E-waste management practices in Australia

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23.1 Introduction

According to Solving the E-waste problem (Step), the term "E-waste" is an abbreviation of "electronic and electrical waste." A key part of the definition is the word "waste" and what it logically implies—that the item has no further use and is rejected as useless or excess to the owner in its current condition (STEP, 2019b). E-waste became a global environmental problem due to shorter product lifespan and posing serious challenges to policymakers managing such waste in environmentally, socially, and economically sustainable manner (Islam et al., 2016). Global E-waste generation reached 44.7 million tons (Mt) in the year 2016 and expected to reach 52.2 Mt by the year 2021 with an annual growth of 3%−4% (Balde et al., 2017). E-waste is generally categorized into six major product categories, as shown in Table 23.1. EU WEEE Directive is considered as the most comprehensive regulatory initiative based on extended producer responsibility (EPR) principle. Organization for Economic Co-operation and Development (OECD) defined "(EPR) as a policy approach under which producers are given a significant responsibility—financial and physical—for the treatment or disposal of post-consumer products." Metal fraction (ferrous and nonferrous), plastics, glass, and several rare-earth elements (REEs) are the major components that can be recovered from E-waste. On the other hand, if not properly managed, metals such as lead, cadmium, and mercury can seriously damage to the natural environment and human health. Recast of the Directives introduced 5% increase of collection (recovery) and reuse and recycling of several E-waste categories, for example, large household and small equipment from the previous mandate. Circular economy and urban mining are some of the critical policy implications that are now being implemented in several European countries, for instance, Belgium, Germany, and Denmark. Switzerland is one of the countries in Europe which implemented E-waste-related regulation far earlier (in 1998) than the inception of the Directive. Both in terms of harmful chemical components present and valuable secondary material recovery potential, E-waste possesses significant challenges to stakeholders in both developed and developing countries. Until recently, many of the developed countries disposed of their E-waste either to landfill or export to the developing countries, such as China and India where E-waste is recovered by following the crude process without considering human-health and degradation of the environment.

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Table 23.1 E-waste categories and recovery and/reuse/recycling percentage according to EU WEEE Directive 2012/19/EU.

Category	Product category	Example of product	Recovered (%)	Prepared for reuse or recycled (%)
1	Temperature exchange equipment	Temperature exchange equipment, more commonly referred to as cooling and freezing equipment: refrigerators, freezers, air conditioners, and heat pumps	85	80
2	Screens and monitors	Televisions, monitors, laptops, notebooks, and tablets	80	70
3	Lamps	fluorescent lamps, high-intensity discharge lamps, and LED lamps	-	80
4	Large equipment	Washing machines, clothes dryers, dish-washing machines, electric stoves, large printing machines, copying equipment, and photovoltaic panels	85	80
5	Small equipment	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	75	55
6	Small IT and telecommunication equipment	Mobile phones, global positioning systems (GPS), pocket calculators, routers, personal computers, printers, telephones	75	55

Source: Adapted from Islam, M.T., Huda, N., 2018. Reverse logistics and closed-loop supply chain of waste electrical and electronic equipment (WEEE)/E-waste: a comprehensive literature review. Resour. Conserv. Recycl. 137, 48–75. Available from: https://doi.org/10.1016/j.resconrec.2018.05.026; and STEP, 2019b. What is E-waste? Available from: http://www.step-initiative.org/E-waste-challenge.html (accessed 15.03.19.).

In this chapter, the current management system for E-waste in Australia (as one of the OECD developed countries) will be explored to have an overview of the system architecture, management strategies, and current barriers. Outlook will also be examined to make the system more sustainable, in terms of resource efficiency by proposing an innovative approach by which actors in the E-waste management system can achieve valuable insights in redesigning collection and recovery network.

23.2 EEE import, E-waste source, and generation

Australia is a large country (total area of 7,692,024 Km^2) with a relatively small population (24.6 million as of 2017) where the population is mainly concentrated in the major metropolitan areas and urban city centers which makes it as one of the most urbanized countries in the world (Australia, 2019). Australia is a net importer of electrical and electronic equipment (EEE). From 1988 to 2014, per capital, EEE increased from 10 kg to 35 kg that is growing dramatically between 2001 and 2004 (Fig. 23.1). Similar quantities of EEE consumption was experienced in the USA (23.5 kg/capita) and the UK (24.4 kg/capita) in the year 2012 (STEP, 2015). Australia shares a similar pattern in customer purchasing power parity (PPP) like as other European Union (EU) countries (Golev and Corder, 2017). Fig. 23.2 shows the EEE import in various categories, which is mostly dominated by the small IT, small equipment, and large equipment (mainly temperature exchange equipment) and screen and monitors. Products such as the laptop, tablet under the screen, and monitors dominate the most in the category. All these products represent almost 88% of the total EEE import. Screen and monitor category showed a relatively declining trend in the recent import, whereas small equipment (see Table 23.1) predominately possesses the largest share of EEE import. Overall, the import of EEE in Australia increased 10-fold from the year 1988 to 2014, and in the last decade, the import was doubled (Golev et al., 2016).

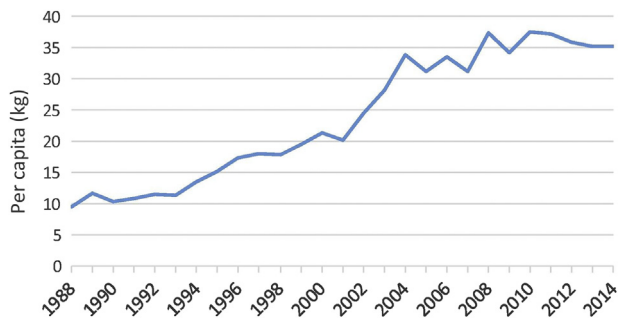

Figure 23.1 Estimation of EEE imports to Australia per capita.
Source: Adapted from Golev, A., Schmeda-Lopez, D.R., Smart, S.K., Corder, G.D., McFarland, E.W., 2016. Where next on E-waste in Australia? Waste Manag. 58, 348–358. Available from: https://doi.org/10.1016/j.wasman.2016.09.025.

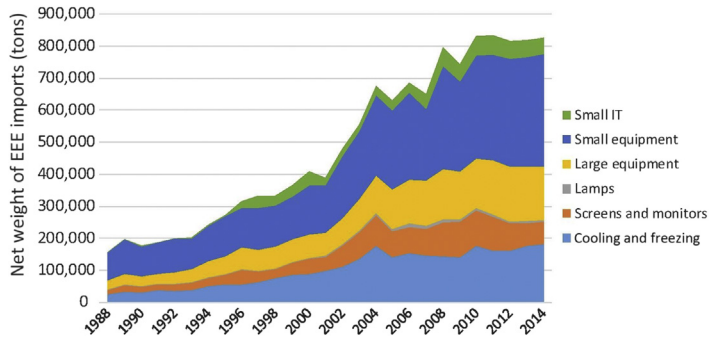

Figure 23.2 EEE imports to Australia (in net weight).
Source: Adapted from Golev, A., Schmeda-Lopez, D.R., Smart, S.K., Corder, G.D., McFarland, E.W., 2016. Where next on E-waste in Australia? Waste Manag. 58, 348–358. Available from: https://doi.org/10.1016/j.wasman.2016.09.025; UNComtrade, 2015. United Nations Commodity Trade Statistics Database.

