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Chapter 4

The e-waste development cycle, part III—policy & legislation, business & finance, and technologies & skills

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4.1 INTRODUCTION AND READERS' GUIDE

This Chapter 4 provides the third part of the e-waste development chapters in this handbook, which were first introduced in Chapters 2 and 3. It describes possible interventions and experiences related to the key development areas of "Policy and Legislation," "Business and Finance," and "Technologies and Skills." Development of take-back systems is a time-consuming and complex process. As proposed in Chapter 2, it is recommended to adapt an iterative and tailor-made approach for countries starting their e-waste policies, countries with systems in place and even for established countries with many years of experience, as there is still progress to be made. An iterative approach is needed due to the heterogeneous character of e-waste and its quickly changing material compositions and economic values, combined with different cultural and socioeconomic conditions and organizational and technical capabilities. It is therefore important to start tackling the issues with a realistic action agenda with a limited scope. In later cycles of policy development, more items can be added. The additional advantage of this strategy is "learning as you go" compared to more time-consuming linear approaches. For this reason, the next sections provide a comprehensive overview about what to consider on one hand as well as an **"a la carte"** action-based approach on the other hand. This dynamic character stimulates quicker piloting and developing of experience without having to specify every single detail.

Table 4.1 provides an overview of the key development questions as well as a readers' guide for where to find additional information. For the full reader's guide covering the Chapters 2–5, see Table 2.1.

The outcomes of the previous country and impact assessment phases in Chapters 2 and 3 usually lead to a multitude of defined problems and a collection of qualitative and quantitative facts. This forms the basis for further interventions in the development areas of Policy and Legislation, Business and Finance, and Technologies and Skills. The objectives for defining such new interventions or revising existing development components are structured around the starting points of "more collection and better treatment" into three levels:

Table 4.1 Key development questions posed (covering Chapter 4 of this handbook)

Development areas	Starting countries	Emerging countries	Established countries
Step 4: How and where to intervene with Policy and Legislation? (Section 4.2)			
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?
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 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?
Step 5: What needs to financed and how? (Section 4.3)			
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?
Step 6: What Technologies and Skills are needed? (Section 4.4)			
Technologies 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?
(forward to Step 5, Implementation Road Map (Sections 5.2, 5.3 and 5.4) and Step 6, Conditions for Success (Sections 5.6, 5.7 and 5.8)			

1. **Primary objectives** are defined as direct environmental aims such as material and energy recovery, control over toxic emissions, less waste volume to landfill, and incineration. After defining them, these objectives can be translated into direct legal targets such as collection amounts and toxic control or material reclamation levels. They can also be translated into guidelines in accompanying standards or into less tangible development elements such as piloting or investing in better recycling technology (research).
2. **Secondary objectives** are defined as supporting and indirect objectives that support the primary objectives such as, for instance, the reduction of exporting from developed countries to developing regions and of importing in developing countries, which are prevention objectives to limit the level of environmentally relevant substances. Another example is aiming at increased life span and reuse quality by improved product quality.
3. **Tertiary objectives** are defined as those that support the overall efficiency of the take-back system and include, for example, enhancing infrastructure in collection and treatment, cost-effectiveness, and higher transparency and awareness levels amongst all stakeholders.

These objectives obviously require formulations that are more precise in order to be further translated into legislation, adjacent policies and technology, and financing interventions. Ideally based on and combined with outcomes of the previous assessment steps sketched Chapters 2 and 3, this ultimately ends in a specific description of e-waste system objectives.

In many countries, setting up e-waste legislation and adjacent policies has proven to be a significant incentive or even the sole activity triggering change. However, besides development of e-waste regulations, in essence there are three other main domains where initial decisions (for starting countries), improvement and extension decisions (emerging countries), and efficiency decisions (for established countries) need to be taken. The three domains are:

1. **The legal basis**, describing who is in charge at what time, that forms the main content regarding the development area of Policy and Legislation as presented in Section 4.2;
2. **The financial basis**, describing where funding is coming from to cover sustainable financing of collection and treatment for the development area Business and Finance as presented in Section 4.3;
3. **The organizational basis**, describing who will be executing various tasks and specifically what Technologies and Skills are needed in relation to arranging logistics, collection, and treatment as presented in Section 4.4.

For all three domains in Chapter 4, the key questions listed in Table 4.1 for starting, emerging, and established countries form the starting point for describing common issues, tasks ahead, recommendations, and already available tools and useful sources of information.

The focus of this chapter is to describe all individual intervention options. However, practical implementation requires alignment of possible interventions from the three development areas in conjunction. Therefore, the organisational process of practical goal setting, reviewing of different implementation options, and selecting of actual interventions is described in Chapter 5, which aims to accumulate the systemic efforts into one national road map.

4.2 POLICY AND LEGISLATION

A key question for starting, emerging, and established countries regarding developing Policy and Legislation is:

- Step 4: How and where should intervention (continue to) occur with Policy and Legislation?

4.2.1 Starting countries

For starting countries, commonly without government involvement, little to no development is realized. Having one single organization in the lead at the beginning is instrumental for the initiating steps. In some cases, however, voluntary programs stimulated by producers, recyclers, and/or NGOs on smaller scales have emerged. In McCann and Wittman (2015), there is no distinction made between the initiating role and executing roles, which do not necessarily have to be the same and can alter later. For starting countries, based on the country status analysis of Sections 2.4–2.7, it is advised to use an existing overview of organizations (possibly) involved or construct a new or updated overview when not existing. In case no policy has been developed so far, the entirety of decisions regarding the legal basis, possible organizational arrangements, and the financing structure is challenging to comprehend. There are, however, plenty of examples available on how countries have approached the issues previously. Considering these examples makes it easier to develop a focused and country-specific agenda rather than starting from scratch or spending substantial efforts to reinvent the wheel. Commonly, the key issues for starting countries are the lack of formal treatment facilities, a strong informal sector, and substantial volumes of (il)

legal imports of e-waste and used products (McCann and Wittman, 2015). Often, organizational structures are also absent, such as those representing producers, recyclers, and government entities. These conditions vary country by country and are inherently different compared to the situation for emerging and established countries. The challenge is to adapt the drafting of Policy and Legislation for these conditions instead of copy−pasting mature legal texts from established countries. The latter may introduce redundant or too-mature requirements that are unreachable for the specific situation in starting countries. Therefore, a key question here is:

- How should sensible regulation for e-waste be developed that timely covers the necessary basics and is sufficiently comprehensive for future expansion?

To cover the basics for starting countries, the main policy elements suggested are with regard to the legal basis, who should primarily be in charge, and how to deal with usually well-established informal sectors. Secondly, a decision on the product scope and basic definitions is relevant, and thirdly, the key interventions and initial implementation rules need to be decided upon.

4.2.1.1 The legal basis

For the legal basis, it is to be realized that the appropriate treatment of e-waste always costs money. There is a chain deficit irrespective of which country or region in the world is being considered. Financing of this deficit should therefore have a clear legal basis. Experience shows that if there is no strong legal basis for the financing part, discussions about this are endless because for financing, there are inevitable conflicts of interest between stakeholders. The actual options for financing mechanisms are elaborated upon in Section 4.3, while the legal basis for starting countries is discussed here. Although in most cases EPR (extended producer responsibility) is the starting principle, a range of possibilities and variants exist that delegate or distribute the responsibilities to actors in an alternative manner. Hence the key questions here are:

- Who should primarily be in charge?
- How are the informal sectors included?
- How is an initial collection target substantiated?

In many established countries, producer organizations have historically already been present. Thus, they are a logical choice for being assigned to take the responsibility from the legal basis, leading in the long run to less reliance on government entities as the (sole) initiating organizations. Nevertheless, it is important to distinguish who is in charge of initiating the e-waste development process and who has a more coordination or delegated role in executing the legislation later. It is recommended to analyze this decision against the stakeholder analysis performed in the country assessment part of Sections 2.4–2.7. Here, ideally the current presence and functioning of key stakeholders is described. The analysis of the existence of and the strengths and weaknesses of, amongst others, (other) government entities, producer organizations, recyclers organizations, and reuse and repair associations, can support the decision regarding the assignment of responsibilities. Here, ideally speaking, a more positive starting point in the initial discussions is "**who can contribute to what**" rather than "**who should pay**."

