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DOI
10.1016/B978-0-08-102158-3.00002-1

Publication date
2019

Document Version
Final published version

Published in
Waste Electrical and Electronic Equipment (WEEE) Handbook

Citation (APA)
Huisman, J., Stevels, A., Baldé, K., Magalini, F., & Kuehr, R. (2019). The e-waste development cycle - part i, introduction and country status. In V. Goodship, A. Stevels, & J. Huisman (Eds.), *Waste Electrical and Electronic Equipment (WEEE) Handbook* (2nd ed., pp. 17-55). (Woodhead Publishing Series in Electronic and Optical Materials). Elsevier. https://doi.org/10.1016/B978-0-08-102158-3.00002-1

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Chapter 2

The e-waste development cycle — part I, introduction and country status

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CHAPTER OUTLINE

Waste Electrical and Electronic Equipment (WEEE) Handbook. https://doi.org/10.1016/B978-0-08-102158-3.00002-1
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2.1 READERS' GUIDE (ALSO COVERING CHAPTERS 3–5 OF THIS HANDBOOK)

This chapter and Chapters 3–5 propose an iterative, multidimensional, and experience-based approach, called the e-waste development cycle. The e-waste development cycle proposed in more detail in Section 2.3 is purposely structured around key questions for each step of the development cycle to guide the reader through the most relevant elements. Table 2.1 lists these questions, including the numbering of the sections where more information is available.

To support answering the above questions, for each step in the development cycle proposed in Section 2.3, the following approach is taken in each section for "starting," "emerging," and "established" countries (which are defined in Section 2.1.2):

1. **Aim of the step in the development cycle.**
   A description of why the step is needed, the rationale and focus behind it, and the position in the development cycle in relation to other parts.
2. **Characterization, key questions (per type of country).**
   Characterization of the status in the country by means of elaborating on above key questions instead of providing of "precooked" answers.
3. **Common issues, experiences, and recommendations.**
   A description of the most observed common issues and of the probable tasks ahead.
4. **Possible tools and information sources**.
   A short listing of potential tools, experiences, and information sources available in the national and international domain.

2.1.1 E-waste and sustainable development goals

Since the rise in sales of electrical and electronic equipment (EEE), especially since the 1990s, societies are increasingly confronted with a multifaceted challenge when these products become e-waste or waste electrical and electronic equipment (WEEE). Electronics bring many improvements in basically every part of our daily life in the form of thousands of product types, applications for households and businesses as well as in all kind of energy, transport, and other infrastructures. At the same time, electronics contain a large variety of valuable components, materials, and elements plus toxic substances like mercury, cadmium, lead, and certain flame-retardants. Moreover, high global warming and ozone-layer depleting substances like

Table 2.1 Key development questions posed (also covering Chapters 3—5 of this handbook)

Development areas	Starting countries	Emerging countries	Established countries
Step 1: Country status: What is the status quo? Who is doing what? (Sections 2.5—2.7)			
Stakeholder involvement	2.5.1 Which government entities to include and who from outside?	2.5.2 How are stakeholders currently organized?	2.5.2 What are the current strengths and weaknesses of the e-waste system?
The wider policy framework	2.6.1 Which national and international regulations, policies, and standards are already in place?	2.6.2 How are the regulations in place functioning and how can implementation be improved?	2.6.3 What are the structural obstacles difficult to overcome?
Problem (re)definition	2.7.1 What are the core issues and magnitude of the problem?	2.7.2 What are root causes for lack of progress?	2.7.3 How to incentivize more collection and quality of treatment?
Step 2: How to collect more and treat better? (Sections 3.2 and 3.3)			
Assessment of collection	3.2.1 What basic data on e-waste volumes is available?	3.2.2 How to get better data for the complementary flows?	3.2.3 What is the quality of collected and reported volumes? How much scavenging takes place?
Assessment of treatment	3.3.1 How to improve formal and informal treatment?	3.3.2 How to optimize dismantling vs. mechanical treatment?	3.3.3 How to economically reward innovation in technology?
Step 3: What are the societal impacts (environmental, economic, and social)? (Sections 3.4—3.6)			
Environmental impacts	3.4.1 What are the most pressing environmental issues?	3.4.2 How to maximize environmental performance per collection category?	3.4.3 How to improve environmental performance of complementary recycling?
Economic impacts	3.5.1 How much funding is needed to set up initial infrastructure?	3.5.2 How to direct financing to treat complex fractions efficiently?	3.5.3 How to realize a level playing field? 3.5.4 How to optimize eco-efficiency of the system?
Social conditions	3.6.1 How many jobs are involved and what are the working conditions in the informal sector?	3.6.2 What are new job opportunities? How to improve health and safety?	3.6.3 How to enhance consumer education?
Step 4: How and where to intervene with Policy and Legislation? (Section 4.2)			
What needs to financed and how? (Section 4.3) What Technologies and Skills are needed? (Section 4.4)			
Policy and Legislation	4.2.1 How to timely develop sensible regulations for e-waste?	4.2.2 How to run a successful revision?	4.2.3 How successful is implementation in reality?

Continued

Table 2.1 Key development questions posed (also covering Chapters 3—5 of this handbook) *continued*

Development areas	Starting countries	Emerging countries	Established countries
The legal basis	4.2.1.1 Who should be in charge?	4.2.2.1 Which elements need specifically to be updated and extended?	4.2.3.1 How to improve proportionality and efficiency?
Scope, definitions, and requirements	4.2.1.2 Which products should be in the scope?	4.2.2.2 How to complement policies with implementation rules and standards?	4.2.3.2 How to mature implementation rules?
Responsibilities	4.2.1.3 How to include the informal sectors?	4.2.2.3 How to align stakeholder responsibilities?	4.2.3.3 How to mature stakeholder cooperation?
Business and Finance	4.3.1 What is affordable and what is not? Who can provide initial financial resources? Which financing mechanism to select?	4.3.2 Does the financing mechanism work properly?	4.3.3 How to reward quality in collection and treatment beyond basic compliance?
Technologies and Skills	4.4.1 How to develop a basic collection and treatment infrastructure?	4.4.2 How to improve preprocessing? Where to send complex fractions?	4.4.3 How to steer and stimulate innovation beyond economic optimized levels?
Step 5: How to develop a national road map? (Sections 5.2—5.4)			
Implementation Roadmap	5.2.1 How to be both ambitious and realistic in the first policy round?	5.2.2 How to plan a review round carefully and well and on time?	5.2.3 How to target the more complex challenges in conjunction?
Step 6: How to successfully implement the policy framework/road map? (Sections 5.6—5.8)			
Monitoring and Control	5.6.1 How to develop a basic monitoring framework? How to measure progress? What indicators to use?	5.6.2 How to improve reporting and a more structured monitoring and enforcement framework?	5.6.3 How to track system performance more real time and establish smart enforcement?
Education and Awareness	5.7.1.1 How to inform consumers about the initial collection infrastructure and enable quick learning for the informal sector?	5.7.1.2 How to extend consumer education and continuously involve all end users? How to involve local collectors, municipalities, and regional authorities?	
Design feedback	5.8.1 What about prevention measures in the policy framework? 5.8.2 How can green procurement and government asset management contribute? 5.8.3 What product information do recyclers need?		
(back to step 1: Country status and input to evaluation for the next development cycle)			

chlorofluorocarbons (CFCs) and even components with safety issues during transport (lithium ion batteries) are also part of EEE. At the end of the life cycle, e-waste poses considerable problems in multiple domains.

According to the latest Global E-waste Monitor, by 2016 the world had generated 44.7 million tons of e-waste. Of this volume only 20% is reported to be recycled through designated channels and only 41 countries in the world collect international statistics on e-waste (Baldé et al., 2017). This is showing a lack of assessment on the country level, although 66% of the world's population is currently covered by some form of e-waste legislation, despite not everywhere enforced. However, discarded end-of-life electronic products are not confined within national borders. Both the production side of electronics builds on an extensive global supply chain as well as the final fate of many products distributed all over the globe. Efforts to collect and treat electronics in a responsible manner contribute to a **global circular** reverse supply chain instead of a **linear** one. It requires that more countries' national e-waste systems and the eco-efficiency of existing systems are further raised. Developing these national e-waste systems goes beyond developing e-waste policies alone. For example, enacting stand-alone legislation on paper does not automatically create infrastructure for collection and treatment, nor does the presence of recycling infrastructures automatically result in the adoption of the best available technologies or internationally recognized standards. Creating producer responsibility organization does not necessarily make different stakeholders cooperate instantly. The development of national e-waste systems requires a whole range of policies, multistakeholder cooperation, interventions in many stages of collection, trade, and treatment, and both implementation and adaption of policies in a dynamic manner.