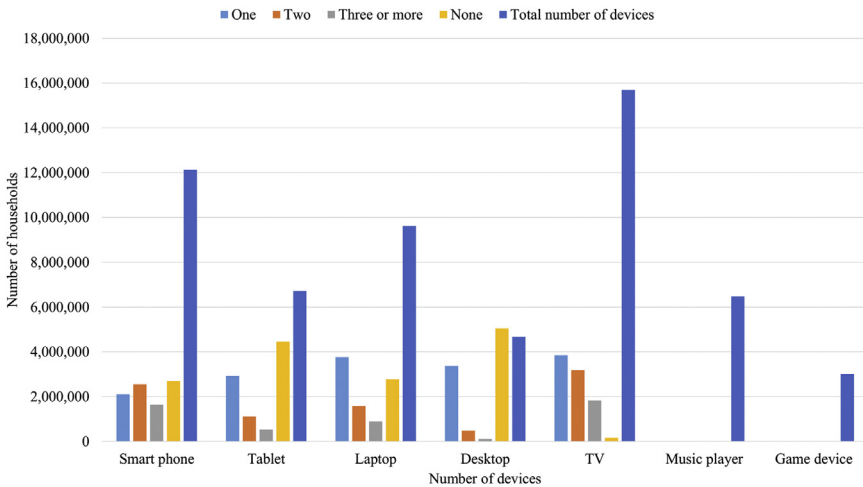

Figure 23.3 Number of households having electronic devices.
Source: Adapted from Zhu, X., Lane, R., Werner, T.T., 2017. Modelling in-use stocks and spatial distributions of household electronic devices and their contained metals based on household survey data. Resour. Conserv. Recycl. 120, 27–37. Available from: https://doi.org/10.1016/j.resconrec.2017.01.002.

A research study by Zhu et al. (2017) showed that within the product category of screen and monitor and small IT equipment, Australian households possess a significant number of equipment per households. Fig. 23.3 shows that TV sets stood the first in terms of possession (approximately 4 million households have at least one TV set) by the households, followed by smartphones (estimated 2 million households have two smartphones) and laptop (over 3 million households have at least

one laptop). According to the latest study by Australian Communications and Media Authority (ACMA), approximately 18.7 million working TV sets are available in the Australian households with an average number per households 2.2 (based on research conducted in the year 2011). This research also identified that the number of TV sets present in a household depends on the number of people (considering both adults and children) resides in a household. Sales of liquid crystalline display (LCD) and plasma TV sets increased from 1,348,000 to 3,036,000 units from the year 2007 to 2010 (ACMA, 2012). On the other hand, over 6 million households and close to 4 million households have a music player and gaming devices in their households. Several households that have tablet are higher compared to the mobile phone (for one item) (Zhu et al., 2017).

The state-wise distribution of various EEE components across Australia is shown in Fig. 23.4 indicating the highest number of the selected EEE (in all category) are in the state of New South Wales (NSW) followed by Victoria and Queensland. Most of these items fall under the category of small IT and screen and monitor. Mobile phones represent one of the key EEE items that are in use in all the states. By the end of 2014, in-use stocks of mobile in Australia reached approximately 46 million units, which are around two phones per person. Besides, in-use stock, there is an increasing amount of waste (obsolete) mobile are currently residing at the Australian home, which reached about 22.5 million units (Read, 2015). Laptop and Flat screen TV are the other items that also represent high in-use stock across the states in Australia. In the year 2017, around 800,000 units of laptop/notebook computers were shipped to Australia, which is higher than the Desktop and other workstations which were shipped roughly about 300,000 units (Spencer, 2018). This research has been carried out by International Data Corporation (IDC) which also

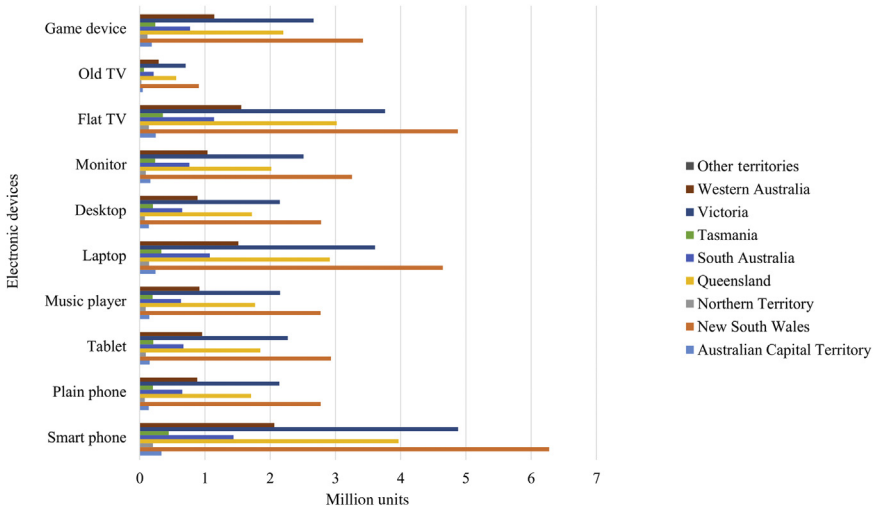

Figure 23.4 Number of electronic devices in Australian households across states (Zhu et al., 2017).

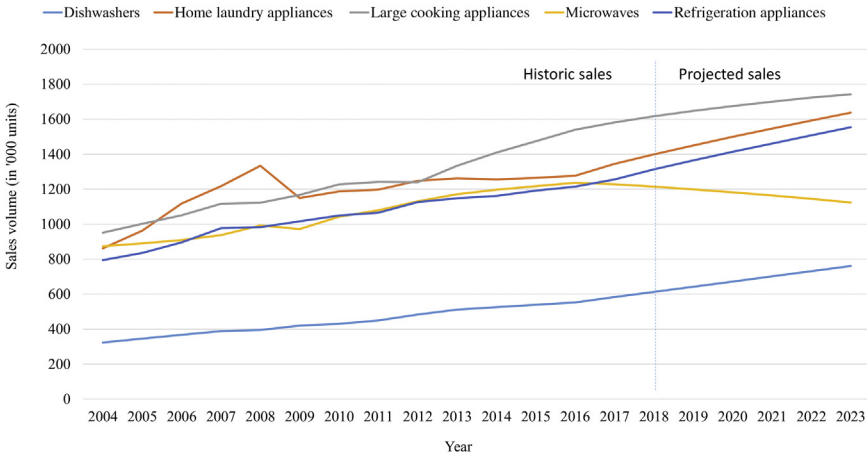

Figure 23.5 Sales volume of major consumer household appliances in Australia.
Source: Data from Passport, Euromonitor International (Euromonitor, 2019. Major consumer appliances in Australia. Available from: http://www.portal.euromonitor.com/ (accessed 22.03.19.)).

show that at the end of 2017, household customers (around 0.5 million customers) were the major buyer of traditional personal computer devices (IDC, 2018). These products fall under the product category of small IT equipment, which is higher in the concentration of precious and REEs.