The legal basis—primary responsibility

McCann and Wittman (2015) distinguish two main options of having either government or producer responsibility organizations (PROs) in charge of managing the system. (In this chapter, "PRO" is used instead of third party organization (TPO) in the original version.) These two options are by far the most common; however, other possibilities do exist. In the Table 4.2, three more options are added, including the option to let individual producers steer collection and recycling entirely individually. This option can function for professional types of products and niche sections of the market that have a very direct collection possibility due to, for instance, lease contracts. However, for setting the initial scope in starting countries, inclusion of professional and low-volume equipment types may only complicate the basic steps required at this stage (see Section 4.2.1.2 for more details). Another option exists occasionally in a few emerging countries, which is the choice to put recyclers in charge of the system; the advantage is that the strengths and weaknesses of the collection and recycling market are commonly well known, and it may be easier to bring higher collection volumes into the reporting system. The disadvantages are potentially lower environmental standards, lack of transparency over the actual business activities, and the risk of solely preferring economic optimization over environmental concerns. A fifth and more complex option organizationally is to have a "three-partite governing" model, which sometimes coexists, for instance, in the form of a governing council adjacent to a PRO in some countries—for instance, for monitoring purposes only. This option for the system at large is somewhat theoretical. However, if feasible, organizationally it has a

Table 4.2 Pros and cons of main entity in charge for the e-waste system management

Entity in charge	Pro	Con
Government	Have powers of enforcement: for instance, by levying fines and ban noncompliant producers	Not always most efficient economically, as this can lead to additional layers of administration
		Can stifle (quick) innovation
	No potential conflict of interest	Money flowing into and out of government departments can be problematic
PRO in charge	More flexible—can adjust rules and outcomes more easily	Potential lack of enforcement mechanism
	Easier for PRO than government to develop relationship with members	Can focus too much on their members and do not have the wider community and environment as interested stakeholders
	Business incentive as costs and program can more easily be controlled and influenced	No economic interest to maximize collection volumes and treatment quality
Individual producers	Only responsible for own (share of) products.	No 100% control over collection channels
		Can focus only on own products
		Expensive to collect and sort only own products
		When producer is relative newcomer, little return volume expected.
Recyclers	More grip on collection and treatment	Less control over quality of treatment, risk of cherry picking only and economic optimization only.
	Less administrative and reporting burden	
Recyclers, producers, and government	There are always two out of three organizations in favor of more collection and higher quality of treatment. Similarly, two out of three organizations will be in favor of keeping costs down and proper reporting and monitoring.	More complex to arrange than a single stakeholder in the lead.
		Individual responsibilities potentially less clear

Last three rows extended from the original source: McCann, D., Wittmann, A., February 13, 2015. E-waste Prevention, Take-Back System Design and Policy Approaches. Solving the e-Waste Problem (StEP), Green Paper, Bonn, Germany. ISSN: 2219-6579.

substantial advantage in creating proper economic incentives for high collection rates and quality of treatment on one hand (government and recyclers will be in favor), and keeping the system cost-efficient on the other (government and producers in favor). The disadvantage, in particular for starting

countries, is the added complexity in negotiations and the need to have all three organizations already available and relatively well organized from the beginning. Therefore, the option can also be considered at a later stage in the development process in a second or third development round.

In all cases above, it is recommended to align the presence and strengths of the stakeholder actively present into a set of decisions and plans that will first assign who will be in charge of initiating the system and secondly who will receive operational responsibilities versus monitoring and control responsibilities. It can also be considered to change primary responsibilities over time, because those taking the initial lead may not be best positioned for mere operational tasks later on.

Individual versus collective responsibility

The question of who is responsible is a relevant and necessary one. However, in the past many lengthy and fruitless discussions on the advantages and disadvantages of the EPR principle and of individual producer responsibility (IPR) have been held. From experience, the discussion on the starting principles and whether a "polluter pays principle" versus EPR, or "collective" versus "individual" responsibility, has delayed the decision process significantly. It also distracts, in particular, starting countries from the most pressing environmental issues, which is to realize "old-fashioned" end-of-pipe solutions first. This said, this does not mean that prevention measures should be ignored. There are many cases where product design and "design for recycling" as a subset of ecodesign are leading to less environmental accidents built in. Obviously, improved product design is a meaningful long-term prevention strategy as such. Besides the relevant point that external costs should be internalized somehow, the original idea of IPR is that when producers are responsible for recycling, to minimize costs they would make their products more recyclable. This envisioned design feedback loop in the previous version of the European Union's (EU's) Waste Electrical and Electronic Equipment (WEEE) Directive (European Parliament and Council, 2003; European Parliament and Council, 2012) never materialized in reality (Huisman, 2013). This does not mean that design incentives should be discarded altogether. First of all, it is recommended that this area continues to be integrated and present in product policies instead of in waste policies to enable proper balancing with other ecodesign requirements. Secondly, it is recommended to be considered at a later development stage when both communication loops and reporting and analysis frameworks are more established and mature. Therefore, the topic of "design feedback" is discussed separately in Section 5.8.

Various additional sources, StEP Initiative white and green papers, TU Delft and EMPA publications developed over the years contain more examples of combinations of decisions taken in various countries regarding EPR-based policy frameworks (Huisman et al., 2006, 2008; Gregory et al., 2009; StEP Initiative, 2009, 2010, 2014, 2016, 2018; Schluep, 2012; Schluep et al., 2012; Stevels et al., 2012; McCann and Wittman, 2015).

4.2.1.2 Setting the initial scope and definitions

Following the starting principles regarding who are responsible, the setting of the product scope, proper definitions, and the first standards require attention. For setting the scope and making adequate definitions, practice shows that it is impossible to cover all outstanding and possible issues directly from the beginning. A successful approach is therefore to use scarce financial, organizational, and technical resources primarily for tackling those issues that are most pressing and to aim for interventions that have the maximum immediate effect. In particular, the scope of products could include all types of products ideally. However, initially it can be much more effective and faster to have a reduced scope to keep the legal, organization, and financing measures proportionate. Therefore, for starting countries, the key questions are:

- Which products should be included in the initial scope?
- Which definitions are crucial?

Setting the initial scope

The setting of the product scope has many consequences for basic management of the system. There are two basic options to start with, a limited scope consisting of the most relevant products or a full scope, potentially with certain exemptions (McCann and Wittmann, 2015). Generally speaking, the wider the scope, the more resources for registrations, expected volumes, and reporting, monitoring, and enforcement requirements will be needed, all adding to more complexity. The narrower the scope, the lower the expected volumes and the risk to leave relevant products untouched for the short and midterm. Here, the iterative approach of the development cycle allows starting countries to select a phased scope, allowing later extension by including more products (see also Section 4.2.2.2). The advantage of such a phased scope is to limit administration and registration burdens and to focus on the most environmentally relevant products first while maintaining the possibility for a full scope. The disadvantage can be that later such

extensions are not made and the existing legal framework is left as is. When selecting the phased scope, the choice of which products to include can be based on the environmental relevancy of specific products and high shares to total volumes entering the market. From the EU WEEE Directive review study (Huisman et al., 2008), a clear prioritization of environmental issues is provided related to individual equipment types such as mercury in energy-saving lamps and (older) LCD panels, CFCs from refrigerators and air conditioners, lead from the CRT glass of old TVs and monitors, and specific small and IT products with batteries such as laptops, tablets, and mobile phones, and possibly also batteries separately. These products are explicitly mentioned because they are clearly identifiable and can represent the collection category they belong to later, including additional product types that are relatively similar. Also, products with a high metal or precious metal content such as computers can be prioritized in the first definition of scope. See McCann and Wittmann (2015) for more background on the choices and later developments made in individual countries.

A specific subset to consider is the option to focus on equipment in use by government and semipublic entities such as schools. Because ownership is already with the public sector, collection can be arranged more easily and can provide for the first volumes to be steered to pilot treatment facilities.

Setting basic definitions

Directly related to scope decisions is the definition of actors in the chain and of various steps in the collection and logistics and of treatment. Even in established take-back system countries, many definitions are often incomplete, unclear, overlooked, or lacking. The consequence of this can be legal uncertainty or "escape routes" for stakeholders. Therefore, for example, definitions of "producer," "recycler," and "collector" are needed to adequately determine the legal status in relation to assigned responsibilities. This may seem trivial; however, experience shows that even minor differences and open interpretations between countries may lead to long discussions, legal issues, "escape routes," and suboptimal implementation in the long run. In this regard, a good recommendation is to learn from what others have done and not to try to invent everything independently. Fortunately, substantial documentation on the matter is available. For various principles, requirements, and a summary of definitions related to standards for collection, storage, transport, and treatment of e-waste, one can refer to Deubzer (2012). Examples from now-established countries can be found in the EU WEEE Directive (European Council and Parliament, 2012) and StEP Initiative (2010). In StEP Initiative (2009), common definitions for reuse are found, and in StEP Initiative (2014), specific definitions for e-waste are

summarized. For starting countries, the SRI project (2018) provides a comprehensive and useful list of such definitions as well. Finally, for individual countries, the StEP Initiative World Map provides links to all available e-waste-related legal texts for all countries in the world with a policy framework and their scopes and definitions (StEP Initiative, 2018).

Setting an initial collection target

Collection targets form an important incentive and translation of the e-waste policy objectives into tangible units. In the case of starting countries, the main difficulty is that not much information is available on what is achievable in coming years due to a lack of experience and data. In this case, the following sources provide benchmark information and time-series as reference points for comparable conditions (Baldé et al., 2015a, 2017; StEP Initiative, 2018). In addition, Baldé et al. (2015b) provides guidelines and classifications for starting the data collection process based on international trade statistics for starting countries in order to substantiate market inputs. In case sufficient information is available, one can start with a single, simple weight-based approach reflecting the chosen product scope, and in later stages further develop more sophisticated options (see Section 4.2.2.1). Alternatively, one can also define what efforts need to be done in order to initiate collection, such as the setting up of a minimum number and type of collection points, or that products within scope from specific sources, such as government entities, schools, universities, and larger businesses, must be collected within a certain time frame, and then gradually expanding coverage of the collection system without yet specifying a tangible goal.

4.2.1.3 Choosing initial requirements

The previous decisions on the legal basis and the scope and accompanying necessary definitions form the basis for the most important step in the initial policy development stages—the initial selection of requirements for national e-waste regulations. It can be rather complex to find a balance between the most pressing short-term objectives as well as preparing the framework for longer-term development, which is more difficult to envisage and for which resources and capacities are often not yet within reach.

- How far-reaching should the requirements be?
- How to involve the informal sector?

