yes
Mauritania	Africa	3794	1.3	5.1	no
Mauritius	Africa	1259	8.6	11	no
Mexico	Americas	122273	8.2	998	yes

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Micronesia (Federated States of)	Oceania	103	1.7	0.2	no
Mongolia	Asia	3014	4.7	14	no
Montenegro	Europe	623	10.0	6.2	yes
Morocco	Africa	33827	3.7	127	no
Mozambique	Africa	28751	0.6	17	no
Myanmar	Asia	52254	1.0	55	no
Namibia	Africa	2300	6.0	14	no
Nepal	Asia	28834	0.8	23	no
Netherlands	Europe	17030	23.9	407	yes
New Zealand	Oceania	4712	20.1	95	no
Nicaragua	Americas	6342	2.2	14	no
Niger	Africa	18194	0.4	7.9	no
Nigeria	Africa	183636	1.5	277	yes
Norway	Europe	5263	28.5	150	yes
Oman	Asia	3957	14.9	59	no
Pakistan	Asia	192996	1.6	301	no
Palau	Oceania	18	9.3	0.2	no
Panama	Americas	4086	8.0	33	no
Papua New Guinea	Oceania	7911	0.9	7.0	no
Paraguay	Americas	6855	6.4	44	no
Peru	Americas	31481	5.8	182	yes
Philippines	Asia	104195	2.8	290	no
Poland	Europe	37967	11.9	453	yes
Portugal	Europe	10419	17.3	180	yes
Qatar	Asia	2578	11.3	29	no
Republic of Korea	Asia	50823	13.1	665	yes
Republic of Moldova	Europe	3553	1.8	6.3	no

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Romania	Europe	19760	11.6	229	yes
Russian Federation	Europe	143440	9.7	1392	yes
Rwanda	Africa	11530	0.5	5.9	no
Saint Kitts and Nevis	Americas	56	12.1	0.7	no
Saint Lucia	Americas	174	9.3	1.6	no
Saint Vincent and the Grenadines	Americas	110	8.3	0.9	no
Samoa	Oceania	195	2.6	0.5	no
Sao Tome and Principe	Africa	208	1.2	0.2	no
Saudi Arabia	Asia	32013	15.9	508	no
Senegal	Africa	15406	1.0	15	no
Serbia	Europe	7132	7.1	51	yes
Seychelles	Africa	93	11.5	1.1	no
Sierra Leone	Africa	6439	0.5	3.4	no
Singapore	Asia	5591	17.9	100	no
Slovakia	Europe	5422	12.3	67	yes
Slovenia	Europe	2065	16.1	33	yes
Solomon Islands	Oceania	601	0.7	0.4	no
South Africa	Africa	55870	5.7	321	no
Spain	Europe	46356	20.1	930	yes
Sri Lanka	Asia	21252	4.5	95	no
Sudan	Africa	39599	1.3	51	no
Suriname	Americas	563	9.6	5.4	no
Swaziland	Africa	1132	5.1	5.7	no
Sweden	Europe	10027	21.5	215	yes
Switzerland	Europe	8325	22.2	184	yes
Thailand	Asia	68981	7.4	507	no
The former Yugoslav Republic of Macedonia	Europe	2073	7.2	15	yes

Country / Economy	Region	Population (1000)	E-waste generated in 2016 (kg/inh)	E-waste generated in 2016 (kt)	National regulation in force in January 2017
Timor-Leste	Asia	1188	3.0	3.6	no
Togo	Africa	7509	0.9	6.4	no
Tonga	Oceania	105	2.4	0.3	no
Trinidad and Tobago	Americas	1364	15.8	22	no
Tunisia	Africa	11224	5.6	63	no
Turkey	Asia	78967	7.9	623	yes
Tuvalu	Oceania	11	1.2	0.01	no
Uganda	Africa	41087	0.6	25	yes
Ukraine	Europe	42501	6.5	277	yes
United Arab Emirates	Asia	9856	13.6	134	no
United Kingdom of Great Britain and Northern Ireland	Europe	65572	24.9	1632	yes
United Republic of Tanzania	Africa	48633	0.8	38	no
United States of America	Americas	323978	19.4	6295	yes
Uruguay	Americas	3427	10.8	37	no
Vanuatu	Oceania	275	1.0	0.3	no
Venezuela (Bolivarian Republic of)	Americas	31029	8.2	254	no
Viet Nam	Asia	92637	1.5	141	yes
Yemen	Asia	29132	1.5	42	no
Zambia	Africa	16717	0.9	15	no
Zimbabwe	Africa	14501	0.9	13	no

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