Developing national e-waste systems obviously contributes directly to the Sustainable Development Goal #12 (SDG12), Responsible Consumption and Production, by reducing the net footprint of electronics products and its waste. It also contributes many other areas of the SDGs indirectly (see Fig. 2.1): E-waste repair and dismantling could offer job and income opportunities and less poverty (SDG1); more efficient technologies especially in waste treatment supports good health and reduces casualties (SDG3); proper reuse and recycling enables equipping schools in poor countries with electricity and access to the Internet (SDG4); upgrading treatment and the banning of highly polluting treatment practices reduce the stress on water systems in developing countries (SDG6); new energy technologies, in particular small scale solar power and energy storage, supports the development of rural areas (SDG7, see also Magalini et al., 2016b, 2017a,b); the creation of jobs and more responsible types of work foster economic growth (SDG8);

■ **FIGURE 2.1** The sustainable development goals (United Nations, 2017. The Sustainable Development Goals Report 2017.).

the recycling industry can be expanded and become more innovative and can provide materials and components for economic growth (SDG9); e-waste collection and repair reduces municipal solid waste amounts, environmentally sound management of e-waste mitigates the toxic effects of hazardous waste, and proper treatment reduces air pollution for sustainable cities and communities (SDG11); and finally, reclaiming materials and components replaces mining of primary resources and the control over CFCs from refrigerators, in particular, both reduce CO_2 impact substantially (SDG13).

2.1.2 Three types of country e-waste development status

The contribution of countries to the sustainable development goals differs due to different priorities per country in relation to the above goals. Therefore, three types of countries are targeted with this document. Distinguished are countries **starting** with e-waste policies or considering them, **emerging** countries that have e-waste policies and some forms of regulated collection and treatment in place, and **established** countries with take-back systems in

place for a number of years and a considerable amount of regulated collection and treatment practices. Contrary to existing literature, in this chapter, these terms deliberately do not refer to their economic situation. Although a high correlation may exist, there are countries that are economically well developed but lacking national e-waste policies and collection and recycling infrastructure and also vice versa; there are also countries economically less advanced, but already developing their national system for electronics collection and recycling in the "emerging" countries group. The distinction is purposely made in this chapter as well as in Chapters 3—5 since different goals for developing national e-waste systems due to varying urgencies exist depending on the development status of the e-waste system:

- "Starting countries" are referred to as those without an e-waste system at all, or starting to explore lessons from other countries and considering drafting e-waste policies. **Their main goal typically is: "disaster prevention" and realization of basic toxic control and initial infrastructure development.** The focus is more on local (worker) protection and collection of the most hazardous items. The starting phase can include small pilots in collection and recycling that support figuring out basic environmental and economic parameters feeding decision-making processes. Also included are developing simple requirements desired for financing plus simple interventions, as well as improving the social conditions for e-waste workers by relatively simple measures providing a basis for potential (better) job creation. The nature of the steps to be taken are ideally as practical, noncapital intensive as possible, enabling quick learning with relatively little capital.
- "Emerging countries" are those with e-waste policies recently in place or still drafting legislation and/or discussing other measures. **The main goal commonly is the actual implementation and expansion of the initial collection and treatment system as well as upgrading practices to make the system more mature and efficient**. Often the main struggle is to modernize technologies and find better treatment options for various complex and hazardous fractions abroad when large facilities are not available in the country itself. Their main efforts commonly are to create a system that expands the initial collection system and more and more to include additional flows and incentives to the recycling industry to professionalize. The steps to be taken in this phase are to develop basic treatment standards, clear implementation rules, and the first steps in having a monitoring framework.
- "Established countries" are those that have e-waste policies implemented in practice, already reviewed their e-waste system and national

policies, and are modernizing and fine-tuning them. The main focus here is commonly on improved implementation and on including all waste flows in national reporting and monitoring systems. **Their main goal commonly is to get more value from materials and components and critical raw materials from e-waste product streams, to improve the quality of what is collected, to stimulate an innovative recycling industry, secure high levels of depollution, and adapt and limit the financing to where the market does not function by itself.** Here, full deployment of standards and having a full monitoring system in place are targeted.

The above groupings are intended to discuss the linkages and main themes most commonly found in relation to the e-waste development stages. The groupings are not intended as strict divisions nor as a qualification of individual country performance but refer rather to their approximate development stage regarding e-waste. It is quite well possible that countries are rather established in certain parts and less so in others. To our knowledge, besides a few countries approaching, no countries have a fully established and completely efficient take-back system. The reason is that collecting everything and processing all fractions at the highest possible level evidently does not occur in any country

See (StEP Initiative, 2009; StEP Initiative, 2014) for the various definitions used in this article.

2.2 THE NEED FOR A MORE ITERATIVE APPROACH

There are a number of existing sources describing the complete development process for e-waste systems and many more describing specific parts of it. Many articles and reports are written at various development points in time and from various perspectives. Most of these touch upon the complex process that e-waste system development is. Some of the approaches focus predominantly on the legislative principles and implementation (Magalini and Huisman, 2007; StEP Initiative, 2010), others focus more on the development needed for countries without any e-waste management (Schluep, 2012; Schluep et al., 2012; Méndez-Fajardo et al., 2017) or on countries emerging, for which technological options are being more discussed (Li et al., 2015; StEP initiative, 2016) and others focus more on countries with relatively well-established legislation and implementation like the European Union (EU) (Huisman et al., 2008; Magalini et al., 2016a) or the international developments like (Kuehr, 2018) in Chapter 1 of this handbook.

In addition, many good examples for individual countries and regions are found in reports like those for the United States (US EPA, 2011), Japan (Yoshida and Yoshida, 2013), and Hong Kong (Lau et al., 2013). Also for Korea (Yang et al., 2015), China (Wang et al., 2013a; Zeng and Li, 2018), East and Southeast Asia (Honda et al., 2016), India (Ganguly, 2016), Brazil and South Africa (Ghosh et al., 2017), and also for many developing countries there are structured assessments available, and for many African countries (Schluep, 2012) as well.

Only a few sources provide a more holistic and long-term perspective. When available, they are generally providing a rather linear approach by attempting to "copy-paste" the structures and measures of established e-waste systems to starting ones. Hardly any source provides a more flexible and iterative process focusing on the development at large, over long periods of time with changing priorities and with varying influences of stakeholders involved. Therefore, based on the conclusions from these existing approaches, combined with experiences observed in practice over many years, it is concluded that there are four basic needs for developing national e-waste systems, being the need to:

- Have balance between legislation, financing, and technological possibilities (Section 2.2.1)
- Have an iterative approach (Section 2.2.2)
- Have a more fact-based approach (Section 2.2.3)
- Have a differentiated approach (Section 2.2.4)

2.2.1 The need for balance between legislation, financing, and technologies

Systemic issues require systemic solutions

Legislation is important, but not the sole component of an e-waste framework. In almost all cases globally, the initiative for starting e-waste related legislation lies with national governments, their states or provinces. Adequate collection and treatment does require financing that is not automatically generated from the e-waste traders and recyclers whereas the revenues from secondary materials do cover the costs or the financing is not set aside to cover for logistics, depollution, and taking care of materials with a negative intrinsic value. Hence the start of e-waste system development usually means intervention in the markets (if present) with waste policies and regulations. However, the following must be considered:

1. Legislation is a vital but not the sole component for successful e-waste management. It is generally deemed necessary and even the prime

focus for many countries starting to develop their e-waste system. It can however not function without a proper implementation and enforcement and simultaneous structural financing of collection and recycling, development and transfer of technology and infrastructure, and cooperation of all actors involved in the product life cycle of electronics (Huisman, 2013). Furthermore, the actual efficiency under which a take-back scheme can operate like consumer behavior, lack of infrastructure and undesired trade, are usually both far outside the scope of legislation itself, beyond the control of the compliance scheme's influence, and heavily determined by the social, economic, and cultural conditions of individual countries.