Possible key interventions for starting countries relate to the involvement of the informal sector, the banning of the most polluting practices, improving working conditions, and limiting imports of low-quality used goods and waste where applicable. Supporting actions can be organizing first collection and treatment trials, which is further discussed in Section 4.3.1.

Involving the informal sector

In case policy design is based on existing frameworks from established countries, the risk is that the informal sector either remains ignored or is reduced in areas where informal workers may provide necessary services for collection, repair, reuse, and waste treatment. These sectors do not directly contribute to the economy in the form of taxes (Bonner, 2009) and commonly do not take care of depollution of e-waste. Still, the informal sector can play an important role in providing sorting, repair, and reuse of electronics for low-income groups, providing many jobs, and collecting much larger volumes than formal sectors do in developing countries (McCann and Wittman, 2015; GIZ, 2011; Gunselius, 2017). The large involvement in dismantling activities that separate e-waste in purer fractions than achievable with modern mechanical separation technologies has a significant added value from both an environmental and an economic point of view (Wang et al., 2012). In most subsequent stages of treatment, there are specific disadvantages. Due to collection of the economically attractive fractions only and discarding or burning of the remaining, significant pollution frequently occurs. The economic efficiency and reuse value of products and components in the informal sector, combined with the absence of rules and taxation, poses an obstacle for developing a formal sector for the longer term. Organizationally, there are also opportunities that differ from those in emerging and established countries in the past. Smartphones offer a tremendous connectivity opportunity to inform and bring all parties involved in the e-waste sector together. So far, the potential of this opportunity has been grossly underestimated. Easily available information, exchange about best practices, dismantling instructions, quantities, and prices of secondary materials, available capacity, and possible outlets for valuable and critical fractions can be of great help, particularly for the informal sector.

Banning polluting practices

Important first intervention decisions are related to whether and where to keep the informal sector active in collection and dismantling. Here simple requirements can be proposed to avoid (further) pollution by banning the most impacting practices such as cable burning, acid leaching of printed circuit boards, the dumping (and burning) of plastics and other negatively

valued treatment fractions such as CRT glass, mercury components, and batteries. An example of a relatively simple change in practices is presented in Font (2014), providing simple and more efficient and thus affordable solutions to avoid cable burning. Positively, from collecting funds to professionalize the existing informal sector involved in the preprocessing stages, the accumulation of environmental relevant fractions can be realized. Here also, the role of municipalities should be defined, in case solid waste management is sufficiently organized, in facilitating own collection points and in permitting local collection points that can include informal recyclers and repair groups.

Reducing imports of low-quality goods

Specifically for starting countries with a significant influx of used and waste electronics, implementing the Basel Convention properly can limit the final amounts of waste entering the country. Besides the Basel Convention (1989), many other national rules and guidelines exist to limit net export flows of environmentally relevant waste products to developing countries (UNEP, 2015). Important here is also to spend some effort on understanding the main routes and actors in the import of used equipment and wastes. According to the Countering WEEE Illegal Trade (CWIT) project (Huisman et al., 2015), specific cooperation and information exchange with the sending countries can reduce the share of undesired imported volumes. For more information on the policy decisions possible, see also McCann and Wittman (2015), StEP Initiative (2016), Odeyingbo et al. (2017).

Improving working conditions

Usually, there is a lack of overview of the informal sector's specific functioning and in particular actual working conditions, which can be far worse than can be monitored from the outside. Thus, formulating a clear strategy of whether to involve the sector is difficult to take. McCann and Wittman (2015); SRI project, 2018) contains various options to formalize the informal sector by improving the level of organization in the form of cooperatives and associations. They also provide options such as arranging for specific types of financing of activities or buying of residual waste fractions, the establishment of partnerships between formal recycling industry players, and informal collectors and preprocessors buying both valuable and nonvaluable fractions at the same time. The B02W concept (Wang et al., 2012) and subsequent studies (Manhart, 2015; WorldLoop, 2018) provide a specific approach for organizing the preprocessing merely by the informal sector and the end-processing stages more around formalized sectors. Although the concept provides for useful direction to evolve over time, the crucial element remains that funds are needed to compensate for negative values

of (capital intensive) end-processing (abroad) and the logistics costs of complex fraction such as screens, CRT glass, brominated flame-retardant plastics, and batteries. Here, the Bo2W business model should be implemented integrally to avoid cherry-picking by taking care of all treatment fractions. Alternatively, when the seeking outlets for complex fractions is too cost-inefficient due to low volumes and/or high logistical costs, temporary storage of these fractions for later shipment can be considered.

Prepare for future updates and revision; provide a mandate to develop standards

The StEP White Paper "Guiding Principles to Develop E-waste Management Systems and Legislation" (StEP Initiative, 2016) contains additional elements and a range of case study examples that can be considered in initial stages. In short, the main recommendation is not to develop an "one round fits all" fully comprehensive legislation, but to start with relatively simple requirements to avoid polluted sites and gather funds to professionalize the existing informal collection and recycling activities as well as to block the most undesired import activities. Regarding setting targets, it is advised to set rules that are ambitious but still relate to the current situation and leave room to move quickly to the next stage in case improvements are indeed realized. Finally, revision deadlines for the way the scope is defined, as well as for the basic collection and treatment requirements in the first version, should be included. Finally, it is recommended to provide a mandate for developing the necessary implementation standards for collection and treatment. Section 4.2.2.2 provides more details here. Regarding initial reporting requirements, see also Section 5.6.1.

4.2.2 Emerging countries

After the initial legal basis and assuming also the initial instalment of financing and development of the basic Technologies and Skills from the previous implementation round, the focus at this point is to develop a revision round of legislation efficiently and implementing acts and standards that can be updated more regularly than the legislative framework.

For emerging countries with a first version of e-waste legislation enacted, a key question regarding the legal basis is:

- How should a successful revision of the initial legislation be run?

Commonly, the informal sector is present in emerging countries but gradually becomes more formalized and still needs improved working conditions. The same counts for the initial collection and recycling activities. Here, similarly, professionalization, realization of economies of scale, and connections to the international markets for recyclables and outlets for the critical fractions need to be established. Setting various standards and implementation guidelines is presented in Section 4.2.2.2. Extension of the initial scope and additional assigning of responsibilities is needed. Prior to this, Section 4.2.2.1 deals with the extension and improvement of the initial legal basis and specifically discusses the scope extension and the setting of the next system development goals. In Section 4.2.2.3, various additional interventions are discussed. Specifically, from a monitoring point of view, some reporting may take place, but more elaborate and reliable declarations over activities may be required. Also, improving control and further restricting imports is discussed.

As an example of a second round development cycle, the study for the recast of the EU WEEE Directive for the European Commission provided where specific adaptations and/or new elements are possible. A full analysis of many intervention options for the EU related to scope, collection, recycling and recovery, recycling targets, reuse targets, and treatment requirements is presented in detail in Chapter 10 of Huisman et al. (2008).

4.2.2.1 Update legal principles; extend the scope and set next goals

A key question regarding the legal basis for emerging countries is:

- Which elements need specifically to be updated and extended?

There are basic principles for which the e-waste take-back and treatment system should be stable and not subject to constant change. However, the implementation rules connected to them should be easily adaptable to changing circumstances as the system develops. This may be due to increasing technical sophistication and skills, market prices, changing quantities, and the composition of e-waste volumes.

Primary responsibility

First, based on the country assessment from Sections 2.4—2.7, the specification of complementary responsibilities in collection, treatment, and reporting can be reviewed and altered where needed. See again Table 4.2 from Section 4.2.1.1, which provides options to shift, for example, certain organizational responsibilities to other stakeholders.

Extending and updating the product scope

A second area of revision is the review of the scope. In case a limited scope is selected prior, an extension is possible to include more products. Here two possibilities exist. One is to expand with a listing of products that jointly form a collection category. The advantage here is that it is clear which products are targeted for future years. The disadvantage is that products change rapidly over time, making the lists possibly outdated at some point. Another option is to choose a more open scope like the EU WEEE Recast (European Parliament and the Council, 2012). Here the advantage is that newer products are automatically covered. The disadvantages are that there are always grey areas and certain exemptions needed to make the scope practical for declarations and reporting. Specific difficulties are related to dual-use products and whether professional equipment types should be covered. In some cases, financing requirements (see also Sections 4.3.1 and 4.3.2) are different for consumer versus business products. The FAQ of the WEEE Directive—Section 3 (European Commission, 2014), contains some practical explanations and examples of what is covered by the legislation and what is not. McCann and Wittman (2015) provides three basic options to: firstly, exclude business products altogether in case these are already collected to high degrees; secondly, apply the same regime for business as for consumer products throughout; or thirdly, to specifically address and list the criteria in case a distinction between consumer and business products is required in relation to the defined goals, financing requirements, and/or reporting requirements. In addition to this, specific criteria are needed for excluding products with a strictly professional application and often a dedicated return channel such as, for instance, by dedicated installation (and decommissioning) companies. Here also, the FAQ section to the WEEE Directive (European Commission, 2014) contains specific criteria for exemptions in this case. In addition, more analysis on the advantages and disadvantages of different options regarding the scope, in particular for "part of other equipment, military equipment, medical equipment, large industrials tools," can be found in Chapter 9 of Huisman et al. (2008).

Collection targets and options

As stated in Section 4.2.1.2, collection targets form an important incentive and translation of the e-waste policy objectives into tangible units. It is advised to set targets that are ambitious with respect to the current situation, but that are not so overambitious that they are perceived to be unrealistic and discourage further action. In case an initial collection target is used, the basic options to expand from an original target are the following:

1. Maintain the defined targets.
2. Apply specific targets per collection category.
3. Change from a simple weight-based target to a percentage of market input and/or waste generated.