Besides the small IT equipment category, huge sales volume is observed in other categories of EEE items, for example, large and small equipment. Fig. 23.5 shows the sales volume of major appliances in Australia from 2004 to 2018, where projected sales volume is estimated from the year 2019 to 2023. Small equipment, such as microwave ovens experienced a sales growth by 28% from the year 2004 to 2018, which will be stabilized in the future years as per projection. Refrigeration appliances, mostly temperature exchange equipment, such as freezers/fridges sales, were 873,000 units, which then increased to 1,313,000 units in the year 2018. It is obvious that with the increasing population (in other terms as a number of households), the major consumer equipment category will tend to increase as these are an indispensable part of modern households.

After the useful life or service life, the EEE items became obsolete and being disposed of in several channels. As mentioned earlier, Australia is one of the highest per capita E-waste generating nation with an average E-waste generation close to 25 kg/capita in 2014 as per research conducted by Golev et al. (2016) which will increase to 30 kg/person in the year 2024 (see Fig. 23.6). This figure is similar to some of the advanced nation in the European Union, for example Switzerland, wherein 2014, the per capita E-waste generation was 26.3 kg (STEP, 2019a) but slightly above in the context of other large countries, such as Germany (E-waste generation was 21.7 kg/capita in the year 2014) (STEP, 2019a). A wide variety of E-waste (depending upon the product types starting from small equipment to large

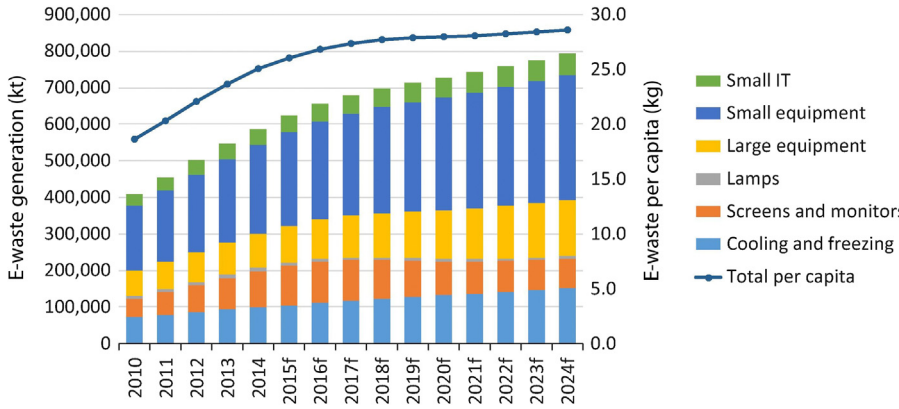

Figure 23.6 Estimated E-waste generation in Australia.
Source: Adapted from Golev, A., Schmeda-Lopez, D.R., Smart, S.K., Corder, G.D., McFarland, E.W., 2016. Where next on E-waste in Australia? Waste Manag. 58, 348–358. Available from: https://doi.org/10.1016/j.wasman.2016.09.025.

Table 23.2 The average lifespan of different EEE.

Sl. no.	EEE product	Average lifespan (in years)
1	Desktop computers	3–8.4
2	Flat-panel display (FPD) televisions, excluding CRT television sets	3.5–13
3	Laptop	2–9.1
4	Printer	3.4–8
5	Monitors (excluding CRT monitors)	1.8–10

industrial electrical and professional appliances) is generally generated from multiple sources, for example, households, businesses, and organizations. From Fig. 23.6, it is also evident that small equipment category consists of the highest proportion in the Australian E-waste generation scenario.

After the import to EEE products, customers use the products for several years (depending upon the lifespan of the product/service life of the components) then eventually reaches end-of-life phase or E-waste. Table 23.2 shows the average lifespan of different IT equipment and TV sets based on extensive data mining on the lifespan-related literature published in the international peer-reviewed journals.

At present, in Australia, households and small businesses can dispose of IT (mainly computer desktop and laptops), printers, and other IT peripheries and TV sets through National Television and Computer Recycling Scheme (NTCRS). The scheme is an industry-funded recycling program organized by the federal government, local government, and State and territory authorities via coregulatory

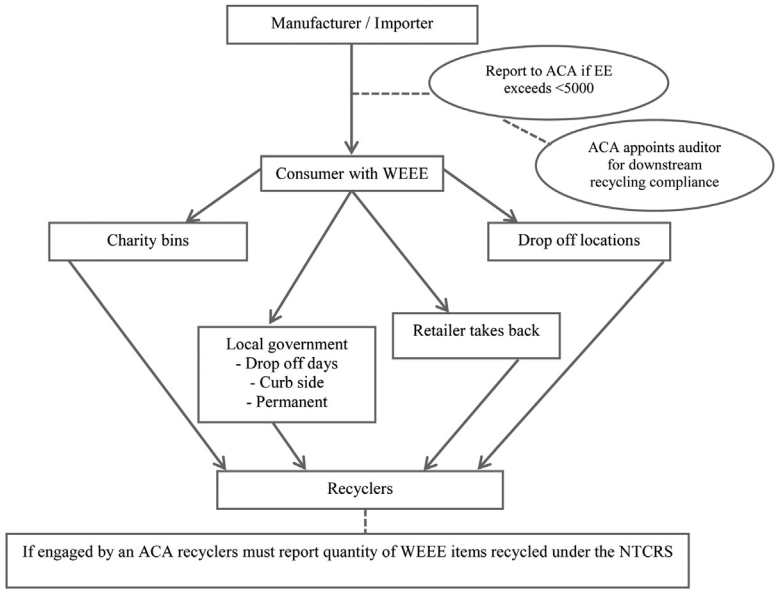

Figure 23.7 Flowchart of Australia's system for WEEE auditing, compliance, and reporting under the NTCRS.
Source: Adapted from Morris, A., Metternicht, G., 2016. Assessing effectiveness of WEEE management policy in Australia. J. Environ. Manage. 181, 218–230. Available from: https://doi.org/10.1016/j.jenvman.2016.06.013. ACA refers to approved co-regulatory arrangements.

agreements (detailed description will be given in Section 23.3). Customers from the households can drop-off their waste TV sets and computers and IT peripherals (later these are called as NTCRS products) at different locations such as local council collection points, event collections or via mobile community recycling centers (see Fig. 23.7). The latter is recently being introduced in some councils in greater Sydney metropolitan areas organized by the local councils and funded by Environmental protection agency (EPA) of the New South Wales (NSW) government. The collected waste TV sets and IT equipment then transferred to storage facilities to coregulatory arrangements (CRAs) which later then taken to approved licensed recyclers assigned by the coregulatory agreements. The CRAs work on behalf of the government to audit and report the amount of E-waste collection and material recovery. Details of the roles and responsibilities and structure of the NTCRS scheme and the CRAs activities are described in Section 23.3.

It is to be noted that customers from the households can only dispose of their NTCRS products under the current scheme and other types of E-waste (small and large equipment), as well as batteries, are not covered by the NTCRS. Majority of the products under small and large categories are either collected via scrap metal recyclers and disposed of in the council clean up a collection that eventually goes to landfill as customers have no other options available for the categories. Mobile phone and battery are currently collected and recycled under a voluntary scheme

Table 23.3 E-waste-related regulatory scheme and industry-funded collection programs.