2. Business conditions and finance are a second area of high importance. Without proper financing for the right activities, e-waste systems do not develop or only partially. In all countries and all situations, there is always a difficult balance to be found by those parts that "cannot pay for themselves" versus arranging for collection infrastructure, depollution of materials and components with a negative value requiring expensive final processing in dedicated facilities. Ideally all of this must be done in the most cost-efficient way without causing competition disruptions for recyclers and traders.
3. When financing is involved, obviously those paying for the system and ultimately selecting technologies and innovations will have to align themselves. Here, independently of who pays primarily, either consumers, producers, recyclers, or government (entities), both fierce as well as continuous discussions over the respective financial interests are common and inevitable. Section 4.3 does not provide one single recommendation nor a single optimal financial mechanism but rather focuses on the various options available. This also includes the relations and consequences of financing to the other domains. This is also a goal-dependent element that will change over time when the national e-waste system evolves. When these discussions between the financing and the other domains are not synchronized, which is unfortunately also a common finding, then delays and malfunctioning are evitable. This is the main reason why in the planning and decision focused Chapter 5, where the goals and interventions options are discussed, the three key development areas of legislation and finance (Section 4.2), Business and Finance (Section 4.3), and Technologies and Skills (Section 4.4) are to be aligned in the policy development process. Simply said, legislation alone will not work if there is no matching funding and no infrastructure present to implement the desired goals in practice.

Systemic issues require systemic solutions. Therefore, a national e-waste system development road map, including policy configurations as well as increased stakeholder cooperation and communication, increased knowledge exchange, training and education, plus research into successful strategies and basic fact finding are all required. Starting with policy analysis that considers political interests, the development of a feasible strategy toward sustainable solutions is possible. A multiplicity of factors such as the social and political inertia as well as economic interests and social contrasts, different interpretations of the present are comprehensively taken into account in the systemic approach proposed in Chapters 4 and 5. This approach is based both on scientific inputs as well as essential practical experiences gathered over the past 20 years in different countries and regions.

2.2.2 The need for an iterative approach

A circular issue requires a circular solution

The e-waste complexity requires a more circular solution for future generations instead of a linear solution. Taking into account the heterogeneous nature of e-waste products and an uneven distribution of the above issues per region, any approach in solving or mitigating the e-waste related problems has to be both tailor-made and preferably also include long-term evolution at the same time. The issues to solve are not just temporarily pressing but also affect future generations. In the long term, future generations will have to pay for the external effects of overconsumption and pollution in our generations. From this starting point, many sources and articles attempt to review, compare, and then filter the best approaches without taking the evolution component into play. It is understandable for academic authors, policy makers, and NGOs to be comprehensive in this regard. Nevertheless, practice shows a high degree of complexity, realization of progress is time consuming, as well as large differences per country, economy, and culture do exist. This usually means elements that are well functioning in established countries are "blindly" copy-pasted to countries where some elements are too far out in the future or not possible to align with existing economic conditions. Moreover, as introduced in Section 2.1.2, the goals for different countries are distinct and will change over time. Hence, it is important to note that EEE products have multiple societal impacts related to their consumption and recycling:

- Functionality: From a product design point of view, the first aspect is usually an inevitable material selection issue. Although not preferable for end of life, specific materials in electronic components and

products provide typical functionality that cannot be achieved to the same level by other means via substitutes. Almost the entire periodic table of elements is used in electronics due to complex functionalities. Often an environmental sacrifice in the material selection phase leads to functional and other gains in the life cycle load, like in lower energy consumption or product weights. Or recyclable materials are connected in such a way that separation becomes difficult and either labor or energy intensive.

- Potential toxicity: A clear environmental impact is intrinsic toxicity related to certain materials like cadmium, lead, and flame-retardants used in electronics design. Besides this, there is extrinsic and indirect toxicity coming from high energy consumption in extraction and refining and hydrometallurgical routes as well as from informal processing like stripping of circuit boards for gold in informal sectors.
- Emissions: Another type of environmental impact is direct nontoxic emissions from gases or substances present in electronics like CFCs from refrigerators with very high ozone layer depletion and global warming potentials. Indirectly, a large amount of environmental impacts is related to energy needed for material extraction, especially for precious metals and other metals with low ore concentrations and of course from incineration of plastics.
- Resources security: As a combined environmental and social impact, both long-term scarcity and short-term availability of materials is at stake. Most of the so-called critical materials are already scarce, so using more of them brings them closer to their depletion and generally higher energy consumption levels are needed for extraction. In other cases, there are fewer long-term concerns but significant fluctuations and short-term insecurities in the supply chain. Furthermore, another aspect is the strategic and political aspect related to certain critical materials coming from one of a few countries only. This applies to the certain elements with a geographically monopolistic potential or elements potentially critical for military equipment.
- Social: Another impact element refers to the social dimension. Here there are two subcategories: critical materials from conflict zones in, for instance, Africa, like tantalum and cobalt, and/or the sourcing of materials (both in extraction and waste) taking place in countries with social injustice (the ethical dimension), involving poor health and safety standards, inefficient extraction, and low-paid untrained personnel.
- Economically: Finally, of course the economic impact of collection and recycling is highly relevant. But also, as a consequence of the resource aspect, there is an economic dimension of sustainability when it comes to future availability and related prices of materials needed in

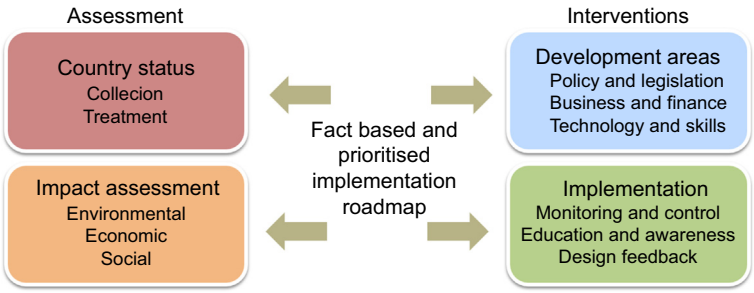
EEE products. In the short term, this issue this is seen in forms of price instability as a result of speculation on raw material prices.

An important source of information on how to arrange for the stakeholder consultations and ownership of topics is presented in Méndez-Fajardo et al., (2017). This document proposes a systemic design of the policy drafting process. However, these types of structured approaches are rarely feasible and cover many years with multiple parties involved. Commonly, long-term resources available for the suggested institutional, technical logistics, and methodological leadership that are proposed are not available. From a policy development perspective, to arrange for all of these above goals for all countries in the world, in one perfect development round, is virtually impossible. The necessary experiences, data, resources, and cooperation of actors are never available on time and in a balanced way. Moreover, the perspective toward the societal impacts and relevancies is very different for countries. Simply said, different priorities are based on the specific cultural and national context. Complex systems like take-back and recycling therefore require a growth model and many years to develop to higher performance levels as can be witnessed from the implementations in many of the established countries. This is the reason why in this and the next chapters, a more iterative approach is proposed.

2.2.3 **The need for a more fact-based approach**

If you cannot label it, you cannot measure it. If you cannot measure it, you cannot manage it.

An independent, continuous, and structured search for key data related to the performance of the national e-waste system is not luxury but very instrumental to a fast, forward-looking, focused, and flexible development. Therefore it is recommended to systematically conduct assessment of the collection and treatment infrastructure and the system's environmental, economic, and social impacts. Analysis of technical performance supports the selection of options independently to enhance the development of e-waste management significantly. Besides direct tangible results, a more fact-based communication pattern with actors holding the data and thus the system controls pushes also for better alignment of long-term objectives. At the same time, in the long run, unnecessary costs and environmental impacts are prevented. Countries able to tap into targeted assessment can benefit from research capacity and are likely tuned to base policy development on available facts and thus also more capable, faster, and more eco-efficient in their development pace. Therefore, we present the structure of



■ **FIGURE 2.2** The assessment versus interventions part of the e-waste development cycle.

the development cycle in two parts as illustrated in Fig. 2.2. In order to provide better clues in improving management, one needs to structure and label what parts are essential for developing national e-waste systems, which in turn forms the basis for assessment of the current situation, the thresholds, and the potential to improve. Therefore, the left-hand side of Fig 2.2 described in this chapter as well as in Chapter 3 provides the structure and assessment framework. The right-hand side described in Chapters 4 and 5 focuses more on the actual policy interventions and the management part in providing for different development stage experiences, tools, and improvement potential that are based upon the left-hand assessment side of Fig. 2.2.

2.2.4 Learning by doing

One size does not fit all.

This is one of the most important lessons drawn from years of experience in e-waste system development.