The purpose of more elaborate collection targets is to stimulate collection, in particular of equipment with significant environmental impacts. In addition to these targets, additional requirements are possible to improve the collection infrastructure, for instance via specification of the type, number, and access to collection points for consumers. There is substantial information available on the design, level, and implementation of collection targets in Huisman et al. (2008) and in the specific study to develop a common methodology for the collection targets for all countries in the EU (Magalini et al., 2016).

Treatment targets

Setting specific targets for treatment can be challenging due to the heterogeneous nature of the various treatment categories and the changes in composition of products over time. This is particularly the case due to rapid miniaturization and the increasing use of plastics instead of metals. Treatment targets can ideally be defined per collection category or be material focused when expressed as a minimum recycling or recovery rate. They can additionally also be defined as removal targets for hazardous substances, capturing levels for greenhouse gases, or recovery rates for critical raw materials. They can also be defined as rather qualitative or specific minimum thresholds to be achieved.

The obvious purpose of recycling and recovery targets is to increase the actual amount of recycled content. A substantial amount of literature is written on the meaningfulness and scope of weight-based recycling targets such as in Huisman (2003), Huisman et al. (2008), as well as in the more recent EU review of these targets in Seyring et al. (2015). In most cases, a weight-based target is used. There are, however, other options, ranging from more simple requirements dedicated to the treatment of specific negative value

fractions such as CRT glass and plastics to very complex options such as environmentally weighted equivalents, which are not recommended here for direct application due to the level of modeling and impact assessment work that needs to be standardized and commonly agreed upon. It should be noted that even when using relatively simple weight-based targets, the definition of what is included is crucial and not always meaningful (Kalisvaart et al., 2000). This applies for instance when the weight of the fractions entering a recycling facility is counted instead of the actual recovery of, for instance, the metal content itself. As such, a weight based target can be a driver for higher inputs of residue materials instead of as-clean-as-possible inputs. In any case, when considering whether to use specific types of treatment standards, the challenge is to develop requirements that form an actual incentive for recycling beyond the economic optimization of recyclable content with a positive value. Options to further explore this are presented in Sections 4.2.3 and 4.3.3 for established countries. In many countries, setting minimum requirements is arranged by implementing dedicated WEEE treatment standards (see the next Section 4.2.2.2, which also reflects on reuse targets).

4.2.2.2 Develop implementing acts and standards to align responsibilities

The development of a national e-waste system is dynamic, and the formulation of legal requirements per definition cannot cover every single detail. To allow for flexibility, it is recommended to complement policies with a series of implementation rules and standards. Hence, a key question for emerging countries is the following:

- What is needed to complement initial policies with implementation rules, standards, and agreements?

From the previous legislative framework, a translation into practical terms is necessary. The outcomes can, for instance, consist of a set of elements that support more collection, better treatment, higher reuse levels, more transparency in reporting of final product and recycling fractions final destinations, enhanced toxic control, technical development of the recycling industry, higher reclamation of relevant materials, less local and toxic emissions and safety of workers, better separation of e-waste from residual waste, and various system organizational improvements.

E-waste standards have clearly evolved over the last few years. The technical guidelines from the SRI project (SRI, 2018) structures are a good example of such guidelines for collectors, collection centers, logistics, preprocessors (recyclers), and end-processing (disposal). The European WEEE-CENELEC standards series 56025 (CENELEC and EERA, 2017, Herreras and Leroy, 2018) provides clear guidance. These standards are split into the standards themselves (CENELEC—EN 50625) and their technical specifications (CENELEC TS-50625). For an overview, see also (JRC, 2018). Older documentation exists that covers more generic global standards (ISO, 2017) and specific US standards (R2 and E-stewards) (Deubzer, 2012).

Guidelines and standards for collectors and collection centers, and transport and logistics

Both the SRI project (2018) destined for starting and emerging countries and the European CENELEC standards (CENELEC and EERA, 2017) provide a specific listing of the implementation requirements related to registration, prohibited activities, management requirements, and materials management related to storage, transport, and handling (including requirements for the safety of workers). In addition, for collection centers, data erasing, packaging, and record keeping requirements are applicable and available. Also, requirements related to transboundary movements, transport documentation, and road traffic requirements are available. CENELEC specifically has the technical specification with more information numbered as (CENELEC − TS 50625-4).

Guidelines for treatment facilities

Various standards are available for reference. The SRI project (2018) includes specific rules per collection category for depollution and the monitoring of depollution (EERA and CENELEC, 2017). The CENELEC series provides detailed instructions for depollution with target values for batteries and other limit values for the removal of hazardous substances. In addition, management requirements are listed, and downstream monitoring requirements for hazardous fractions aim to provide necessary transparency. In particular, the (CENELEC − EN 50625-1) standard contains general requirements followed by specific standards per collection category: (CENELEC − EN 60625-2-1) for lamps, (CENELEC − EN 60625-2-2) for displays, (CENELEC − EN 50625-2-3) for cooling and freezing, and (CENELEC − EN50625-2-4) for PV panels. Templates for record keeping are provided, enabling comparison for monitoring purposes.

Guidelines for final processing

Specific WEEE-derived guidelines are rather scarce, partly because many end-processing facilities treat quantities from multiple origins. However, in Europe the (CENELEC—TS −0625-5) drafted outside the original mandate covers the end-processing of copper and precious metals fractions. See also EERA and CENELEC (2017).

More information on the development process of the WEEELABEX (source project)/CENELEC is available in Chapter 9 of this handbook (Herreras and Leroy, 2018).

Reuse targets and preparation for reuse

CENELEC has standards for reuse preparation (EN 50614). Reuse is obviously ranked higher in the waste hierarchy; however, not much practical documentation is available to realize higher repair levels and longer life spans of equipment (Bakker et al., 2014), as well as data security. Chapter 5 of the StEP Green Paper contains some e-waste prevention possibilities (McCann and Wittmann, 2015). The few existing guidelines are mainly focused on the prevention of damage to reusable products in the logistics process and access to these products at the initial sorting stages. More information on the advantages and disadvantages of targets for reuse and whether they should be included in the e-waste legal framework or in adjacent policies can be found in Seyring et al. (2015), in Section 9.4 of Huisman et al. (2008) and Chapter 9 of this handbook (Ijomah and Danis, 2018).

Design-related legislation and other policy interventions are not included here. The reason for this is that the main focus is on the e-waste management framework and less on prevention, which is an important topic discussed separately in Section 5.8.

4.2.2.3 Aligning stakeholder responsibilities

With an updated legal framework and specific implementation rules, the next step is to align stakeholder responsibilities to the proposed adjustments. Hence the key questions are:

- How can stakeholder responsibilities be aligned?
- What additional interventions are possible?
- Which measures can have an immediate effect?
- Are there sufficient resources for the various stakeholders to apply the implementation rules?

A clear identification of who is primarily responsible for execution of the drafted requirements supports the implementation. This also means analysis of whether the intended actor is indeed able to fulfill the selected requirements from the previous step in practice. An example table for the EU describing all stakeholder responsibilities is found in Huisman and Stevels (2008). It shows what specific direction could potentially lead to more consensus and harmonization and thus to more eco-efficient collection and treatment of WEEE. A further, more elaborated version is provided in Table 4.3, also based on Gregory et al. (2009).

4.2.3 Established countries

For established countries where Policy and Legislation plus all implementation rules have existed for several years, they are likely to be revised from those of the original framework. Commonly, despite all efforts, there is still quite a distance from the desired situation for various reasons. Substantial e-waste flows bypass the designated systems and control mechanisms due to economic realities in certain parts of the e-waste and metal trade sectors. Therefore, optimization and broader coverage of the system are the main objectives in this third loop. This can, for example, be realized by changing the economic incentives (see Section 4.3.3), reviewing the proportionality and efficiency of requirements (Section 4.2.3.1), fine-tuning the scope (Section 4.2.3.2), and more direct intervention based on "real-time" monitoring of collection and recycling performance (Section 5.6.3). Hence the general questions for established countries are:

- How successful is the implementation in reality?
- Where in the collection and recycling markets do economic mechanisms not promote higher collection and treatment quality?

A key word for established countries is flexibility. This means that there is preparedness to change if practice shows that the set of rules that has been set before does not work effectively and/or that expectations about the rules turn out to be incorrect.