Type of E-waste	E-waste category according to EU WEEE Directive	Name of the regulatory scheme	Type of scheme, year of inception	Collection results (latest reported)
TVs, monitors, laptops, tablets, desktops, printers, computer parts, and peripherals	Screens and monitors, small IT	National Television and Computer Recycling Scheme	Co-regulation, 2011	41,630 tons (2014/15)
Mobile phones (including batteries and accessories)	Small IT	Mobile Muster	Voluntary, 1998	76 tons (including 423,000 handsets) (2015/16)
Household batteries	—	Australian Battery Recycling Initiative (ABRI)	Voluntary, 2008	403 tons (10 million batteries) (2012/13)
Printer cartridges	—	Cartridges 4 Planet Ark	Voluntary, 2003	1500 tons (4 million cartridges) (2015/16)

Source: Adopted from Golev, A., Corder, G.D., 2017. Quantifying metal values in E-waste in Australia: the value chain perspective. Miner. Eng. 107, 81–87. Available from: https://doi.org/10.1016/j.mineng.2016.10.021.

named as MobileMuster and Australian Battery Recycling Initiative (ABRI), respectively. Large companies and institutions are generally used third-party leasing companies to take back the used IT equipment which is later sent to overseas for reuse. Table 23.3 represents the collection activities of different schemes in the existing E-waste management system in Australia.

The waste arising or the E-waste generation (under the NTCRS) is being calculated by the Australian government using the following Eq. (23.1):

$$\text{Waste arising or } E-\text{waste generation} = \frac{\text{Total weight of imports over past three years}}{3} \times \text{Scaling factor} \quad (23.1)$$

Here scaling factor depends upon the product type which was 0.8 for computers and 0.88 for printers at the beginning of the scheme (Government, 2018b) and now changed to 0.72 and 0.71 for computers and printers, respectively as per recent change in the regulation in the year 2018 (Government, 2018a). According to ANZRP (2017), use of scaling factor and subsequent calculation regarding E-waste generation is a good proxy of E-waste generation estimation, which considers the fact that all imported products will replace the existing e-products (that eventually disposed of as E-waste) that are currently in use. The scaling factor is related to

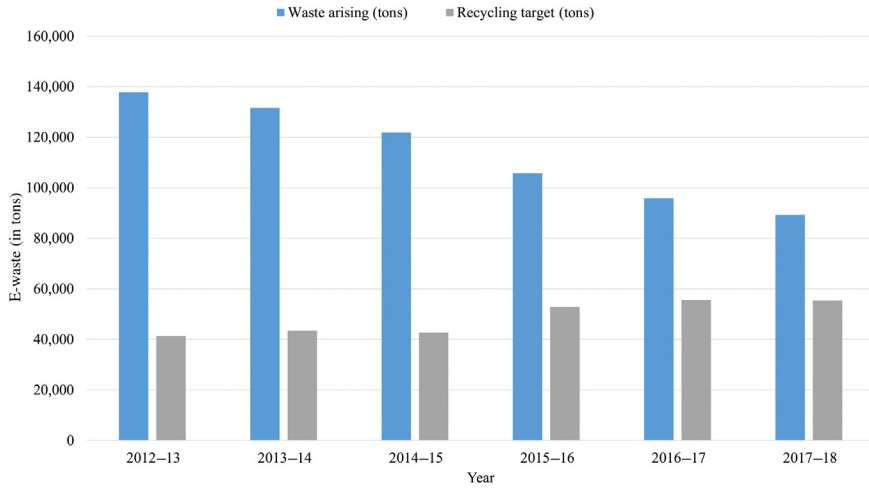

Figure 23.8 E-waste arising and recycling target over the years under NTCRS.
Source: Government, A., 2018b. Review of the Product Stewardship Act 2011 including the National Television and Computer Recycling Scheme. Available from: http://www.environment.gov.au/protection/waste-resource-recovery/product-stewardship/consultation-review-ps-act-incl-ntcrs (accessed 25.03.19.).

replacement level factor which was set previously 90% (or 0.9), meaning that in the same year, 90% of the products that are imported will result in the amount (in percentage) of as E-waste in that year. In terms of methodological approach results in overestimation and the total amount of E-waste generation (ANZRP, 2017). Fig. 23.8 shows the E-waste arising and recycling target using the formula shown in Eq. (23.1). It is seen that during the start of the scheme, the waste arising was higher compared to recent year (i.e., 2017−2018). This is because recently the scaling factor was adjusted and for computers and printers because presently it is considered that not all imported products replace existing products, and also some of the products do not become waste in Australia but instead of exported to other countries (Government, 2018a). Recycling target was achieved close to 60,000 tons in the year 2017−2018. However, there is still a considerable gap between the waste arising and recycling target. In the year 2015−2016, out of 105,699 tons of E-waste, only 43% of the E-waste was recycled (Government, 2018a).

23.3 E-waste-related regulation and program and management structure

The federal government of Australia enacted the National Waste Policy 2009 (Australia, 2009) in the year 2009 to update and integrate the existing waste management-related policy envisioning for the next ten years plan. Later on, in 2011,

under the policy statement, Product Stewardship Act 2011 (Government, 2011b) was established based on the EPR and product stewardship principles, "to effectively manage the environmental, health and safety impacts of products, and in particular those impacts associated with the disposal of products and their associated waste". The Act included three different types of product stewardship—voluntary, coregulatory, and mandatory. From Table 23.2 (illustrated before) showed that at present, there is no mandatory product stewardship scheme found active in Australia for E-waste management. NTCRS falls under the category of coregulatory product stewardship (PS) scheme. After the inception of the scheme in 2012, in the year 2012−2013, a total of 40,813 tons of E-waste (mainly TV and IT equipment) were recycled which increased to 46,206 tons in the year 2015−2016 (Australia, 2018). Up to today, the scheme has successfully recycled approximately 230,000 tons of electronic waste (Australia, 2018).

Initially, five CRAs were introduced in the scheme to conduct the operational activities (collection, auditing and reporting to the federal government) which is now become four as of the year 2018. Manufacturers, users, distributors and importers (later on called as "liable parties") of EEE who imports more than 5000 products or 15,000 peripherals need to subscribe with one of the CRAs with an obligation to collect and recycle a percentage of the items they import or manufacture in a year (Morris and Metternicht, 2016). One of the main outcomes of the act was to initiate the NTCRS providing the framework managing waste generated from computer, TV, and their peripherals. At present, there are four major CRAs working under the scheme named as Australian and New Zealand Recycling Platform (ANZRP), E-cycle solutions, EPSA, and MRI PSO. A total of 105 liable parties are currently involved with the CRAs under the scheme who are mainly importing EEE products to Australia. The parties fund the CRAs for the smooth running of the system, which also facilitates the "free" of charge drop-off services to the customers (i.e., households and small businesses).

The main duties of the CRAs as enterprises are achieving NTCRS outcomes (i.e., fulfilling collection and material recovery targets set by the Department of the Environment) and communicating with the public regarding the information on collection and recycling. The other important stakeholder in the NTCRS is the electronic waste recyclers who are contracted by the CRAs as per regulation of the NTCRS and follows the Australian Standard (AS5377) (Australia, 2013). Australian Government (the Department works on behalf of the government) is the supreme authority that computes the amount of NTCRS product's waste generation based on import data as well ensure compliances of the liable parties and CRAs meeting the scheme outcomes. Besides, these main actors, local government and state and territory government plays an important role in collecting the E-waste from the customers. However, their obligation is not mandatory, and they are authorized to execute any external measures for managing E-waste under their jurisdictions. Customers are not obliged to return their waste e-products under the scheme (Government, 2011a). As there is no substantial responsibility being placed on the households/general consumers, there is a presence of "free rider" effect on the system. For example, customer can dispose of their waste TV, computers, and printers

with the other bulky household wastes at the local government council's clean-up collection. Fig. 23.9 shows the roles and responsibilities of different actors under the NTCRS scheme. The whole scheme is funded by the industries (by liable parties) and the Australian government regulates it.