1. Many documents and discussions on the principles behind e-waste system development exist. However, principles do not bring change by themselves, **only learning by doing** provides direct feedback on what works well and what does not. Here, there is a difference between blindly copy-pasting versus learning from free experiences observed elsewhere. There are of course many free lessons from other parts of the world, in particular where the roles of physics, money, and technology are very similar. Local conditions can differ substantially, hence implementing free lessons from elsewhere to these conditions are preferable over lengthy discussion rounds about principles and what-if scenarios. Especially as mentioned in Section 2.1.2 for starting countries,

initiating the process by running small collections and dismantling pilots is significantly speeding up the development process.

2. **The development inevitably costs money**. This shows that from the start a decision who will pay and how needs to be taken as early as possible and adapted when needed. It will get broader acceptance when the chosen (initial or existing) financing level is transparent, delivering maximum performance and is as low as possible.
3. **Government** entities can have an initiating, leading, and coordinating role, but **need partners to execute policy measures.** Here, a practical form that is not often selected is to establish a coordination group that includes, besides government, also producers and recyclers (or their associations). The advantage is that in this case there are always two out of three (government and recyclers) in favor of collecting as much as possible and of high quality and two out of three in favor of keeping costs as low as possible. More direct communication also stimulates working together to make the development a national success. Jointly starting or updating a national implementation plan is another benefit. Such plans can be compared against other experiences in the world and further supported by scientific research and technology development work.
4. Products do not come back as individual pieces but as streams. Besides managing collection and the financing of treatment, also **monitoring of the system is crucial.** Since not every consumer, business, trader, and recycler will behave conscientious since making extra money at the expense of the environment is often tempting. That is why mapping and researching the type and size of informal treatment is relevant information. This forms the basis for attempting to maximize the inclusion of informal sectors and metal scrap traders as much as possible into the system, which in turn might even reduce the amount of rules in the long run without losing environmental benefits.
5. The issue of **noncompliance** also **requires pragmatic intervention** by means of enforcement. Some of the less desired environmental practices are less impacting than others. Simply said, when for example washing machines end up in car shredders, this is far less an environmental concern than when this happens with CFC-containing refrigerators. Since one cannot control every individual piece of discarded electronics, differentiation towards types of e-waste will be needed to steer limited enforcement resources to the highest urgencies.
6. Certain things are unpredictable. There is a wide range of external conditions that affect the implementation process. Hence, also **legislation can be designed in a more dynamic way** covering the basic elements in the core document from the start and connected implementing rules

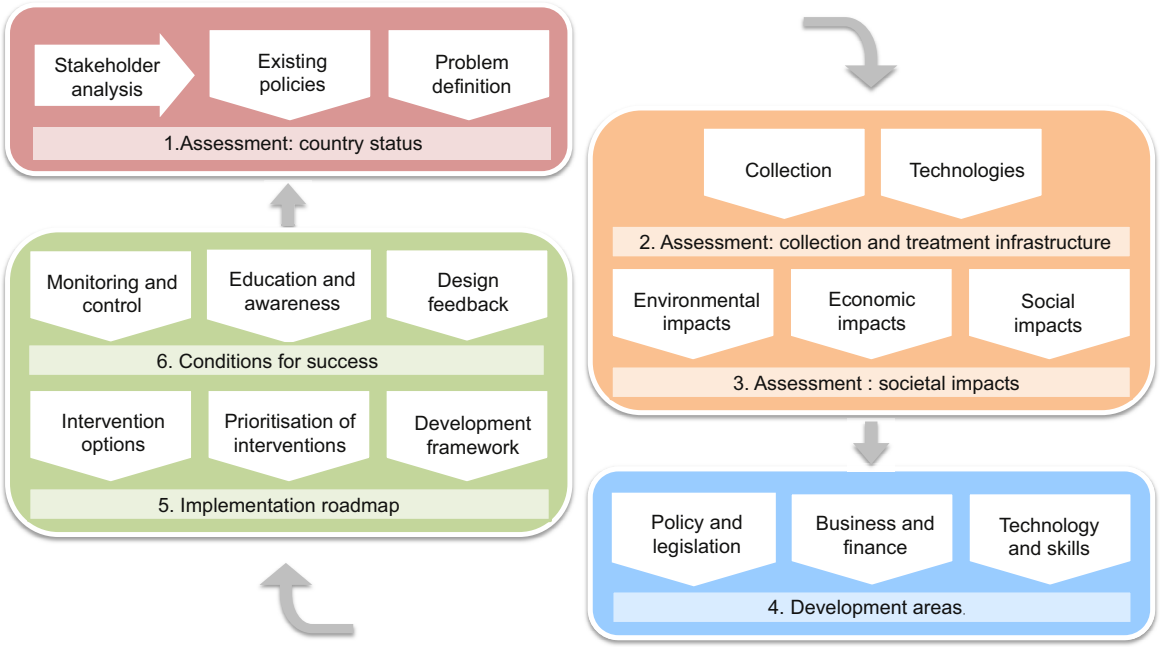
in separate acts, implementing decisions, guidance documents, and FAQ's. This allows for much quicker adaptation when actual development requires new directions. Such implementing decisions can later be formalized when needed in a second or third development round.

Following the introduction of Section 2.1 and the rationale in Section 2.2 explaining **why** there is a need for a different approach to e-waste system development since countries are in very different development stages, the next Section 2.3 proposes the newly developed e-waste development cycle explaining **what** the steps are that can be taken and in **which** order.

2.3 THE E-WASTE DEVELOPMENT CYCLE

Sometimes you go faster when running in circles.

The main aim of policy analysis is best summarized by Thomas R. Dye: "Policy-analysis is finding out what governments do, why they do it, and what difference it makes" (Dye, 1976). E-waste policies can only be effective when they go beyond the realm of explanations and programs and are realized as intended by the plans for implementation. During this process various realization elements or phases can be observed in which the various actors play different roles. If these phases are pictured as forming part of a close series, the result is the policy cycle, a model of an iterative process. This in turn allows policies to be viewed as a process of problem solving, which can be divided into different sequences. This e-waste development cycle is combined with specific methods developed in the StEP community and over 20 years of experience in fact-based scientific support to different actors and countries (StEP initiative, 2018). Multiple research projects in different regions have been performed, from which valuable lessons are converted into this chapter. This includes knowledge from (Huisman, 2003; Huisman et al., 2003), which provided a first systemically conducted environmental and economic impact assessment applied to the review of the original European Union WEEE Directive (European Parliament and Council, 2003, 2012). This resulted in the extended impact assessment and listing of options to improve the European e-waste take-back and recycling regulations (Huisman et al., 2008). Furthermore, various StEP, UNU, TU Delft, and EMPA publications are used as a basis for Fig. 2.3 (Huisman et al., 2006; Stevels, 2007; Huisman et al., 2008; Huisman and Stevels, 2008; Gregory et al., 2009; StEP initiative, 2009; StEP initiative, 2010; GIZ, 2011; Wang et al., 2012; Wang et al., 2013a,b; Wang, 2014; StEP initiative, 2014; Magalini et al., 2016a,b; StEP initiative, 2016; Baldé et al., 2017; StEP initiative, 2018;



■ **FIGURE 2.3** The e-waste development cycle.

Huisman, 2012; Schluep, 2012a; Schluep et al., 2012b; Mendéz – Fajardo et al., 2017; Magalini and Huisman, 2018; SRI project, 2018).

The presented dynamic development cycle of Fig. 3.2 is meant to provide guidance on the complexity of the development process. It illustrates the key building blocks needed for successful take-back system development. As explained in Section 2.2, the left-hand side includes structured assessment, problem definition, and review of the status of collection and treatment infrastructure. This in turn forms the basis for environmental, economic, and social impact assessment (Chapter 3). The right-hand side represents the implementation steps including the key development areas being "Policy and Legislation," "Business and Finance," and "Technology and Skills" (Chapter 4). These three defined development areas are also commonly present in existing approaches and are positioned in Fig 3.2 at the heart of the development process. Chapter 5 provides guidance on how to align interventions from the previous three development areas in a structured manner. This in turn forms the basis for a national development road map. Sections 5.2–5.5 describes the prioritization and selection process for decision-making, as well as the timing, resources, and responsibilities needed for

implementation. In Section 5.6 three commonly used development areas, being "Monitoring and Control," "Education and Awareness," and "Design Feedback" are positioned slightly differently compared to existing approaches. The reason is that they are important conditions and in particular Monitoring and Control requires **continuous attention** as it forms the necessary evaluation basis for starting a new development round.

The development cycle is designed for use by all stakeholders that have a role in the take-back and recycling system and for policy makers specifically. It provides structure and overview of practices and tools that match best for specific situations prevailing in different countries, rather than being a description of "good or bad" practices.

