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Case Study on Critical Metals in Mobile Devices

Draft Report

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GLOSSARY

ATSDR	Agency for Toxic Substances and Disease Registry
CIS	Commonwealth of Independent States
DfE	Design for Environment
DoE	Department of Energy
EC	European Commission
EEE	Electrical and Electronic Equipment
EOL	End of Life
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
ESM	Environmentally Sound Management
EU	European Union
ICT	Information and Communication Technology
IPP	Integrated Product Policy
IPR	Individual Producer Responsibility
MPPI	Mobile Phone Partnership Initiative
NSL	Nokia Substance List
OECD	Organisation for Economic Co-Operation and Development
REEE	Refurbished and Reused Electrical and Electronic Equipment
RoHS	Restriction of Hazardous Substances Directive
SMM	Sustainable Materials Management
UEEE	Used Electrical and Electronic Equipment
UN	United Nations
UNEP	United Nations Environment Programme
WEEE	Waste Electrical and Electronic Equipment
WGWPR	Working Group on Waste Prevention and Recycling
WTO	World Trade Organization

EXECUTIVE SUMMARY

Box 1. Key messages

To address market and regulatory failures, policy gaps, and incoherence in policies across the life-cycle of critical metals in mobile devices, this study recommends that policy makers prioritize policies that: increase collection and triage of mobile devices in OECD countries;, and develop Environmentally Sound Management (ESM) capacity in developing countries with large informal sectors.

To support these priorities, this report recommends secondary measures that:

i. encourage the development of consistent, harmonized frameworks for collecting, triaging, and managing mobile devices in OECD countries;

ii. support state/provincial and industry-led initiatives encouraging mobile device take-back in OECD countries;

iii. educate consumers on appropriate management practices of used and end-of-life mobile devices; and

iv. ensure existing policies and programs consider economic, environmental, and social impacts across the life cycle of mobile devices.

Focusing on actors along the life cycle, their interests, and alignment with existing policies is critical to the analysis of case studies in SMM. It is also important to adopt a material, product, and geographic focus that represents relevant issues and life-cycle stages.These approaches help identify the underlying mechanisms that contribute to market or regulatory failures, or where policy gaps or incoherencies exist.

Background

The OECD's Working Party on Resource Productivity and Waste (WPRPW) [1] has explored applications of Sustainable Materials Management[2] principles since 2004. The WPRPW investigated whether the application of the SMM concept is useful when considering the availability of critical metals in relation to the end-of-life management of mobile devices in a 2009 case study, "A Sustainable Materials Management Case Study: Critical Metals and Mobile Devices". This case study validated the importance of applying Sustainable Materials Management (SMM) principles to address availability of critical metals during the end-of-life management of mobile devices and explored opportunities for applying SMM; however, the Working Party identified a need to develop concrete actions to operationalise SMM along the mobile device life cycle.

[1] This Working Party is the successor body of the Working Group on Waste Prevention and Recycling (WGWPR) and had its first meeting in June 2011. Following the restructuring of the OECD's Environmental Policy Committee, WGWPR was upgraded to a Working Party.

[2] OECD has described SMM in a working definition as "an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life cycle of materials, taking into account economic efficiency and social equity."

Goal, Scope, and Outcomes of this Report

The goal of this report is to evaluate the usefulness of a case study approach to operationalising SMM policies, and to develop concrete policy recommendations for OECD member countries to improve the SMM of mobile devices with a focus on critical metals. It achieves this by identifying issues of policy incoherence, incentive structures, and market and regulatory failures at different phases of the entire life cycle of critical metals in mobile devices.

The outcomes of this report are as follows: First, it identifies lessons learned to inform a methodology for evaluating SMM policy issues that can be applied in other case studies (detailed in the text box below). Second, it provides a prioritized list of concrete policy recommendations, including priority actions for member countries, secondary measures that involve leveraging existing activities that are aligned with SMM outcomes sought by this case study, and areas for further follow up to address data gaps and better understand issues where there is less evidence of specific market or regulatory failures.