In terms of collection of the E-waste, as mentioned earlier, for NTCRS products, customers and small businesses can dispose of their waste TV and IT equipment to designated collection points provided by the CRAs. As per 2015−2016, there are just over 1200 collection points are made available for the customers to drop-off their E-waste, "free of charge" under the scheme, which collected approximately 50,000 tons of E-waste. Fig. 23.10 shows the collection amounts and the number of collection points available under the NTCRS over the years. From the figure, it is seen that the collection amount does not correlate with the collection points. One of the main mandates of the NTCRS scheme is that to provide reasonable access to collection points all over Australia, regardless of the characteristics of the area—metropolitan, inner regional, out regional, and remote locations. The collection points are generally organized by the local government councils. CRAs are being funded by the liable parties and collects E-waste from the permanent collection centers placed in the local government council areas. CRAs work towards achieving scheme target set by the Australian Government, and if they over-collect, they are not generally being paid off by the liable parties or any other source. It is to be mentioned that logistics services are being contracted by the CRAs to collect E-waste from the collection points to the storage areas and finally to the recycling facilities. The over-collection leads to removal of collection points from the certain council, which is often criticized by the residents of the council (ANZRP, 2017). This creates another problem for the councils that leads to landfill the E-waste, which is considered as the cheapest solution for them. On the other hand, even though reasonable access is required by the scheme, collection center locations are not optimized, especially for the rural and remote areas (DOEE, 2017). Another important choice of E-waste collection by the local councils is arranging an event drop-off event across Australia by which a considerable amount of E-waste is being collected. E-waste is also collected by the recyclers directly from the customers, but in some cases, they have to pay a nominal fee for the refurbishment of the product. However, this practice is not widely implemented by recyclers.

After the collection of the E-waste from the collection drop-off points, event drop-off, they are transferred to the recycling facilities for initial separation, segregation, and disassembly/dismantling. As per the regulation of the NTCRS, these recyclers are called first stage recyclers those are located in Australia. After initial processes, almost 90% of the materials (sorted) goes to overseas for further processing, and this process is called downstream recycling where sophisticated material recovery process is performed, such as pyrometallurgy, hydrometallurgy, and electrowinning. Schematic diagram of the entire supply chain (both forward and reverse flow) is shown in Fig. 23.11. In Section 23.4, the E-waste recycling process and technology used to conduct preprocessing is described.

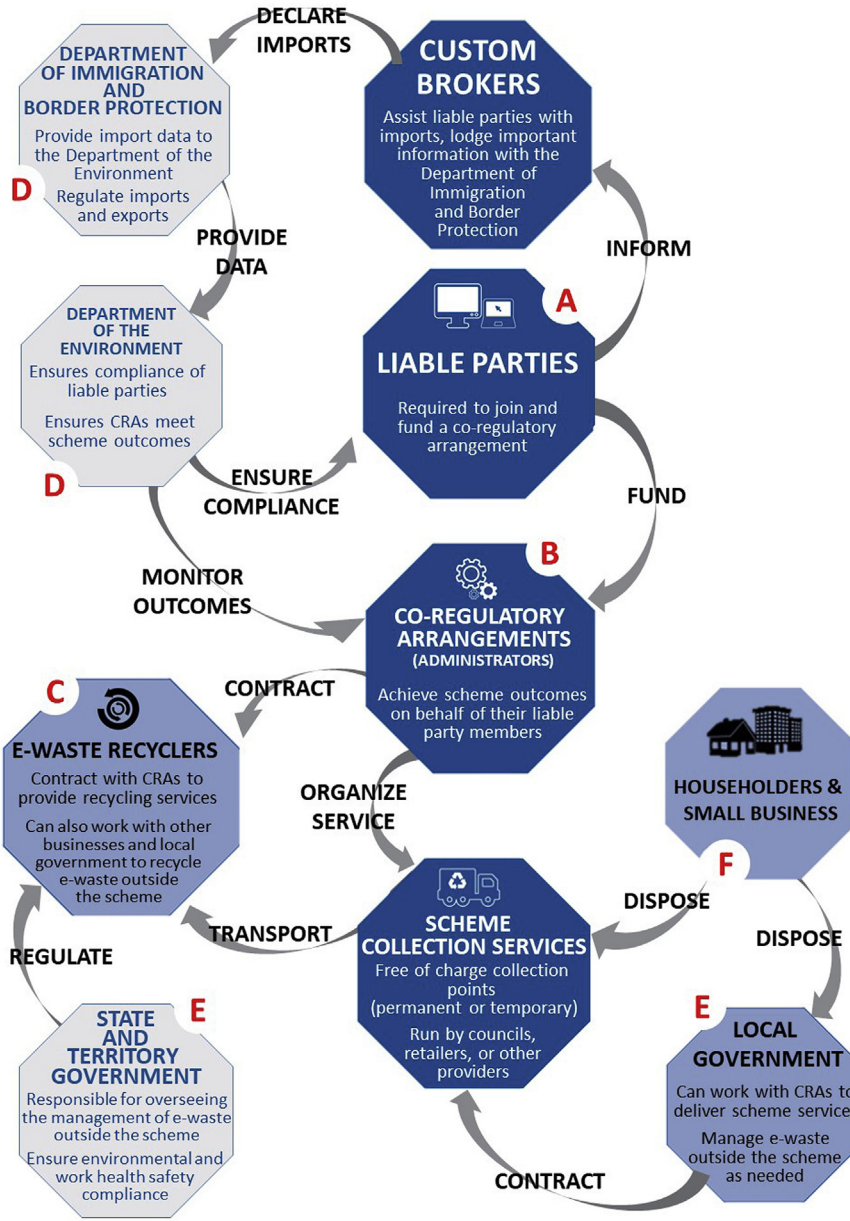

Figure 23.9 Roles and responsibilities under the NCTRS scheme.
Source: Adapted from Dias, P., Bernardes, A.M., Huda, N., 2018. Waste electrical and electronic equipment (WEEE) management: an analysis on the australian E-waste recycling scheme. J. Clean. Prod. 197, 750–764. Available from: https://doi.org/10.1016/j.jclepro.2018.06.161.

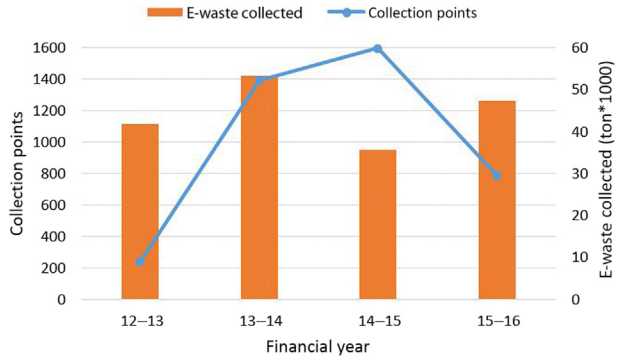

Figure 23.10 Permanent drop-off collection centers in Australia and collected amount of E-waste under NTCRS.
Source: Adapted from Dias, P., Bernardes, A.M., Huda, N., 2018. Waste electrical and electronic equipment (WEEE) management: an analysis on the australian E-waste recycling scheme. J. Clean. Prod. 197, 750–764. Available from: https://doi.org/10.1016/j.jclepro.2018.06.161.