Although not used as a basis for the development cycle, after developing the approach of Fig. 2.3 and the finalization of this chapter as well as in Chapters 3–5, it was observed that it is rather similar to the Plan-Do-Check-Act (PDCA) approach used, for example, in the Environmental Management Systems Standard ISO 14001 (ISO, 2015). In this regard, the Plan stage is similar to the Country Status in red on the top left of Fig. 2.3. The Do phase is rather similar to the Development areas, and Implementation road map in blue on the right. The Assessment of Infrastructure and Impacts part in orange on the left is similar to the Check stage, sometimes also referred to as the Study stage (PDSA). The bottom green part on the right representing the actual Implementation part is similar to the Act stage of the PDCA approach. Despite these "accidental" similarities, the proposed approach here in Chapter 2, however, is not (intended to be) matching one to one with the ISO approach. The first reason is that there are multiple actors and organizations involved that do not nicely follow the structured approach since e-waste systems develop in a rather complex and partly unpredictable manner. The development is not a software product, (environmental) management system nor a production process that can usually be much more controlled. Therefore, the application of this structured approach is not strictly following the PDCA steps as it can delay the development process itself when one meticulously waits for each stage to be completed. The advice is rather to use the relevant parts and experiences presented in Chapters 3–5 to improve, steer, and speed up the ongoing process where possible. The idea behind the structure provided above is to illustrate elements required or improve successful take-back system development, which can be used proactively.

Obviously there can be tension between a well-structured and timed approach and the complex and commonly chaotic play of things in reality. The fact that many actors are directly and indirectly involved makes it inherently difficult to arrange everything in perfect balance right from the

beginning. Therefore, it is important to highlight **how** the proposed experience-based approach can be used in practice. The main idea behind Fig 3.2 is that it should **not be consumed as a** "**full menu"** but relevant elements **be selected** "**à la carte**," depending on the national situation. This **à la carte** idea is explained further with five "f's":

- First of all, those involved at the heart of the process, the development cycle, allows to be much more **forward** looking by means of illustrating the next stages one can take in the development.
- Secondly, the approach also brings more **focus**—not everything is equally important in each round nor can all wishes be accommodated in one single round.
- Thirdly, leaving sufficient room for later adaptation and additions in a subsequent round that are not necessarily included in the present stage provides much more balance in the efforts to achieve the desired progress in a **feasible** manner and concentrates scarce resources to the most pressing issues.
- Fourthly, since the development process can be rather unpredictable, the **à** la carte and "learning by doing" nature of the approach provides **flexibility** as an important element in the process.
- Finally, timeliness is a major issue since basically all of the developed countries have struggled and debated long over major and minor items in the policy framework, thus severely slowing down actual implementation. Here, the urgency of the problem combined with the rapid changes in the electronics sector require a **faster** approach that focuses more on maintaining a good development pace rather than having the ultimate perfect policy framework.

To fuel a higher development pace, **flexibility** and some level of opportunistic **forward** looking in setting new goals is recommended. Therefore, considerable focus is given to the development of a policy framework that clearly describes the basic goals, principles, and mechanisms without describing every single detail. Here, proper balancing between the policy framework and **implementation rules** is considered crucial.

By means of the e-waste development cycle, this chapter and the next Chapters 3–5 are postulating and trying to answer the following key questions:

1. What were the global and national responsibilities of some sample countries as regards the e-waste problem? How and to what extent did they have direct and indirect impact on environment and development?
2. Who were the key national actors and institutions formulating, implementing, and evaluating the e-waste policies, and how did they do it?
3. What is the net effect of these policies?

4. How could these policies be strengthened? What are the future perspectives, and what could the countries learn from each other?

The next sections elaborate on the first step of the development cycle, including the description and evaluation of the country status (Section 2.4), which includes stakeholder analysis (Section 2.5), analysis of existing and adjacent policies (Section 2.6), and problem definition (Section 2.7), forming the starting point for Chapters 3 and 4.

2.4 ASSESSMENT OF THE COUNTRY STATUS

For all countries, a key starting question is:

- Step 1: What is the status quo? Who is doing what?

A first component for steering the development of e-waste systems is the description and understanding of the status quo in the country. The aim of the step is to have a structural assessment of the country status and who is involved in what and to understand existing or missing roles and responsibilities. The rationale of this step is to acquire more information about who can deliver to the intended goals. These country-dependent goals can for instance be increasing control over toxics, improving efficiency of measures by maximizing gains of recycling and reducing costs or social improvements. It is important to understand and describe who is organizationally necessary for the achievement of such goals and who affects success or failure in the development the national e-waste system.

To address this, the first part of the assessment half of the development cycle of Fig. 2.3 (in red) is a mere qualitative description starting with a stakeholder analysis to identify key roles and actors as described in Section 2.5. Secondly, the national development of specific e-waste policies should be related to and aligned with related national and international policies and regulations as described in Section 2.6. Thirdly, from the analysis, a country-specific qualitative definition of focus areas becomes the start for both further assessments in the next stage as well as input for the description of development areas in Section 2.7.

2.5 STAKEHOLDER ANALYSIS AND INITIAL CONSULTATIONS

Who is involved in what is the first general but crucial question. Stakeholder analysis is the first step to understand who is and potentially can

be involved and a way to recapture who has been involved to what extent in actual implementations for emerging and established countries after previous development efforts.

Obviously, specific socioeconomic conditions like the presence of relevant actors, cultural influences, and geographical aspects determine when and where interventions and changes in e-waste take-back and recycling systems can be made. It is recommended to perform stakeholder analyses or so-called value chain analyses, which also includes the data, processes, and value-added services (Kaplinsky and Morris, 2001). The aim is a practical identification of what is unique for the specific country as well as identifying what is very common in comparison to other countries. Analyzing the roles of key players and their respective roles as well as the information flows in the country or region is particularly helpful to understand the problems in the next step. Simple mapping of the type and number of actors involved in all stages of market inflows, outflows, collection, reuse, trade, and treatment is very useful for understanding the mechanisms and thresholds in the current or future system. It forms a relevant starting point for possible solutions. Secondly, it also provides a structured overview in case dedicated stakeholder consultations are organized, like the approach in Méndez-Fajardo et al. (2017) for starting countries or in case of country studies for emerging and established countries like in Huisman et al. (2012b) and Magalini et al. (2012)when more elaborate quantitative assessment is needed. Specifically for issues that are similar compared to other countries, one can build on solutions that worked in countries with comparable conditions or avoid those that have proven not to work.

2.5.1 Starting countries

For countries starting with e-waste legislation, specific key questions to answer are:

- Which parts of the governmental organization have to be involved?
- Which partners outside government have to be looked for? Are they merely absent, present but not functioning properly, or do working relations not yet exist?

Since there is no existing evaluation of the current status in the country, the first step here for starting countries to identify “all basic information” that is retrievable. This includes information that is raised and transferred by different groups, individuals and institutions involved in the process, in a

timely and very basic manner. In most cases, when e-waste starts to become the subject of public debate and on the political agenda, usually no or very limited analysis framework exists. As a consequence, naturally these countries start to look at developed countries. The risk here is to overlook what is already available inside the country itself. Subsequently, there is copy-pasting of measures that are not transferable due to missing government and other actors, as well as capabilities not or not yet existing. It is advised to look internally first to which government entities can be involved, like the Ministry of Environment, Economy/Industry, Heath/Safety, Interior, and other executing agencies like a waste agency, customs, port and border authorities, and tax offices. Assuming there (temporarily) is a single leading organization, then also organization of events with recyclers, producers, importing, and reuse or other consumer organizations can be organized in second instance. Simultaneously, identifying internal or external (international) experts in the process for independent and experienced guidance is highly recommended and often a catalyst in the speed and focus of the development process.

For example, besides containing a well-structured but linear assessment approach Schluep et al. (2012b) provides several useful templates for surveying various stakeholders developed by the Sustainable Recycling Industries (SRI) project, to provide a more structured and theoretical framework for the policy design process, particularly regarding the organization of stakeholder consultations and installing a systemic design team (Méndez-Fajardo et al., 2017). When feasible, as suggested by the SRI project, it can certainly contribute to select an institutional, technical, and methodological leader. However, in the majority of cases, many more stakeholders are involved. These are frequently from different organizations having a vote in the process as well as. Secondly, due to frequent personnel changes over time, the suggested leadership cannot be sustained by few individuals. As a result, the development process and resulting stakeholder influence to it are generally more unpredictable and chaotic compared to the proposed ideal schema. Therefore, the analysis in this and the next stages requires more an **à la carte approach** in an **à la carte world**. What is common, though, is that it is recommended to have key representatives from the institutional side and academic or knowledge institutes **trained** and available in the future in a reviewing and supporting role. These researchers are preferably from the home country itself who understand the local conditions and can be available also in the longer term. Where needed they can be accompanied by knowledgeable international experts. As a first task in the development, doing a structured stakeholder analysis (even in the simplest form),

inventory of policies, and clear problem definition for the individual country is a valuable task that enhances the knowledge base for the national researchers.