Table 4.3 Stakeholder lessons from eco-efficiency studies/system implementations worldwide (Gregory et al., 2009)

Legislators
Adhere to "better regulation" and "minimizing the administrative burdens" principles: for example, in the EU, 28 different transpositions and interpretations of the WEEE Directive have led to high costs, disorder, delays, and lost focus on the original environmental intent. Increasing harmonization can improve compliance and avoid free-riding. Enforcement is essential to avoid free-riding, illegal exports, and low quality of treatment, and to create positive incentives for collection.
Producers have three types of responsibilities
Financially: Whatever financing mechanism is applied for the collection categories with net costs, the mechanism itself should not promote doing less. Organizationally: Producers are the only stakeholders with global organizing capabilities. More development of transnational or even global approaches should be welcomed that improve economies of scale, recycling knowledge, and better collection and treatment. Product design: From an eco-efficiency perspective, design should be focused on avoiding specific recycling "accidents." It is challenging to design away net collection and recycling costs. Furthermore, it is difficult to establish a design feedback loop that includes old appliances collected (sometimes 20 + years old) and new products. All design-for-recycling motivated product design changes should be evaluated from a life-cycle perspective to ensure that end-of-life considerations are balanced with other ecodesign principles.
Take back systems/compliance schemes
Develop a joint strategy and positioning towards an "Ideal WEEE Framework" based on compromise instead of debating individual issues separately. There are no one-size-fits-all solutions for all WEEE. Solutions tailor-made for different subsectors (IT, CE, White Goods, Lighting equipment) have completely different environmental priorities and economic models as well as incomparable breakdowns of take-back costs. Realize economies of scale: Educate consumers to hand in old products, make logistics efficient, and aggregate treatment and auditing standards for recyclers. The introduction of market instruments that encourage positive competition for more collection should be further researched.
Municipalities
Maximize collection: Avoid illegal trading and "cherry picking." Provide easily accessible, free of charge collection points for consumers. Mandatory hand-in to compliance schemes can decrease (illegal) trading of collected goods. Furthermore, educate local consumers on easily accessible waste collection points.
Retailers
Maximize collection: Better retail involvement means more service to consumers with more easily accessible collection points and a direct fulfilment of producer obligations for their own-branded products. An "all-for-all" take-back mechanism should be considered: selling a product category means take-back of any type of equipment free of charge with an obligation to forward collected waste to compliance schemes.
Recyclers
Develop "best available" technologies and practices for the recycling sector, particularly monitoring practices for outgoing material fractions. Avoid illegal secondary trading with its associated adverse environmental effects by installing and complying with transparent substance flow monitoring and reporting.
Consumers
Maximize collection: Hand in old products. Consumers will pay in the end, regardless of whether costs are made visible or internalized.
Inspection authorities/Enforcement agencies
Develop inspection plans and arrange for communications with the collection and recycling sector to enable "smarter" inspections.

4.2.3.1 Proportionality and administrative burden

The efficiency of the system at large can be improved, and streamlining in reporting and removal of superfluous requirements may add to such efficiencies. Hence a key question here is:

- How can proportionality and efficiency be improved?

Whereas in previous rounds, a lot of attention is given to compliance as such and wider coverage of the legal framework and implementation rules, as a consequence the environmental effectiveness and economic efficiency is not necessarily considered again. In some cases, areas may have been regulated or rules have become superfluous. Because of increasing awareness or business-to-business arrangements, proper collection and recycling ideally have become the norm instead of the exception. Superfluous requirements can be considered for termination in case environmental evidence can be provided that (parts of) the collection and recycling market can arrange for proper collection and recycling itself. Also, in cases where the administrative burden can be proven to be extreme in comparison to insignificant quantities affected based on the proportionality principle, similarly requirements could be loosened or terminated or the related reporting could be simplified and streamlined.

As a basis for optimization, Section 3.5.4 provides an eco-efficiency approach that can be used for determining where to apply changes in the established system. Monitoring of performance data, as discussed in Section 5.6.3, can be used to compute various improvement options as well as the consequence of removing specific requirements with little effect on the overall system performance.

Scope

The advantage of an open scope option as proposed for emerging countries in Section 4.2.2.2 is that often the product scope needs to be expanded to new or other environmentally relevant items that enter the market. The disadvantage is that this also applies to equipment types that, due to their value, specific functioning, and/or underlying business model, evidently are collected and treated properly. For instance, professional medical appliances with a high "social development value," undergoing refurbishing and export to healthcare sectors in developing countries, can be taken out of scope. In particular, in cases where a circular economy-based business model arranges

for maintenance, repair, decontamination, and decommissioning, removal from scope or exemptions in case contractual arrangements can be evidenced, should be considered to remain flexible and targeted in implementation.

Termination of rules

Also, in other areas, there may be room for reducing administrative burden and removal of requirements where the market has successfully professionalized collection and treatment practices. Accounting for the outputs from the country analysis and impact assessment steps (Chapters 2 and 3), termination decisions can be made in the last steps of the e-waste development model. It is recommended in the monitoring and reviewing round after the current development cycle to not only focus on additional requirements but also at the removal of unnecessary, ineffective, and outdated elements. Thus, termination has a character similar to that of selection. If political action was successful or the framework conditions change to such an extent that the measures seem pointless, parts of the legal framework and implementation rules can be discontinued completely. Although this activity is seldom planned systematically, the rationale behind this step is that by doing so, long-term public support and acceptance remains; in particular, also from industry stakeholders when negotiating more extended cooperation to improve the efficiency of the system where most needed.

4.2.3.2 Update and mature implementation rules

- How to mature and update implementation rules?

Improve quality of collection volumes

The standards and their accompanying technical specifications introduced in Section 4.2.2.2 need regular maintenance and updates due to the rapidly changing compositions of EEE products and sometimes due to new recycling process innovations. It is recommended to link this discussion directly to the monitoring and reporting framework and in particular to the harmonized formats for batch testing and analysis of the chemical content of products and fractions and the analysis of collection quality as highlighted in Section 3.5.3. More information and templates can, for instance, be found in Magalini and Huisman (2018) and from the ProSUM project (Huisman et al., 2017; Rotter at al., 2017).

Improve quality of treatment

As already illustrated in Section 3.5.3, often the collected volumes in the designated system are the oldest and lowest product types that are frequently scavenged for valuable components. This has clearly both an environmental and economic effect. Section 3.5.4 discussed how to better monitor this. However, the information is relevant for updating and maturing existing implementation rules. For instance, for determining depollution threshold values, the scavenging effect has a detrimental influence on what can be achieved compared with more complete collection. In the case of Europe, the WEEE Directive (Annex VII in European Parliament and Council, 2012) does not (yet) contain specific requirements on reporting the amounts of hazardous components obtained from selective treatment and their destinations. Adding such reporting requirements in the future can support more transparency and form an incentive for higher treatment quality. See also Section 4.2.2.2 on reporting under CENELEC/WEEE LABEX standards in this regard. It should be noted that some individual countries have made the CENELEC standards mandatory in their national transposition of the WEEE Recast Directive (European Parliament and Council, 2012).

4.2.3.3 Improve system efficiency and cooperation

- How to mature stakeholder cooperation?

"All actors report"

Correct reporting is indispensable for managing the system after rules have been set. Continuous attention for the system through reporting and **analysis of the reporting** is needed to keep it going well and to identify issues that must be addressed in the next stage of the e-waste cycle. EU countries face the common problem of nonreporting, incorrect reporting, and underreporting of collected and treated WEEE amounts. Nonreported and incorrectly reported WEEE flows are particularly prone to illegal trade and improper treatment. It has been observed that some compliance schemes only monitor and control a part of the WEEE collected and treated. In addition to this, many holders and recyclers of WEEE already report, but not to a unified database on a national level. In some countries, producers and compliance schemes report WEEE collected to different competent bodies, sometimes using different, and worse, incompatible codifications. Another

recurring issue is the mixing of WEEE with mixed metal scrap. Improved reporting will enable more accurate country- and EU-level statistics and other monitoring linked in particular to estimating the "true amounts of illegal WEEE" shipped annually from Europe to developing countries.

Various country studies have attempted to quantify WEEE flows outside the reported systems [(Huisman et al., 2012; Magalini et al., 2012, 2015) as well as the CWIT project from a European perspective (Huisman et al., 2015)]. Subsequently, the EU study regarding a common methodology for measuring collection rates (Magalini et al., 2016) highlighted the need to improve reporting **through all routes**. The actual reporting possibilities and templates will be further discussed in Section 5.6.2. As an example of how requirements look from a legal point of view, the EU WEEE Directive—Recast (European Council and Parliament, 2012) states that such information should become available (Art.7) and needs to be actively gathered by Member States (Art 16). Also, the corresponding FAQ document (European Commission, 2014) clarifies that they should adopt measures to involve all actors in WEEE collection and receive the information of WEEE quantities collected through all routes (European Commission and Digital Europe, 2017). The latter reference highlights different practices and tools in development to improve reporting by the metal scrap sector. In some countries, it is made mandatory in the national implementation to report these volumes, but reluctance in the sector to report either mandatorily or voluntarily remains. This counts specifically for valuable but illegal volumes that are commercially very attractive.

The value of improved reporting can be further exploited when key stakeholders are involved in both the research and the analysis as well as the interpretation of the mechanisms behind noncompliant and complementary collection and treatment. The examples of the UNU country studies did not only generate new information but were also pivotal in feeding and focusing stakeholder discussions via **joint analysis of the results** on how to achieve upcoming collection targets.

Cooperation with other compliance organizations for other waste streams

Some synergies may exist in reporting and management between related waste sectors such as systems for collection and treatment of batteries, vehicles and plastics, for example. In particular related to batteries, more jointly covering this waste stream from an organizational point of view can lead to significant synergies. Also, monitoring and comparing results for both streams in conjunction makes sense, because large volumes of

batteries are often embedded in electronics products and are recovered separately in e-waste treatment facilities.

4.3 BUSINESS AND FINANCE

It is of utmost importance that fund management is directed toward maximizing collection and treatment. Financing of downstream e-waste activities and allocation of economic responsibilities along the downstream chain have proven challenging in countries with existing take-back schemes and in countries discussing potential take-back system architectures (Magalini and Huisman, 2007). Hence a key question is:

- Step 5: What needs to be financed and how?