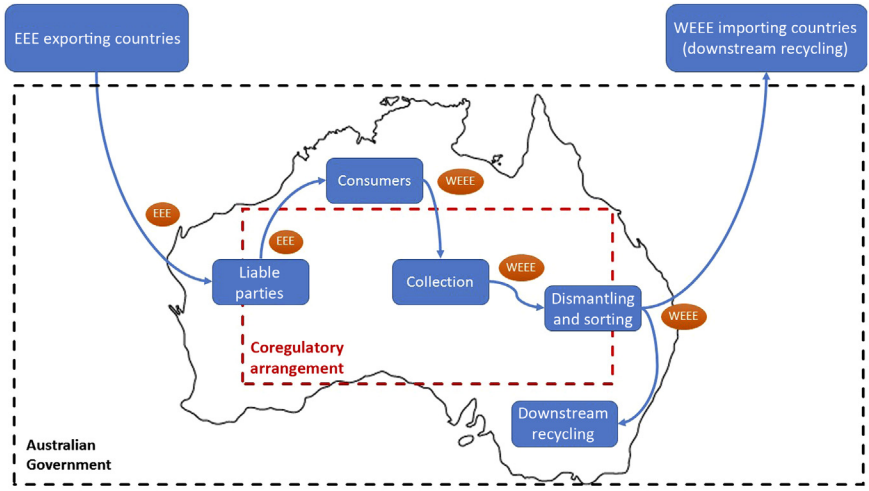

Figure 23.11 The current structure, WEEE flow and responsibility boundaries of the NTCRS.
Source: Adapted from Dias, P., Bernardes, A.M., Huda, N., 2018. Waste electrical and electronic equipment (WEEE) management: an analysis on the australian E-waste recycling scheme. J. Clean. Prod. 197, 750–764. Available from: https://doi.org/10.1016/j.jclepro.2018.06.161.

23.4 E-waste recycling system and treatment processes

The E-waste collected from different sources, customers, and businesses transferred to recycling facilities. Dias et al. (2018) identified that there are currently 31

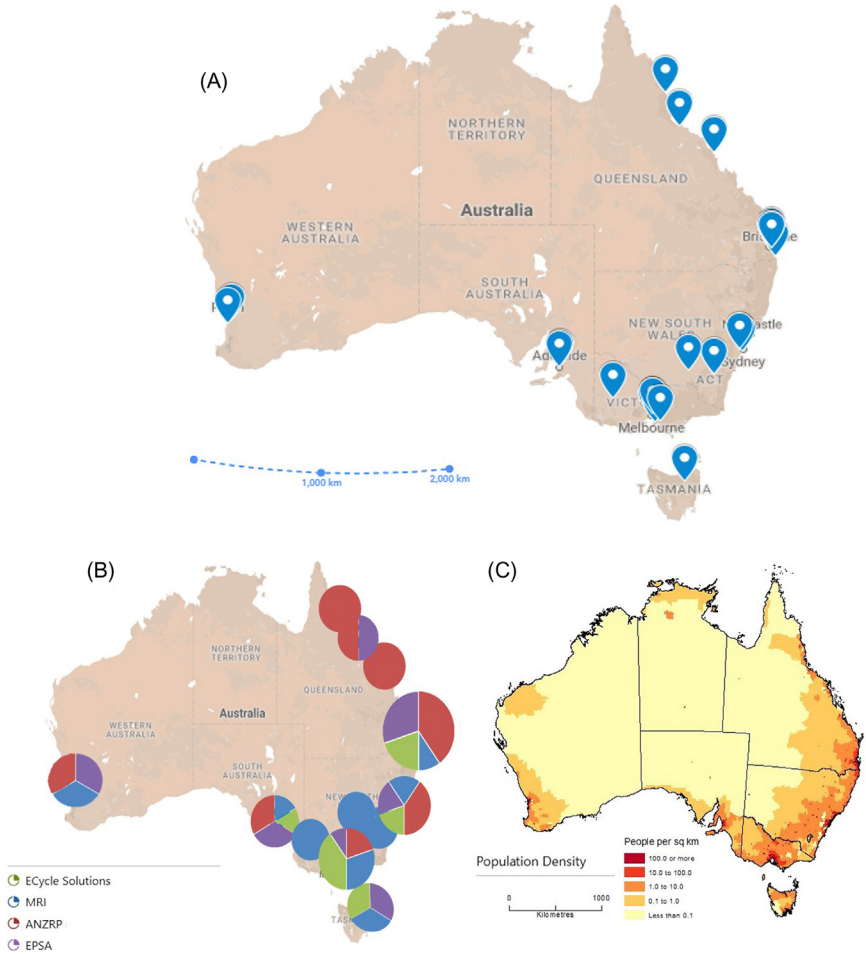

Figure 23.12 (A) Distribution of WEEE recyclers under the NTCRS in Australia; (B) influence of CRAs per facility per location; and (C) the population density in Australia in 2016.
Source: Adapted from Dias, P., Bernardes, A.M., Huda, N., 2018. Waste electrical and electronic equipment (WEEE) management: an analysis on the australian E-waste recycling scheme. J. Clean. Prod. 197, 750–764. Available from: https://doi.org/10.1016/j.jclepro.2018.06.161.

recycling facilities (run by 18 different E-waste recycling companies) in Australia under the NTCRS, which are responsible for initial processing according to the standard for the collection, storage, transport and treatment (AS5377). Locations of the recyclers across the states, the influence of CRAs on recyclers and population density of Australia are shown in Fig. 23.12. However, it is found that in some cases, recycling facilities are not optimized according to the population, especially in the state of New South Wales (NSW) and Western Australia (WA). For example,

one facility for every 500,000 people (Dias et al., 2018). Among the CRAs, ANZRP has the highest number of contracts with the recyclers (around 31.8%), followed by MRI (27.3%), EPSA (20.5%), and E-cycle (20.5%). There are some other recycling facilities that works outside the scheme for NTCRS product recycling which are categorized by independent recyclers (works on behalf of the liable parties), recycling facilities run by the liable parties itself and international and local downstream recyclers (who conducts further material recovery activities after receiving materials from the 31 affiliated facilities). Recycling facilities are often shared by the CRAs (who contract the recyclers and the recycling facilities) to enhanced amount of collection, minimize the reverse logistics fuel-consumption and cost (Dias et al., 2018).

It is to be noted that in general, the recycling facilities have their discretion in determining whether or not E-waste being recycled in Australia or not.

If considered E-waste recycling processes of the NTCRS products majority of the activities fall under the category of initial processing that includes manual sorting, manual dismantling, shredding, magnetic separation, eddy current separation, and so on (see Fig. 23.13A). As mentioned earlier, the recyclers who such processes are called "first stage recyclers." There is only one recycler in Australia that uses Blubox technology (that combines shredding and material separation altogether with high technology separation such as the x-ray separation). After the preprocessing, the material is forwarded to downstream recycler mostly to overseas affiliated recyclers. Exporting E-waste is also widely practiced. However, there is limited information so far identified in which condition and to what extent products are being exported (Fig. 23.13B).