The stakeholder analysis is ideally organized parallel to stakeholder consultation to obtain data from the sector more directly. This supports the qualitative description of current issues and enables to find common ground in identifying possible solutions. Later in the process, one can start to also (re) describe possible roles of those involved. Recommended is to identify who is situated the best to tackle actual problems based on describing the needs, possible means and mandate to execute measures and how to avoid overlaps. These initial discussions should form the basis for identifying who is best positioned to be in charge for what elements and which entity ultimately takes the leadership on the implementation itself. This is an important basis for the later development of actual legislation and avoids developing legally sound measures but without the actors being present and able to convert them into action.

2.5.2 **Emerging and established countries**

For emerging and developing countries, the focus is more to review the presences and roles of those already involved in case of a second and third loop. In particular, lack of progress can be related to the insufficient functioning, missing working relations, or the absence altogether of certain actors. The stakeholder analysis allows obtaining a deeper insight into the values and powers of the identified actors and the types and relevancy of the flows of money, power, and information. The aim of this step is to qualitatively describe the general situation of the e-waste value chain and in particular the role of those who are or should possibly be involved. Thus, key questions in this case are more related to the functioning and the dynamics between actors:

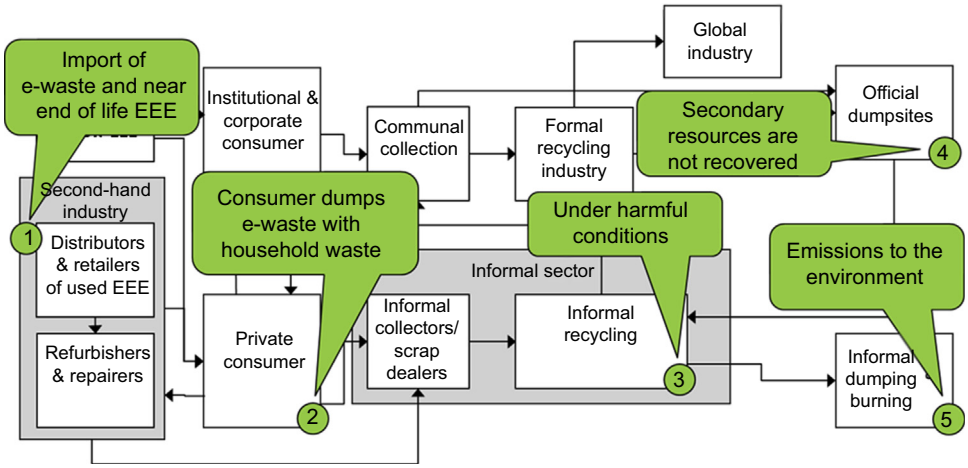
- How are government entities, producers, consumers, recyclers, and waste traders currently organized? Are they all functioning as desired?
- From the previous implementation round (when conducted), what is the advice from academia and or experienced consultants and knowledge institutes? What are the strengths and weaknesses of the system at large?

Whereas for starting countries the stakeholder analysis can be relatively simply, for emerging and established countries it is advised to measure progress of stakeholders in more tangible ways, for instance, in the form of specific performance criteria. The need for this is that generally speaking, issues remain due to the complexity of the e-waste domain. Generally, there is substantial room for improvement in collection and recycling as well as in the efficiency of resources consumed. More often than not, this is due too little or too much coordination and frozen political positions of various actors. An externally steered and independent value chain analysis can be helpful to identify and describe stalled development.

The results of such analysis can be based on the existing monitoring and control framework (when existing, see also Section 5.6) and by using the value chain analysis here again in a more in-depth manner. To facilitate this process and to provide more clarity, the following elements can be actively pursued by one or multiple stakeholders in order to increase understanding of the nature and size of the issues at stake:

- What are the current and desired roles of the current actors involved also in relation to existing policies and standards? What elements are the existing stakeholders satisfied about and what not?
- Who else is involved in collection and logistics, treatment, financing, registration, monitoring, reporting, and currently still not included in the system?
- What current environmental issues have their priorities and perspectives changed from gaining more insights from existing evaluations?
- What is the level and nature of inappropriate treatment in formal, informal, or not reported sectors?
- What are the costs involved in various stages and are there specifically high levels or inefficiencies reported?

In order to answer these questions, various tools exist to support the analysis. First of all, various reports and academic references have compared the implementation by various countries. Secondly, regular and well-structured stakeholder consultations that preferably also include the inspection authorities and monitoring agencies when existing can be organized (Schluep et al., 2012). Structured and recurring dialogues between recyclers, consumers, producers, and government can support raising the necessary information by different groups, individuals, and institutions related to the existing performance of the system (Méndez–Fajardo et al., 2017). Thirdly, a dedicated market survey can be performed by experts. The analysis usually includes a renewed and more quantitative mapping of actors in the recycling chain; qualitative description of environmental issues; the level and nature of



■ **FIGURE 2.4** Example of the mapping of actors and problems. *Schluep, M., 2012. Reference Document on e-Waste Management. A. Mkama and C. Zavazava, ITU.*

inappropriate treatment in formal, informal, or not reported sectors; and the levels and types of inappropriate disposal. For countries going through a second or third round, information from the evaluation phase should be added.

Some mapping examples are presented in a graphical way at the end of Section 2.7 in Fig. 2.4. The aim of such an exercise should not be analysis alone but to define a basis to refocus on the long-term development goals. Hence, the outcomes are both the basis for setting new and more quantitative research questions related to collection and recycling infrastructure and the societal impact assessment of the current system as well as a new starting point for developing a new long-term implementation road map (see Section 5.4). All of this follow-up requires stakeholder interactions and commitment that comes from the actors themselves, supported by the (where then needed revised) legal framework and its actual implementation.

2.6 INVENTORY OF EXISTING POLICIES

After having evaluated the stakeholder behavior in the previous section, closely related to it is the scan of what policies are already in place or not related to the national e-waste related ones (when existing). E-waste policies are often not developed as stand-alone policies and are embedded in more general solid waste policies and other related regulations, standards, and agreements, for instance, regarding restricted use of substances of concern, product design, other waste-type legislation like for batteries and vehicles, import and export rules for waste, waste treatment permits and licenses and standards, as well as organizational and financial requirements.

The outcome of the stakeholder analysis step should be compared (again) and related to any existing policies and (international) regulations. Most countries usually have some form of generic legislation related to waste management, environmental management, and/or health-and-safety regulations on which one can further build on and align with. Other countries have already successfully implemented e-waste legislation and policies and require mere fine-tuning to better cover specific environmental goals, implementation needs, or updates due to technical and scientific progress. The same counts for prevention-related policies like Design for Recycling requirements (DfR), which will be discussed in Section 5.8, and restrictions to hazardous substances (European Parliament and Council, 2011), collection requirements, export/import bans like the Basel Convention (1989) and more dedicated or region-specific guidelines related to reuse and export. Additionally, the outcomes of a previous evaluation phase provide first clues for revising or terminating existing, double, or conflicting requirements and identification of elements previously missing.

2.6.1 Starting countries

For many starting countries, there is no dedicated legislation at all (Baldé et al., 2017), let alone standards specifically for e-waste. In almost all cases though, the Basel Convention is adopted regulating the imports of hazardous wastes. The Basel Convention establishes procedures and control regimes for the shipment of waste, depending on the origin, destination, and route of the shipment, the type of waste shipped, and the type of treatment to be applied to the waste at its destination. It applies to e-waste as well and arranges what is allowed for export from OECD to non-OECD countries as discussed in the Deliverable 3.3 of the Countering WEEE Illegal Trade (CWIT) project. However, the implementation is often far from perfect, and in particular the cooperation between sending and receiving countries leaves room for improvement (Huisman et al., 2015). In order to maximize synergies in their effect and to avoid overlaps, misalignments, and imbalances, key questions to be answered at this stage for starting countries are:

- How is the e-waste issue to be positioned in the national policies? Which national and international regulations, policies, and standards are already in place? Which entity is currently responsible for them?