Often at the beginning of the stakeholder discussion in starting countries, the first question asked is: "Who should pay what?" The posed question is purposely different by asking first: "What needs to be financed and how?" The reason is that due to too much focus on "who," the "what," "why," and "how" of the financing system moves out of sight. Financing enables proper funding to be available to ensure environmentally sound treatment and downstream activities for all waste arising in the country in any given period. It ideally also covers wider support activities including monitoring and enforcement as well as awareness raising and research. Allocation of specific roles and responsibilities when it comes to financing system does not mean addressing only one stakeholder. Many different systems and models coexist. Closely related to the choice for the legal basis as described in Section 4.2.1, the mechanism by which stakeholders financially contribute to different activities varies, and many models exist. For starting countries in particular, the chosen system objectives, intervention areas, and principles need to be translated into a basic financing configuration that matches ambitions. The financing determines to a large extent the responsibilities of relevant stakeholders at local, national, regional, and global levels. From a general perspective, three main stakeholders could bear financial responsibility for end-of-life electronics products (Gregory et al., 2009):

- Producers: This is implementation of various degrees of the extended producer responsibility (EPR) principle. It can be argued that even though a producer may bear "by law" financial responsibility,

customers will eventually pay the end-of-life costs as an increase of the product price, even when no up-front external charges are paid at point of sale.
- Consumers: This can be seen as an implementation of the "polluter pays principle," whereby the polluter is recognized as the person responsible for discarding an end-of-life appliance (or buying the appliance many years before).
- All of society: As e-waste is a societal problem, having an impact not only on consumers but also on the entire population (both in terms of environmental and societal impacts), one can also argue systems could be financed by the entire society (i.e., by taxpayers) (Gregory et al., 2009).

4.3.1 Starting countries

For starting countries, the specific key questions are:

- What is affordable in the start-up phase and what is not?
- Who can provide initial financial resources?
- Which financing mechanism should be selected for my country?

Pilot project funding

As a first step, options should be considered for the very first stages separately from the final financing mechanism and financing level decision. The rationale is that financing for early learning scale activities is smaller and makes it easier to arrange and speed up the development process. Some options exist for the financing of these first more exploratory steps:

1. A small government fund is the first option. The advantage of starting with one's own financial resources allows for full control over the agenda and priorities and does not yet require full cooperation with other actors. Another advantage is that it is easier to arrange in case a pilot collection trial is conducted with equipment from government entities.
2. Funds from the private sector from producers, recyclers, or both. The advantage here is direct involvement of actors later needed for expanding the system. The disadvantage is that later, hesitations may arise to scaling up and providing for more structural financing.

3. Development project funds are an alternative source when limited national resources are available. Various examples include the UNU E-waste Academies (UNU, 2018), UNIDO funding for Ethiopia, Uganda, Vietnam, and Cambodia (Magalini, 2015), from the German BMZ/GIZ in Ghana (Gunselius, 2017), and the Swiss SECO-funded SRI projects in Colombia, Peru, Ghana, Egypt, and India (SRI project, 2018; Méndez-Fajardo et al., 2017). The advantage here is not just external funding but also the availability of global experts for developing e-waste management who are working directly on these programs. Many of these projects have funding for a variety of topics and are rather different in focus and coverage.

The basic financing mechanism

The purpose of selecting the finance mechanism is to ensure structural financing over many years in a stable manner. The basic choices were firstly published by Magalini and Huisman (2007), later elaborated upon by Gregory et al. (2009), and more recently updated by McCann and Wittmann (2015):

1. The up-front fee finances all activities in the system at the time of placing a product on the market. For example, this can be accomplished by joining a PRO or by financing one's own take-back system or collective compliance scheme.
2. Visible fees for historic waste generate revenues from final users to cover waste management costs. The visible fee mechanism was originally introduced by the EU WEEE Directive as a means for producers to share with consumers the burden of financing historical waste. Producers are therefore allowed to share financial responsibility with consumers to cover the costs of historical waste. However, its use has been extended under the EU WEEE Recast (European Parliament and Council, 2012), so that it is now also a mechanism for financing future e-waste.
3. Market share compliance costs are used to allocate market share based on the volume of product placed on the market in a given time frame, usually 1 year. In order to avoid cross-subsidization, the market share is generally calculated either at a product or a product category level. The obligation on producers comes in two forms. Firstly, there can be a requirement to pay the relevant percentage of total operating costs of the entity collecting and recycling the e-waste arising on their behalf. Alternatively, clearing houses (entities responsible for the allocation of responsibility between all producers) can be established to arrange for the collection and recycling of the appropriate amount of e-waste that arises.

4. Return share compliance cost: an alternative is the concept of allocating responsibility based on return market share, which is one way of implementing IPR. This relies on random auditing of the e-waste that is being returned through the take-back system. This method is applied at a product level or a product category level. It requires that the system manager, either a government or PRO, record the brand and volume of each product in order to be able to calculate the percentage of returns that each producer is responsible for.
5. An end of life fee is paid by generators of e-waste (i.e., the last owner of a product who decides to recycle it) to an entity who assumes responsibility for recycling the e-waste at the moment it is handed over to the recycler. The fee covers collection and recycling costs.

In Table 4.4, some additional advantages are included for the upfront visible fee because a key problem for starting countries is the lack of resources for investment in collection and recycling infrastructure. More information is available in various StEP publications, of which McCann and Wittmann (2015) is the most recent.

Setting up a registration system for market inputs

Here, there a two basic options: (1) the most common is to establish a producer compliance scheme in charge of setting up a market input registration system for products chosen to be in scope, and (2) another possibility is to use trade statistics, when sufficiently reliable, in the first instance to avoid setting up a costly and time-consuming new system. Obviously, in the first case producer associations are logic placeholders, and in the second case this is preferably an independent authority such as a department of trade that has access to import, export, and when applicable, production statistics.

Developing a business plan for dismantlers

In Spitzbart et al. (2016), a small tool is provided for business newcomers in e-waste treatment in starting countries. To avoid rudimentary methods due to a lack of economic knowledge, the StEP-Business-Plan-Calculation-Tool supports entrepreneurs in setting up an economically viable e-waste recycling business in an environmentally sound manner. The tool is available at the StEP website (Spitzbart et al., 2016).

Table 4.4 Pros and cons of different fee systems

	Upfront fee	Visible upfront fee	POM-based market share	Return share	End-of life fee
Pros	Simple	Simple	Only actual costs are raised	Only actual costs are raised	Simple
		Transparency to consumer creates awareness	Specific for product types	Most accurately assigns cost to producers causing most impact	Transparent to the consumer
		Creates funds available upfront to invest in infrastructure		Accounts for where product arises as waste and where product POM does not matter	
Cons	Inflexible	Inflexible	POM not necessarily reflective of actual share of recycling volume	In many countries, brand owner will not be the importer and therefore assigning responsibility to the correct party will be challenging	Potential to act as a disincentive to recycle
	Easily generates surplus	Easily generates surplus	Need to account for e-waste collected through producer's own take-back systems	Requires additional work to perform auditing	Major surpluses are raised
	Difficult to address deficits when insufficient funds are raised for a specific product type	Difficult to address deficits	For the first years, funding source needs to be identified as funding is retroactive	Additional work means additional administrative cost	
	Need to account for e-waste collected through producer's own take-back systems	Creates additional administrative burden		For the first years, funding source needs to be identified, as funding is retroactive	
		Need to account for e-waste collected through producer's own take-back systems		Producers are required to create financial provisions to cover the cost of recycling their entire installed base.	

Updated from source: McCann, D., Wittmann, A., February 13, 2015. E-waste Prevention, Take-Back System Design and Policy Approaches. Solving the e-Waste Problem (StEP), Green Paper, Bonn, Germany. ISSN: 2219—6579.

4.3.2 Emerging countries

The key questions for emerging countries are:

- How does the chosen financing system function?
- How can it be refined and adopted where needed?

Financing for critical fractions

For emerging countries lacking their own end-processing facilities, special attention is needed to find proper outlets for complex fractions. Here, specific financing and the underlying organizational efforts are needed to gather sufficient volumes for shipment and to arrange for the necessary paperwork related to transboundary shipments, with work by McCann and Wittmann (2015), Wang et al. (2012), Schluep et al. (2009) containing more information on this topic. An important task is to arrange the handover of critical fractions from informal collectors and recyclers to dedicated collection points or formal recyclers. This is either for free or for a small fee, thus making the additional effort worthwhile. For key fractions with a negative value such as batteries (including lead-acid ones), CRT glass, BFR plastics, plastics from cable stripping, LCD displays, and preferably intact, mercury-containing CFL tubes from flat panel displays, the right price level needs to be determined. A challenging task is to set up a network of collection points, preferably in urban areas first. Often the collection of valuable fractions is also not arranged automatically. For valuable fractions such as metals and printed circuit boards, formal recyclers often face cash-flow problems because of delayed payments when end-processing fractions are only paid out after being first shipped, then assayed, and finally processed often months after initial delivery. Here, the B02W follow-up projects (Manhart, 2015; WorldLoop, 2018) provide some guidance and lessons from individual country implementation attempts.

Streamlining financing

Assuming the financing mechanism is implemented and the funds available, the arrangements commonly can be better streamlined to improve collection and treatment operations where specifically needed. In many cases there are deficits, surpluses, or financial flows that are not directed to the right place in the recycling chain. The original financing mechanism and the levels chosen are frequently adjusted to changing economic realities, material and

labor price changes, increasing volumes, and connected improved economies of scale.