Observations and Lessons Learned

This report focused on four key policy issues: life-cycle externalities, trade policy impacts, material substitution and hazardous waste policies, and used and end-of-life mobile device management. Across these key policy issues, this report has identified the following observations relating to SMM:

1. The informal recycling sector, ie unregulated and unlicensed actors, is adept at collection and triage of used electronic and electrical equipment (UEEE) and waste EEE (WEEE), and at dismantling and pre-processing WEEE. The formal recycling sector processes are more efficient at recovering metals with minimal environmental impacts and health risks. Better coordination between these sectors could theoretically increase the overall recovery rate by as much as 170 percent compared to an efficient formal-sector recycling system. Despite these highly complementary roles, there is little coordination between these sectors due to economic, logistical, informational, and international barriers.
2. Mobile devices have a high reuse value and a high concentration of economically-recoverable materials compared to other types of UEEE and WEEE. This provides a strong economic incentive that may lower the barriers to coordination in informal and formal sectors.
3. Enforcement difficulties, a lack of consistency in defining UEEE and WEEE, and differences between national environmental, health, and safety policies across countries remain challenges for hazardous waste export and WEEE policies.
4. Hoarding of mobile devices (i.e., storage of used mobile devices after they are no longer used) occurs because consumers perceive residual value in their used mobile devices.
5. Material substitution choices involve trade-offs with possible effects across the material and product life cycle.
6. Consumers can play an important role in the mobile device life cycle through demand for devices that are designed for recyclability, and/or which demonstrate reduced environmental impacts and by influencing the quantity of and ways in which mobile devices are disposed. For instance, extending by 50 percent the time that mobile device owners use their phone before buying a replacement would reduce waste by a third. This is equivalent to avoiding the generation of 50 million end-of-life mobile devices in the United States in 2010.
7. Evidence shows that government policies and industry-led activities are working together to achieve SMM goals. These policies and activities include government regulations, voluntary programs, private-sector initiatives, as well as market forces.

8. Trade access can influence SMM policy goals across geographic boundaries and life-cycle stages.
9. Finally, the global picture of mobile device use, UEEE and WEEE has changed: mobile device use rates are increasing rapidly in developing countries and, consequently, UEEE and WEEE generation in these countries is also increasing. Domestically-generated UEEE and WEEE now rival imports in developing countries, particularly in the case of mobile devices.

Recommendations for the management of critical metals in mobile phones

The report identifies two priority actions that involve improving collection of mobile devices in OECD countries and developing Environmentally Sound Management (ESM) systems for waste in developing countries with large informal sectors;

1. To increase collection, decision-makers may want to consider: (i) the use of financial incentives to reduce hoarding and increase collection rates; (ii) adopting harmonized standards and terminology to reduce loopholes and inconsistencies between regional policies for the collection and treatment of used devices; and (iii) implement public-sector UEEE and WEEE management requirements that adhere to ESM principles.
2. To develop ESM systems in developing countries with large informal sectors, decision-makers may want to consider: (i) efforts to support capacity development in the informal sector in developing countries; and (ii) support the commercialisation of cheaper, high-efficiency metal recovery technologies that minimize health and environmental impacts, eg through measures that help reduce high up-front capital costs. Measures that help to reduce the up-front capital cost of high-efficiency recovery technologies in order to lower the barriers to adoption for smaller-scale recyclers.

To support these priority actions, decision-makers may want to consider a set of secondary measures to ensure existing or ongoing activities are well-aligned with SMM goals. These include: (i) performing due diligence on emerging voluntary standards, and adopting these into public-sector management programs where appropriate; (ii) encouraging the establishment of harmonized take-back systems at the state/provincial level or management systems within large institutional or commercial organisations; (iii) using communication platforms to inform consumers about management of used or waste mobile devices, and (iii) incorporating life-cycle thinking more extensively into existing policies and programs, such as chemical management programs, product design policies, and voluntary industry programs.

Finally, decision-makers may also wish to undertake further activities in areas where there are data gaps or less-clear evidence of market or regulatory failures. These include: (i) seeking a better understanding of how the bundling of handsets and service contracts increases mobile device turnover rates; (ii) investigating efforts to encourage consumer demand for devices with lower life-cycle impacts, and (iii) conducting further research to characterize the extent of externalities along the life cycle of mobile devices.