E-waste exporting for processing in overseas countries is continuously increasing, starting from the year 2014−2015. China is the single most important recipient of E-waste from Australia under the scheme, which was over 40% (in all the years) of the total exported E-waste. Indonesia is another importing country that received around 35% of the NTCRS products in the financial year 2016−2017 (Fig. 23.14). India is the recent addition in the importer's group that imported approximately 3% of the E-waste from Australia. The CRAs mention that overseas recycling companies follow the Australian standard (Australia, 2013) for recovering metal from the E-waste items (ANZRP, 2017). However, the issue of monitoring the recycling process of the downstream overseas recyclers is still questionable (DOEE, 2018).

23.5 Challenges and recommendation

Morris and Metternicht (2016) pointed out that even though after the inception of the NTCRS, a significant portion of waste NTCRS products was diverted from landfill, but still there are opportunities for improvements. Some of the key areas such as the expansion of product coverage, refining role, and responsibilities of the E-waste management-related stakeholders, ease to customers and their engagement

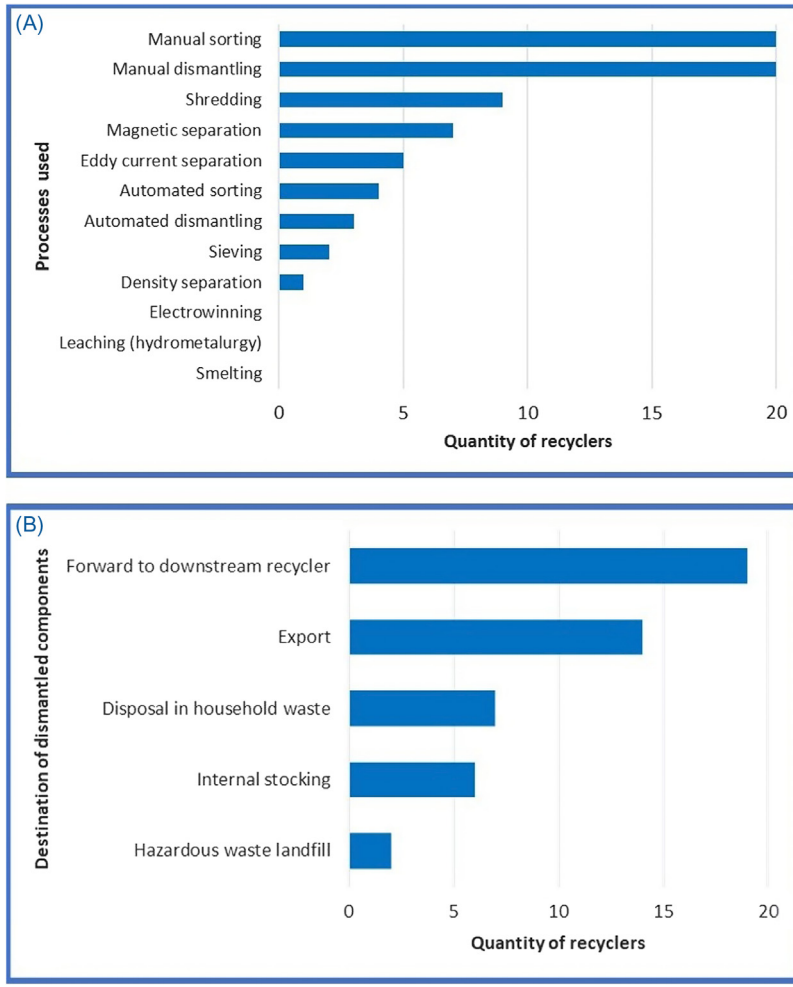

Figure 23.13 (A) Response to which processes are used and (B) response to the destination of the dismantled components.
Source: Adapted from Dias, P., Bernardes, A.M., Huda, N., 2018. Waste electrical and electronic equipment (WEEE) management: an analysis on the australian E-waste recycling scheme. J. Clean. Prod. 197, 750–764. Available from: https://doi.org/10.1016/j.jclepro.2018.06.161.

in the overall management system, setting enhanced and justified recycling, material recovery targets, ensuring audit, and compliance of the material flow of the system need attention. Based on the research identification and with other evidence, there are still several challenges that exist inside the scheme as well as in the whole E-waste management system in Australia, which needs to be overcome. These are described here in brief.

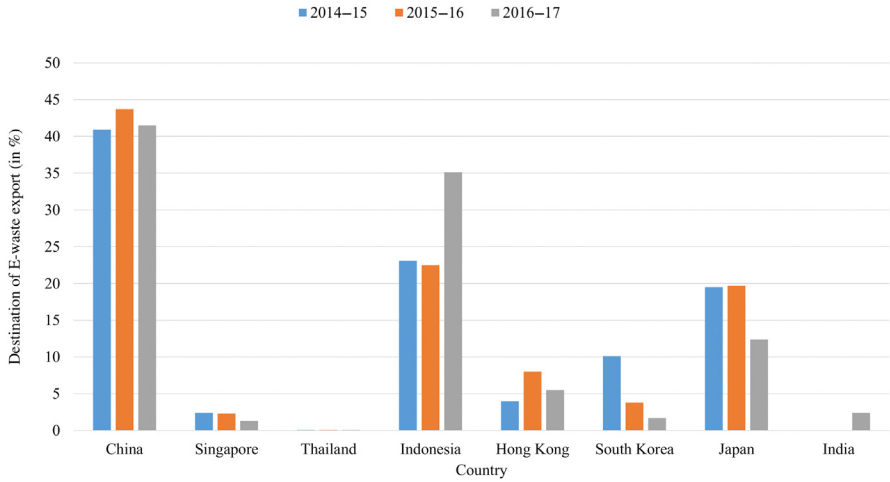

Figure 23.14 E-waste export to various countries from Australia.
Source: Adapted from Dias, P., Bernardes, A.M., Huda, N., 2018. Waste electrical and electronic equipment (WEEE) management: an analysis on the australian E-waste recycling scheme. J. Clean. Prod. 197, 750–764. Available from: https://doi.org/10.1016/j.jclepro.2018.06.161.

23.5.1 Role and responsibilities of stakeholders

Clear and defined stakeholders role in the E-waste management policy in Australia is one of the crucial issues that has been found by Morris and Metternicht (2016). Under the current E-waste management system, state and local governments need to manage E-waste outside of the NTCRS, which is significantly different from the management practice in Japan and Switzerland wherein all level of government need to have an active role in the system. Only the federal government of Australia maintains a consistent and active role in the current system. At present, not all local government councils are not working voluntarily with the CRAs in the NTCRS. However, it is found by the research conducted by Morris and Metternicht (2016) that due to cost effectiveness and service for the households, councils are more likely to engage with the NTCRS actively. Despite local councils are providing one of the most significant facilities to the scheme, which is the permanent collection points, "shared responsibility" from the council's perspective is not clear. Furthermore, local government councils receive the lowest amount of material or financial support, managing E-waste under the current system. Lack of funding as one of the key issues identified by Morris and Metternicht (2016). Increase the level of funding, increased involvement in the collection of E-waste defined the role of the local government council will substantially increase the performance of the E-waste management system in Australia.