Here, several tools and documentations exist with guidance on the policies and regulations mentioned. Since waste imports are frequently a concern for starting countries, besides the international rules, supporting documents and trainings are already available for customs and enforcement agencies. The CWIT project (Huisman et al., 2015) has an elaborate mapping and set of overviews on the rules and regulations and their implementation and an elaborate recommendations road map. The successor DOTCOM.waste project in particular has established an online library that can be consulted (DOTCOM Waste project, 2017) and dedicated training materials in the form of a toolkit (only accessible for law enforcement agencies). More information on the development of national e-waste legislation itself follows later in Section 5.2. Finally, see also Chapter 23 in this book regarding Africa (Schluep, 2018).

2.6.2 Emerging countries

For emerging countries with a first established e-waste policy, a key question is:

- How are the regulations in place functioning and how can implementation be improved by related standards, guidelines, and other legislation?

For these emerging countries, quite often some patchwork exists and minor adjustments will not be sufficient for not matching major issues. A broader program after the initial round needs to be developed to tackle the more complex issues. In particular, developing both adequate and achievable collection and recycling goals based on the first rounds of experience is needed. This sometimes requires drastic revision to the original framework to enable change for issues where initial expectations did not materialize. In addition, the alignment with related policies and standards that focus more on the operational aspects need to be more targeted. Deubzer (2012) provides a thorough overview of the types of standards, principles, requirements, and certifications steps applicable. Chapter 6 of this handbook (Herreras and Leroy, 2018) provides valuable background behind the European Committee for Electrotechnical Standardization (CENELEC) standard for WEEE for Europe. Finally, ISO (2017) also has developed guidance principles for the sustainability of secondary metals for international use.

2.6.3 Established countries

For established countries, a key question is:

- What are the structural obstacles that cannot easily be tackled to further improve collection and recycling?

For developed countries there are plenty of studies and assessments; see in particular also the related chapters in this book regarding Europe (Ylä-Mella and Román, 2018), China (Zeng and Li, 2018), India (Sinha−Khetriwal, 2018), and Japan (Yoshida, 2018). What can be observed is that in many cases structural and complex issues remain that are subject to recurring discussions but not fully tackled. Commonly, these issues are related to a significantly sized complementary trading and recycling sector and structural issues with not being able to economically reward more collection and higher quality of treatment as well as the insufficient monitoring and enforcement of noncompliance. In these cases there will be no easy policy fix that generates results quickly. The way to progress here is to enter a new development round with a specific redefinition of the problem, targeted analysis of the cause, and formulation of new interventions. For established countries, the nature of these issues is discussed at the end of Section 2.7.3.

2.7 PROBLEM (RE)DEFINITION

From the analysis of the actors and the policies in the previous step, an initial problem definition is extracted. In case of a second or later development cycle, outcomes of the previous implementation round are included in the problem analysis here. Obviously the problems are commonly very different for starting countries, emerging countries, and established countries.

For starting countries, existing sources describing the problem definition are commonly available. In Chapter 1 of this book, Kuehr (2018) and Baldé et al. (2017) provide a clear overview and multiple sources with respect to e-waste legislation initiation. Many StEP documents (Gregory et al., 2009; StEP Initiative, 2010; Schluep et al., 2012; StEP, 2016; Magalini et al., 2017a,b; Méndez-Fajardo et al., 2017) are instrumental in determining the definitions and scope of e-waste products to be covered or not covered, product design interventions and determining the necessity of prevention-related measures, improvement of collection levels and treatment quality, both in

formal and in informal sectors. The majority of these sources focus on a qualitative description of the issues at stake. Obviously, for starting countries there is ample (semi-)quantitative information available. Therefore, setting a clear problem definition at this stage should also make explicit what data and information exists and what does not exist for the identified issues.

2.7.1 Starting countries

For starting countries, thus a key question is:

- What are the dominant issues, the scope and magnitude of the problem within the e-waste domain?

These issues can be rather common for all starting countries as well as very specifically related to unique country conditions. The latter can relate to specific environmental impacts related to treatment practices and high toxicity levels for specifically present informal sectors (Puckett and Byster, 2002). The same counts for instance for undesired imports and exports, which can vary significantly depending on the geographic location and economic conditions. Large economic differences do occur between countries or even for regions in one and the same country due to, for instance, differences in population densities, wages, employment rates, and the size of formal and informal sectors. Other country-specific organizational problem areas can be lack of information and research (capacity) needed as a basis for further development, lack of finances or financial incentives for improving collection, and treatment quality. Related to infrastructure status, also lack of operational standards in logistics and treatment can play a role.

More common types of issues occurring in most starting countries are related to typical discarding behavior of consumers due to lack of awareness and education on the related environmental problems. In addition, significant imports of e-waste, informal reuse, repair and cherry-picking practices, lack of formal collection infrastructure, lack of treatment capacity, and expensive return logistics are rather common. Frequently, this is also accompanied by weak governing structures and relatively poor economic situations. Although for many countries seemingly more urgent economic and social development problems exist, arranging for proper waste treatment can still assist significantly in the overall development as indicated with the link between the SDGs in Section 2.1.1. Hence, e-waste system development needs to be synchronized with the overall country's economic

Table 2.2 Possible stakeholder involvement in the e-waste system development (Gregory et al., 2009)

Directly active and primary stakeholders	Indirectly active and secondary stakeholders
Legislators: Responsible for legal consistency and for transposition and interpretations of the WEEE Directive's environmental intent. Prime stakeholder for checking compliance of others, should avoid free riders and illegal imports/exports, low quality (licensing requirements) of treatment and of level playing fields regarding financing.	**Producers** can have three types of responsibilities: ■ Financially: If applicable, the financing mechanism itself should not promote doing less effort. ■ Organizationally: Producers are the only stakeholders with global organizing and logistic capabilities and potentially via their sales (and return) channels. ■ Product design: End-of-life and restrictions on substances aspects need to be balanced in general eco-design directions.
Compliance schemes/producer responsibility organizations (PROs): Responsible for practical execution and efficient and effective organization via economies of scale, PR, auditing recyclers, and possibly via funding of research.	**Municipalities, retailers and informal collectors:** Responsible for accessible local collection, avoiding illegal trading and "cherry picking," and educating local consumers.
Recyclers: Treatment quality and monitoring of outgoing material fractions.	**Consumers:** Responsible for collection at designated collection points.
Repair and trade associations: Responsible for repairs, life-time extension, and imports of used products	**Door-to-door collectors:** Responsible for effective collection and the initial trade of products toward reuse, repair, recycling, and also discarding of remainders.

development agenda. Here it is crucial that the financing mechanism as a minimum enables cost efficient collection and treatment and creates jobs for workers in a safe and environmentally sound manner. It should simultaneously also not terminate existing repair and trade jobs but rather convert and professionalize the informal sectors involved (Wang et al., 2012). Hence the explicit financial questions need to be quantified, as well as the intended costs and benefits of possible measures.

A nonprescriptive example of the mapping of stakeholders and their possible roles in the form of a simple and generic matrix is converted from Gregory et al. (2009). It describes which stakeholders can be invited directly and indirectly related to their possible roles in the actual stakeholder consultation and later implementation stages (Table 2.2).

A country-specific problem (re)definition can include qualitative description of the e-waste flows and status of reuse in formal and informal sectors. The key questions for this stage are to determine which products are to be included in the scope, which current pollution-related practices really need to be stopped, how basic collection can be arranged, as well as rough

estimates of the costs involved for collection as well as treatment. For the latter, also a listing of possible facilities and the way they are organized should be developed. Many publications and tools exist, specifically also designed to assist young researchers to develop themselves regarding this matter as specialists for their home country. See, for instance, the StEP E-waste Academy series (UNU, 2018) with dedicated programs for scientists, managers, and policy makers as well as the dedicated tools for enforcement agencies (DOTCOM Waste, 2017).

2.7.2 Emerging countries

For emerging countries, key questions are:

- What are the root causes for lack of progress? Are these primarily technical, economic, or organizational?

For emerging countries in the process of a first review of the implementation, the main message is **not to accept lack of progress**. Whereas the initial steps supposedly tackled the most pressing issues and pollution, starting a second round requires another focus more tuned to developing the system. Hence a more comprehensive redefinition of the issues at stake is usually required. It is observed that very often policies in emerging countries are very technically oriented, focusing on the use of specific preprocessing and end-of-life processing technologies (Li et al., 2015), but with less focus on the organization and economic circumstances to implement this. Organizational challenges can originate from not involving all stakeholders from the beginning or from not yet adequately tackling the economic and logistic challenges in the collection and recycling chains. Also often a limited scope of products is selected in the first round, which can be up for expansion to capture more types of e-waste. Hence, the basis of the initial policy needs to be widened beyond the priorities of the first development round.