In order to adapt timely and adequately, sufficient information is required, as also exemplified in Section 3.5.3. Key areas of attention are (Magalini and Huisman, 2007):

- The positive and negative effects of competition. When sufficient volumes are present, sometimes multiple compliance schemes function in the same country, potentially reducing prices. On the flip side, competition should not take place via the lowering of collection and treatment quality as discussed also in Section 4.3.3.
- The effect of economies of scale is a very important economic parameter. In general, the larger the scheme, the lower the price per ton that can be asked for collection and treatment.
- The effect of relatively high or low primary raw material prices. Here, specific agreements can be made between recyclers and compliance schemes to reduce the risk when lower than contracted and/or to share profits in case they are higher.
- The accumulation of visible fee funds and/or guarantees. Sometimes past prognoses were too pessimistic, causing interfinancial resources of significant sizes.
- Besides direct costs for logistics and treatment, resources for indirect costs include service, R&D, awareness campaigns, information and education, etc. It should be noted that stiff competition potentially undermines the development of skills, innovation in technologies, and education and awareness.

Penalties

Penalties are a specific area not often considered or embedded in the legal framework or accompanying the implementation rules. In cases of noncompliance in collection and treatment, penalties are regularly arranged for in adjacent general solid waste regulations. What is specific for e-waste systems, however, is free-riding by producers who do not correctly register their quantities placed on the market or do not register them at all. When multiple compliance schemes exist, implementation rules are helpful to allocate the shares of quantities and thus costs, including monitoring, consumer education, and skills development costs over the systems at present. Additional specific measures in the form of penalties to reduce free-riding are recommended. Regarding illegal recycling and trade toward developing countries, penalties vary greatly in terms of monetary fines and prison durations (Huisman et al., 2015). According to the CWIT project, generally in

Europe, participation in WEEE illegal activities does not appear risky to offenders because of the low probability of being prosecuted and sentenced. Even if cases are successfully prosecuted, the penalties foreseen in legislation and/or the penalties applied in court decisions are typically low. In many cases, the fines imposed are less than the profits to be gained from one illegal shipment. Specific recommendations to improve the economic incentive of penalties are available in Deliverable 6.1—Recommendations related to the EU Legal Framework from the CWIT project (Huisman et al., 2015). This includes a further elaboration on assessing and increasing penalty levels, ways to harmonize the classification of offense types, and how to take further-reaching measures in those cases where organized crime is suspected to be involved. More information regarding organizing and managing enforcement is included in Section 5.6.

4.3.3 Established countries

For established countries, the key questions are:

- Why are certain volumes treated outside the designated systems?
- How can quality in collection and treatment beyond basic compliance be rewarded?
- Is financing efficiently steered toward the point of desired intervention?
- Are there sufficient funds for research and innovation in collection and recycling?

Positive financial incentives for collection and treatment in an economically level playing field

An important driver for not reporting all quantities collected and treated is often the much higher value of reuse of valuable products and components from collected volumes. A second driver is compliance costs when reporting and following the logistical and treatment standards mentioned in Section 4.2.2.2. Even when these costs are, relatively speaking, a small share of total costs (see Section 3.5.3 for an example), a major concern is still that the effect of avoiding compliance costs seems to be orders of magnitude higher than the margins of these companies operating in competitive markets. Hence, noncompliance is economically rewarding and potentially leads to competitive distortion at the expense of environmental performance. It is therefore recommended to investigate how operational costs are built-up, such as the costs in the example provided in Section 3.5.3. It is important

here to understand the difference between the costs of full compliance versus the main option below such levels of collection per category (Magalini and Huisman, 2018). What can be arranged in the case of established countries is to specifically and independently determine compliance cost components based on actual (and anonymized) information regarding price difference for the various cost elements related to compliance. This includes costs for reporting, sampling, and mass balance reports, the costs for depollution per collection category and the effect of scavenging of products, components, and materials that degrades material revenues by constructing a scavenging index. Based on this, there are certain strategies possible to mitigate the effect of higher compliance costs. For example, producer compliance schemes can offer dedicated prices for the entire sector to always cover the minimum compliance costs. Alternatively, technical and financial offers could be weighted in such a way that higher performance—e.g., higher depollution levels—is adequately rewarded, and the effect of scavenging is specifically addressed in contract negotiations with PROs.

Financing of collection in starting countries by established systems

One option that is relatively unexplored is the following—from a circular economy thinking point of view, many products originating from well-established markets end up in developing countries. In order to create a net flow of both toxic and recyclable materials relevant for new production cycles to the country of original production and consumption, an idea can be for established countries to finance and arrange for collection in starting countries. The advantage is that, especially when the financial resources are available, this allows PROs to realize their collection targets in starting countries on one hand while speeding up the realization of collection and treatment infrastructure on the other. This is potentially instrumental for countries where a lack of financing is often the most pressing obstacle. The disadvantage is that such schemas require substantial cooperation between countries, and arranging for evidence that collection and treatment is indeed taking place remotely.

4.4 TECHNOLOGIES AND SKILLS

This section focuses on the Technologies and Skills required specifically for collection, treatment, and the further management and training of those who are active in daily operations. The purpose is that beyond the legal framework and the financial resources discussed in the previous sections, the logistical resources and technologies available determine to a large extent

how collection and treatment will function. The management side, being the human resources and skill sets available, is obviously very relevant for developing national e-waste systems. Hence a key question for all three types of countries is:

- Step 6: What Technologies and Skills are needed?

4.4.1 Starting countries

For starting countries, the main challenges are to start with basic education of processors regarding environmental, health, and safety processes, to start small pilots in populated areas alike the "Best-of-2-Worlds" approach (Wang et al., 2012), and to organize a take-back loop of critical fractions and the corresponding administrative procedures for return waste shipments. Hence some key questions are:

- How can a basic collection infrastructure be developed?
- What are the technologies, investments, and skills to be mobilized to get better e-waste treatment?
- Which basic management skills are needed?

Pilot studies on collection and treatment

As a first step in developing collection infrastructure, following the pilot project financial advice of Section 4.3.1, it is highly recommended to start collection trials on a small scale in urban areas. Single or multiple pilot projects can provide valuable insights into the types of equipment available for recycling and their respective values and compositions, including valuable and critical materials and components. In 1997 in the Netherlands, one of the earliest case studies was conducted (Ploos van Amstel, 1997). At that time, collection experience and closely connected recycling experiences were instrumental in speeding up infrastructure development. They provided the key first parameters for determining what technologies and costs levels can be expected. From a treatment perspective, valuable insights are obtained in the composition and share of treatment fractions and what local options exist for further processing. It is advised to develop a simple dismantling and shredding protocol where applicable to determine, per

collection category. the quality of copper, aluminum, steel, plastics, glass, and residue fractions as well as the quantities of critical components such as printed circuit boards, motors, cable, CRT glass, batteries, etc., and their subsequent treatment options as well. In addition, accompanying experiences regarding working conditions, storage, and handling are gathered in this phase.

As a template for starting countries regarding which basic technologies are potentially available and possible process setups, the UNEP report (Schluep et al., 2009) provides a useful overview Table 4.5.

As already indicated and listed in Section 4.2.2.2, the SRI project (SRI, 2018) provides additional checklists and guidelines for collectors, collection points, and treatment facilities.

Table 4.5 Separation and dismantling criteria for E-waste

	Desired treatment/action
1. Separate before treatment	
a. Toxic/hazardous materials	
Cooling fluids and foam	Controlled removal and disposal
Mercury backlights	Controlled depot
PCB capacitors	Controlled depot
Batteries	Sort and process in specialized plants
b. High-value materials	
Reusable components	Refurbish and sell
Circuit boards (High- and medium-grade)	Process in integrated nonferrous/copper smelters
Circuit boards (Low-grade)	Upgrade (manually) and process in an integrated manner Smelters
2. Dismantle, liberate, sort	
Clean plastics	Process further with appropriate technologies
Cathode ray tube glass	Process further with appropriate technologies; glass to glass producer, CRT glass to CRT glass producer or lead smelter.
Ferrous metals	To integrated steelmaking facility or to steel scrap or resmelter (electric arc furnace)
Nonferrous metals: Al, Mg	To secondary aluminum or magnesium resmelter or other appropriate technology. (Low-quality scrap can also be used in steelmaking as a reducing agent (feedstock recycling)
Nonferrous metals: Cu, Pb, Sn, Ni, precious metals	Process further with appropriate technologies
Others	Process further with appropriate technologies

From Schluep, M., Hagelueken, C., Kuehr, R., Magalini, F., Maurer, C., Meskers, Mueller, E., Wang, F., July 2009. Recycling — From E-Waste to Resources, UNEP - DTIE, Paris.