23.5.2 Collection and recovery network

Existing collection and recovery network, particularly for remote and regional areas for E-waste at present is found insufficient research conducted by Morris and

Metternicht (2016) and Dias et al. (2018). Under the product stewardship regulation and the subsequent NTCRS, it is mentioned that "reasonable access" must be ensured for all Australian under the scheme. In that case, the definition of the reasonable access is not well defined, and it is found that currently, one service per 100 km for inner regional towns is operationalized which is found insufficient. In Japan and Switzerland, collection points are being placed in public places where consumers generally visit often, such as transport hubs and shopping precincts (Morris and Metternicht, 2016). However, not only placing the collection points at convenient locations but also substantial efforts have been given in the Japanese and Swiss system in educating consumers disposing of their E-waste in the collection points which is not very much evident in the Australian system. Furthermore, as there are no legal obligations among public disposing of their E-waste in designated collection points, there are hardly any complaints found from the consumers regarding reasonable access. Service areas by establishing collection points in the regional and remote areas need to be increased. Inconsistency has been shown in terms of reliability and access to service in Australian E-waste management. CRAs activities should be monitored regarding servicing or removing a collection site without prior notice given to local government councils. Local government plays an important role in placing collection points, and educating the public for them is easier than other stakeholders. This issue needs to be highlighted shortly by all government level along with how collection points can be established in the highest public proximity.

23.5.3 Expansion of product scope in the E-waste management system

Scope of products, particularly consumer electronics and small devices, need to be included in the future E-waste management system in Australia. At present, majority of the E-waste generated under small equipment category [the extensive list can be found in Forti et al. (2018)] does not belong to any specific recycling scheme, and there is hardly any retailer take-back operation present in the Australian EEE market right at this moment. In small device collection and recycling, customers are considered as the main actor in the entire loop, and EIU (2015) mentioned that retailer-based take back could be an appropriate option for this. Furthermore, Morris and Metternicht (2016) also mentioned that country like Australia, where the population density per kilometer is low, retailer based drop-off point for E-waste collection is one of the most suited options. Expansion of E-waste category in the management system will also eliminate the public confusion on what can or cannot be recycled in the council collection points. Insufficient public awareness of WEEE items exists in the current E-waste management system in Australia (Dias et al., 2018). Local and state governments across Australia should focus much on this issue to bridge the gap by providing adequate education and awareness, raising the program to the public. On the other hand, there are various means in including financial responsibility to consumers such as advanced recycling fees collected at

the point of purchase (like as practiced in Switzerland and the State of California in the United States) or in Finland; consumers must return their small equipment or EEE items to retailers. Another way making consumer responsible in disposing their E-waste at household-level is the introduction of "pay-as-you-throw," or PAYT system currently operated in the Netherlands. The amount of fees is calculated for a particular household based on the amount of waste they throw, which is comparatively higher compared to households that pay flat tax towards disposing of their waste. In the PAYT system, households are given strong incentives for disposing of their small E-waste in the appropriate channels, not as part of the waste generated as household waste. The major identification of the PAYT system in the Dutch E-waste management system found that consumers and small WEEE are a vital part of the holistic E-waste system. Another important fact that need to be understood at the first place that for large, temperature exchange equipment and small electrical and electronic equipment, there is no scheme or regulation currently exists, which gives opportunity to free raiders in the system, and tend to conduct activities such as illegal export despite being one of the signatories of Basel convention. Furthermore, due to lack of expansion, consumers most often dispose of their small and large equipment at the kerbside for council clean-up collection that eventually goes to landfill.

23.5.4 Effectiveness of compliance and audit on material recovery and recycling targets

As mentioned earlier, Australia's current NTCRS has been developed from the experience of Japan, Switzerland, and the European Union's WEEE Directive (Islam et al., 2018). In terms of material and recycling target, the NTCRS follows the example of Japan, and in June 2015, the target was set to 50% for the 2015 − 16 financial year which is envisioned to increase by 80% to 2026−27 (DOEE, 2018). The increase of recycling target resulted from several facts such as WEEE stockpiling, job losses across among the stakeholders, and termination of contracts and services. However, achieving set recycling target under the current management system is well debated (Morris and Metternicht, 2016). With increased recycling target the scheme needs to recycle a total of the 53,000 tons additional waste computer, TV, and IT peripheral, which is again, represents less than 10% of the overall E-waste generation in Australia. Furthermore, without a clear roles and responsibilities of local government councils, achieving such target will eventually a burden on the other stakeholders and without necessary enforcement and compliance measures, it is often hard to achieve such target (Morris and Metternicht, 2016). Also, due to inadequate compliance and auditing measures, it is also found that industry and public, in general, have a lack of confidence in the current E-waste management system. The E-waste management system is currently considered a standard called Australian/New Zealand Standard AS/NZS 5377:2013 for collection, storage, transport, and treatment. However, without the actual auditing at all the stages mentioned in the standard is not in place right at this moment. On

the other hand, as the recycling and labor cost is high in Australia, Morris and Metternicht (2016) mentioned that large volume of E-waste is being shipped to overseas illegally on the top of that lack of compliance and audit measure. The material flow analysis (MFA) is used in the Swiss E-waste management from the starting point of product recovery to the final material recycling providing a transparent outlook of the whole system and producer responsibility organizations in Switzerland are bound to generate such report each year to Swiss Federal Agency for Environment, Forests and Landscape (Wath et al., 2010). After the inception of the NTCRS, the downstream recycling process has not monitored by the CRAs. However, this is not the case for Australia, and a large-scale gap exists in Australian E-waste system for which illegal export of E-waste to developing countries is questionable, and responsibilities as a signatory under the Basel Convention often difficult to measure under the current system. Transparency by conducting an audit is one of the significant tasks that need to be undertaken by the stakeholders.

23.6 Conclusion

Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams all over the world. As a developed OCED country, E-waste generation in Australia showed an exponential growth in the past decades. Electrical and electronic equipment (EEE) of all variety starting from large and temperature exchange equipment to small IT and small equipment, the Australian market is fully saturated confirmed by the various market research organization. Before 2012, almost all waste generated from EEE, go to the landfill, which is loss of valuable metal sources and threat to the environment for possible environmental contamination. However, in 2012, under the product stewardship Act, National Television and Computer Recycling Scheme (NTCRS) has been initiated that diverted large amount of waste television sets, computer, and IT peripherals from landfill. However, the products covered by the scheme only covers less than 10% of the overall E-waste generation in the country. Besides, NTCRS currently MobileMuster is another voluntary, not-for-profit scheme accredited by the Australian government that collects and recycle waste mobile phones. Although NTCRS recovered a significant amount of E-waste from household and small businesses, there are still challenges that exist in the system. For example, allocating collection points in the regional and remote areas in the country, clear definition and shared roles and responsibilities of all stakeholders, especially the local government councils and state government. Lack of consumer awareness is found as one of the significant inhibitors in the current E-waste management system. Retailer-based collection and recovery network is one of the promising ways of recovering small IT and small equipment of the E-waste categories. Expanding the scope of E-waste in the management system is one of the potent ways in achieving economies of scale and avoiding consumer confusion on what can and what cannot be recycled in the system. Developing a detailed material flow analysis (MFA) model starting from the

import of EEE to the material recovery at the overseas under enhanced compliance and auditing is one of the most important and crucial tasks need to be carried out by the stakeholders in the system in the coming future. These all will ensure the sustainability of the E-waste management system in Australia.

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