With all external documentations available, this exercise does not necessary request highly skilled international researchers. As an example, Fig. 2.4 is a graphical presentation of the main flows, key issues and their intervention locations in the end-of-life chain, derived from Schluep et al. (2012a). This research approach can easily be replicated by (new) researchers for the situation in the respective countries.

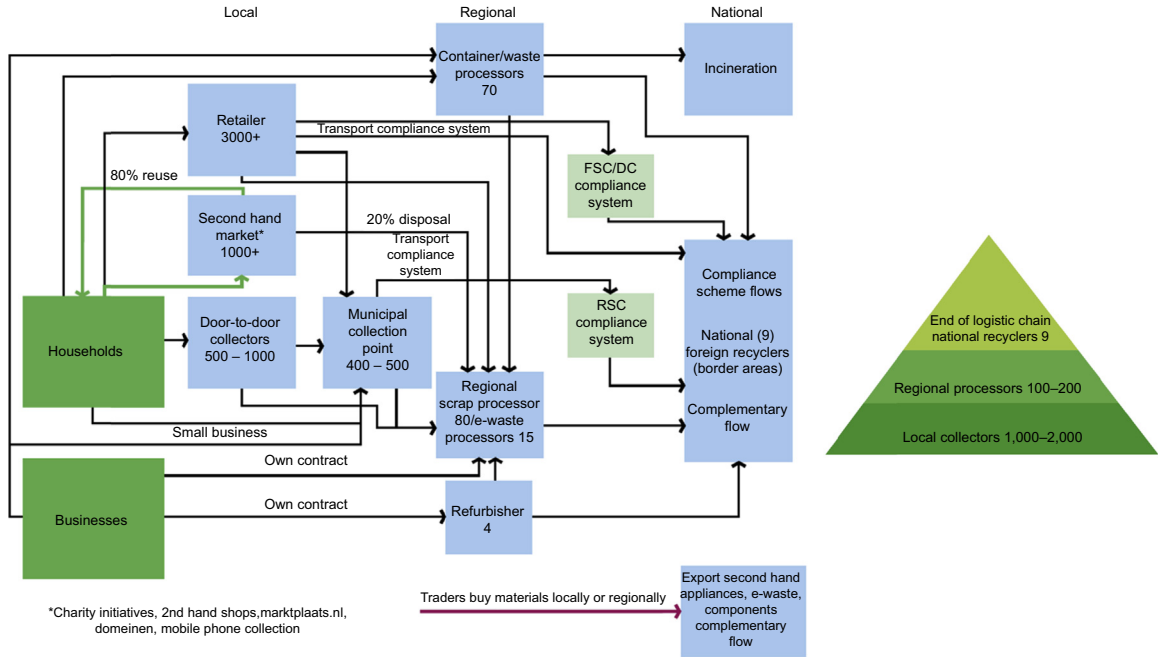
2.7.3 Established countries

For established countries, a key question is:

- How can collection rates be maximized and quality of treatment be economically rewarded?

Almost all emerging and established countries face structural issues in maximizing collection closer to the actual waste-generated volumes (Huisman et al., 2012b; Huisman et al., 2015; Magalini et al., 2015; Magalini et al., 2016a,b; Baldé et al., 2017; Odeyingbo et al., 2017). Similarly, they also struggle to economically reward higher quality in treatment and avoid the widespread trade and scavenging of the most valuable products and components (Magalini and Huisman, 2018) and how to recover also materials regarded critical but without sufficient concentrations or value to be recovered in existing treatment configurations (Huisman et al., 2017).

The reuse value of e-waste is well known by local traders and collection points. Transferring ownership to producer responsibility organizations (PROs) and arranging for logistics and quality treatment generally costs more than the intrinsic material value. In most cases, these issues are recognized but the organizational and financing structures remain untouched, thus not leading to needed restructuring of the collection schemes. Even after many years of development both the flows and economics behind scavenging, export, and trade of second-hand equipment is commonly partially and only qualitatively understood and rarely described in more quantitative detail for roughly one-third of the waste flows (Huisman et al., 2015; Magalini and Huisman, 2018). Here it is advised to restart discussions on the objectives of the system and reorient how collection and recycling can be steered better economically beyond minimum compliance. Very often various forms of noncompliance are widely known and need to be reversed. It is recommended to develop a set of remediation and penalty measures when the legal framework is continuously violated. When a structured mapping of actors and the performance of existing policies is made on the basis of the previous steps, then the problem (re)definition can be improved. It is recommended to explicitly identify the specific places in the value chain where intervention can be done better to allow monitoring and enforcement to be applied more targeted. Finally, where information is missing, additional impact assessment and market surveys can be performed to better describe the renewed problem formulation as explained in the next Chapter 3.



■ **FIGURE 2.5** Example of a more quantitative mapping of actors. *From Huisman, J., van der Maesen, M., Eijsbouts, R.J.J., Wang, F., Baldé, C.P. and Wielenga, C.A., 2012. The Dutch WEEE Flows, 2012b, United Nations University, ISP — SCYCLE, Bonn, Germany, March 15, 2012.*

An example of a more detailed analysis of both the actual number of actors and the flows of e-waste at different levels can be found in Fig. 2.5 from the Dutch Future Flows study (Huisman et al., 2012). This study conducted an extended qualitative value chain analysis with a more specific quantitative market survey for the Netherlands. This in turned formed the basis for later quantification of the national WEEE flows and various interventions in the reporting over collection of complementary recycling flows in the years after the study.

A further list of existing national studies can be found in Baldé et al. (2017), which includes information about all EU member states, Australia, Cambodia, China, El Salvador, Chile, Honduras, Hong Kong Special Administrative region of China, India, Japan, Macau Special Administrative region of China, Mauritius, Mongolia, Norway, Pakistan, Russia, Saint Lucia, Singapore, South Korea, Switzerland, Taiwan Province of China, Thailand, Turkey, and the United States.

2.8 CONCLUSIONS

Environmentally sound management of e-waste contributes directly and indirectly to a number of sustainable development goals (Section 2.1.2). Managing e-waste is, however, not straightforward and needs special attention. It requires a mix of policy measures and national cooperation, plus baseline studies and monitoring of progress to realize various societal goals. The proposed e-waste development cycle and the first step of the analysis of the country status lead to the following conclusions:

1. One can use the proposed e-waste development cycle and its iterative goal-oriented steps to add **more structure** to the national developments of both starting and well-established e-waste management infrastructure.
2. **Getting facts** is instrumental to set priorities and differentiate the development where needed in a more **experience-**based approach rather than a principles-based attempt.
3. The e-waste development cycle provides for a more **systematic strategy** allowing to focus more resources to the elements most relevant.
4. The stakeholder analysis clarifies how to activate and call upon the **necessary cooperation** of those involved.
5. The inventory of policies aims to avoid overlaps, gaps, and misalignments with related policies and formulates the **starting points** for the later policy development.
6. The combined description of the country status provides for a **clear (re)definition of goals** and the starting point for further impact assessment and describes the needs for the policy framework.

All of the above steps combined should provide countries a more forward-looking, feasible, and focused approach to solve the e-waste problem. It should also be more versatile and result in faster development compared to more unstructured or attempts aiming to provide solutions in one single round.

The next crucial step in the e-waste development cycle presents a structured assessment framework evaluating the status of collection (Section 3.2) and recycling infrastructure (Section 3.3) as well as the subsequent environmental impacts (Section 3.4), economic impacts (Section 3.5) and social impacts (Section 3.6). The impact assessment in turn ideally forms the basis for the heart of the development cycle with the three key development areas presented in Chapter 4, with Policy and Legislation presented in Section 4.2, Business and Finance in Section 4.3, and Technologies and Skills in Section 4.4.

From the options derived from Chapter 4, Chapter 5 describes how to come to a national implementation road map by listing all key intervention options in Section 5.2, the selection and prioritization in Section 5.3, and converting this into an implementation road map that includes the description of timing and resources needed in Section 5.4. Finally, important and direct and indirect conditions for successful implementation are listed in Section 5.6 related to Monitoring and Control, Section 5.7 regarding Awareness and Education, and in Section 5.8 regarding Design Feedback and prevention.

DISCLAIMER

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