Pre-processing

The role of preprocessing is well described in the EWA toolkit and copied here entirely (UNU, 2012):

> *"The aim of pre-processing phase is to liberate the materials and direct them to adequate subsequent final treatment processes. Pre-processing technologies can vary accordingly to the specific waste stream. E-waste and generally speaking different devices are grouped for the end-of-life management according to specific technologies and processes needed in the downstream phases. Hazardous substances have to be removed and stored or treated safely while valuable components/materials need to be taken out for reuse or to be directed to efficient recovery processes. This includes removal of batteries, capacitors etc. prior to further (mechanical or manual) pre-treatment. The batteries from the devices can be sent to dedicated facilities for the recovery of cobalt, nickel and copper."*

> *"For devices containing ozone depleting substances such as refrigerators and air-conditioners, the de-gassing step is crucial in the pre-processing stage as the refrigerants used (CFC or HCFC in older models) need to be removed carefully to avoid air-emissions. For CRT containing appliances (e.g., monitors and TVs) coatings in the panel glass are usually removed as well before end-processing. LCD monitors with mercury-containing backlights need special care too, as the backlights need to be carefully removed before further treatment."*

> *"The circuit boards present in ICT equipment and televisions contain most of the precious and special metals as well as lead (solders) and flame retardant containing resins. They can be removed from the devices by manual dismantling, mechanical treatment (shredding and sorting) or a combination of both. It has to be noted that pre-processing of e-waste is not always necessary. Small, highly complex electronic devices such as mobile phones, MP3 players etc. can (after removal of the battery) also be treated directly by an end-processor to recover the metals" (see also Huisman, 2004).*

> *"After removal of the hazardous and other special components described above, the remainder of the ICT, cooling or television devices can be further separated in the material output streams by manual dismantling or mechanical shredding and (automated)*

sorting techniques. Fractions are usually iron, aluminium, copper, plastic etc. It is of utmost importance that the generated output streams meet the quality requirements of the feed materials for the end-processors. A mismatch between the two can lead to the creation of difficult or non-recyclable fractions. Well-known examples are the limits on copper content in fractions for iron/steel recycling, or the limits on iron, nickel and chromium content in aluminium fractions. Furthermore, a quality mismatch can lead to the loss of material resources. For example, aluminium would not be recovered during end-processing when mixed with an iron/steel fraction or with a printed wiring board fraction, iron/steel is not recovered during aluminium recycling, and copper/precious metals are not recovered during iron/steel recycling. The challenge is to define the right priorities and find a balance in metals recovery that considers economic and environmental impacts instead of only trying to maximize weight based recovery rates, regardless of the substances involved. Another aspect could be the mismatch in physical aspects of the materials, such as particle size. One could think of shredded e-waste material while the smelters can easily take un-shredded material" (UNU, 2012).

End-processing

The role of end-processing is also described and copied from the EWA toolkit (UNU, 2012):

"The end-processing from output fractions after pre-treatment takes place at multiple destinations, depending on takes place at multiple destinations, depending on the fractions. Ferrous fractions are directed to steel plants for recovery of iron, aluminium fractions are going to aluminium smelters, while copper/lead fractions, circuit boards and other precious metals containing fractions are going to e.g., integrated metal smelters, which recover precious metals, copper and other non-ferrous metals, while isolating the hazardous substances. Hazardous fractions are also directed to specific environmentally sound treatments/plants. Both ferrous and non-ferrous smelters need to have state-of-the-art off-gas treatment in place to deal with the organic components present in the scrap in the form of paint layers and plastic particles or resins containing flame retardants. During smelting formation of volatile organic compounds (VOCs), dioxins can appear and their formation and emission have to be

prevented. Alternatively, painted scrap, such as painted aluminium can be de-lacquered prior to smelting using appropriate technologies with off-gas control equipment."

"For treatment of circuit boards, it is of utmost importance that the smelter is equipped with state-of-the-art off-gas treatment equipment, since otherwise dioxins will be formed and emitted. Standard copper smelters or hydrometallurgical (leaching) plants however, are not advisable for circuit board treatment due to inadequate handling of toxic substances (such as lead, cadmium or organics) and lower metal yields. In hydrometallurgical plants the special handling and disposal requirements necessary for the strongly acidic leaching effluents (e.g., cyanide, nitric acid, aqua regia) have to be diligently followed to ensure environmentally sound operations and to prevent tertiary emissions of hazardous substances."

Management and organizational skills

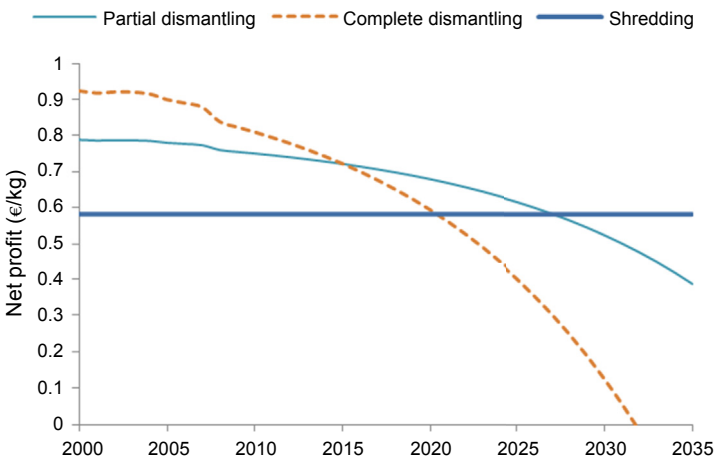
The UNU E-waste Academy series, held since 2010, has two versions for scientists (EWAS) as well as managers and policy makers (EWAM). The academy provides both basic information about the topic from a global perspective specific training related to the different steps relevant for local situations, technologies, management, financing, funding possibilities, standards, monitoring, and enforcement. More information is provided in Section 5.7 and at https://ewasteacademy.org/(UNU, 2018).

Finally, a wealth of information is available in StEP publications (see also http://www.step-initiative.org/publications.html), most notably the *UNU Global E-waste Monitors* (Baldé et al., 2015; Baldé et al., 2017) and the StEP Initiative World Map (StEP World Map, 2018), which includes an overview of market volume estimates for each country, and where available, collection data per country.

4.4.2 Emerging countries

For emerging countries, the key questions are:

- How can an optimal mix in simple versus more advanced technology be achieved?
- Where should the more complex fractions be sent?



■ **FIGURE 4.1** Transformation of preprocessing methods influenced by increasing labor costs in China (2000—09 based on statistical data; 2010—35 is forecast). *Wang, F., Huisman, J., Meskers, C.E.M., Schluep, M., Stevels, A.L.N., Hagelüken, C., 2012. The Best-of-2-Worlds philosophy: developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies. Waste Management 32 (11), 2134—2146.*

Preprocessing

The B02W project (Wang et al., 2012) shows (at that time) the expected development from dismantling operations to more mechanical processing as illustrated in Fig. 4.1. With increasing labor costs over time, the higher the dismantling level, the more these costs play a role compared with the higher value of separated components and materials. As a result, full mechanical separation becomes less attractive over time, and increasingly more mechanical processing and shredding of components from partial dismantling will take place. It is advised here to regularly compute the optimum level of dismantling for remaining the most profitable.

End-processing and managing different fractions

Regarding end-processing and efforts to steer the right fractions to the right destinations, the EWAM toolkit (see in particular the questions and answers provided on pp. 51 and 52 of (UNU, 2012)) provides detailed information. Additionally, the same sources also provide many useful links to video materials that provide additional background in a visual format.

Management

Following the development of implementation acts and standards as mentioned in Section 4.2.2.2, the personnel and facilities will need to acquire licensing and training where relevant. Various documents (Deubzer, 2012; CENELEC and EERA, 2017) and the UNU E-waste Academies (UNU, 2018) provide a wide range of available training information.

4.4.3 Established countries

For established countries, the key questions are:

- Where can the quality of treatment by new or improved technologies be improved?
- How can innovation and treatment efficiency beyond economic optimized levels be stimulated?

Collection

Commonly, most systems still do not capture all flows, nor do they provide full recovery of all critical and environmentally relevant fractions. Understanding collection volumes is specifically discussed in Sections 3.2.3 and 3.2.4. UNU has provided many examples and reference materials (Huisman et al., 2012; Magalini et al., 2012, 2015; Wielenga et al., 2013), harmonization templates (Baldé et al., 2015; Huisman et al., 2017), and quantification tools (Wang et al., 2013) for application in other countries. For more information regarding implementing the all-actors models, see Section 4.2.3.3, the section on Monitoring and Control in Section 5.6.3, and the results from a dedicated workshop on this topic in European Commission, DG Environment and Digital Europe (2017).

Treatment

Several needs for further innovation to enhance metal recovery in preprocessing and end-processing are highlighted in in particular in pp. 135–136 of Reuter et al. (2013). Few innovation incentives exist for optimizing depollution and the recovery of elements with low economic values. The topic and financial intervention possibilities are already discussed in Section 4.3.3. Regarding skills and stakeholder exchange, a creation of further dialogue and a positive investment climate for long-term

improvement is recommended. Administrative hurdles for small companies to apply for technology innovation funds need to be streamlined. In Europe, specific innovation funds such as the EU Horizon 2020 funds and the European Institute of Innovation & Technology—Raw Materials are investing in a substantial number of technology projects, of which many focus on increasing the recovery of secondary raw materials and critical raw materials in particular, of which Huisman et al. (2017) is just one example. For a broader overview of research and innovation activities in Europe, see EIT Raw Materials (2018) and the Raw Materials Gateway tile of the RMIS (JRC, 2018).

4.5 CONCLUSIONS

Based on the e-waste development cycle approach and the country status of Chapter 2 and the structured assessment and factual basis from Chapter 3, the output from this Chapter 4 forms the heart of the policy development process with many possible interventions in the domains of Policy and Legislation, Business and Finance, and Technologies and Skills introduced. The individual options are obviously interrelated, and many considerations are to be balanced in the actual decision process. Chapter 5 provides further guidance on how to develop a coherent and feasible national action plan for practical implementation from the information provided in this chapter. This is done 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 direct and indirect conditions for successful implementation are listed in Section 5.6 related to Monitoring and Control, Section 5.7 regarding Awareness and Educationn, and Section 5.8 regarding Design Feedback.

DISCLAIMER

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