Methodological recommendations for the evaluation of SMM policy issues

This study also identified lessons learned to inform and strengthen the method used in the analysis of SMM case studies. The report recommends that OECD members consider applying the results and methodology of this case study to other materials, products, and sectors; this will help strengthen the methodology and enable a better understanding of concrete steps that can be taken to promote SMM.

The methodology used in this report is laid out in six steps (also see figure 13):

- **Establish the life cycle and geographic scope.** Develop a concise description of the product or material life cycle. Identify potential market or regulatory failures, policy gaps or incoherencies that are affecting economic efficiency, competitiveness, environmental effectiveness, or social outcomes.

- **Isolate key issues.** Narrow the scope by identifying a limited number of key issues to explore. Consider convening an expert workgroup to help identify the key issues.

- **Characterize the key issues.** Describe the current situation (e.g., relevant actors, policy frameworks), the desired outcome, steps being taken to address the issue, and data gaps.

- **Evaluate each key issue with respect to SMM policy goals.** Evaluate the impacts of each key issue on economic efficiency, environmental effectiveness, resource productivity, competitiveness, and social outcomes.

- **Identify lessons learned and data gaps.** Assess data gaps, identify limitations, and develop lessons learned. Consider the usefulness of this methodology and opportunities for improvement.

- **Develop observations and recommendations.** Recommendations should be informed both by observations from the analysis of the key issues, lessons learned, and knowledge of what is being done to address each issue (see diagram below). It is useful to identify policy levers that can help governments identify priorities.

1. INTRODUCTION

1. This report, prepared for the Organisation of Economic Co-operation and Development (OECD), seeks to identify issues of policy incoherence, incentive structures, as well as market and regulatory failures at different phases of the entire product/material life cycle of critical metals in mobile devices and discusses how sustainable materials management policies could be operationalised—or concretely applied—to help address these issues.

2. This study explores the life cycle of mobile devices through the framework of sustainable materials management (SMM), which the OECD has described in a working definition as "an approach to promote sustainable materials use, integrating actions targeted at reducing negative environmental impacts and preserving natural capital throughout the life cycle of materials, taking into account economic efficiency and social equity." This report discusses how SMM practices can help minimize environmental impacts while improving economic and social benefits. Additionally, the report evaluates the effectiveness of existing policies in terms of how they enable and incentivize different actors to meet these SMM policy goals.

3. The OECD Working Group on Waste Prevention and Recycling (WGWPR)[3] has already conducted a case study applying SMM principles to the life-cycle analysis of critical metals in mobile devices, "A Sustainable Materials Management Case Study: Critical Metals and Mobile Devices". That study (known as the original OECD case study henceforth) was prepared to determine the utility of the SMM concept when considering the availability of critical metals in relation to the management of end-of-life products. The original OECD case study focused on mobile devices as a surrogate for products in the rapidly growing consumer electronics sector that contain similar components, and for their relationship with the critical metals antimony, beryllium, palladium and platinum. It provided a detailed analysis of the different life-cycle stages of critical metals in mobile devices, identified several important knowledge gaps, and gave a brief discussion of policy barriers and opportunities.

4. Following the OECD's original case study examining critical metals in mobile devices, the WGWPR's delegates suggested expanding the case study to include an analysis of policies, incentives and market failures to help operationalise SMM approaches for policymakers involved in the mobile device life cycle. This report builds upon the SMM approach undertaken in the original OECD case study and expands it by identifying: key policies and actors at stages within the mobile device life cycle, interactions between each and the influence of policy on actors' incentive structures, and issues of policy coherence, policy gaps, and market and regulatory failures along the life cycle. In addition, this report builds on several key OECD activities related to mobile devices, Information Communication Technologies (ICT), and SMM issues. In particular, this study:

- Complements OECD SMM policy reports developed for the Global Forum on Environment Focusing on Sustainable Materials Management in October, 2010 (OECD 2011a, OECD 2011b, OECD 2011c). These reports establish policy principles for SMM, assess relevant SMM policy instruments, and discuss issues related to setting and using targets for SMM.

- Recognizes OECD's Council Recommendation on Information and Communication Technologies (ICTs) and the Environment—which creates a 10-point list of how governments

[3] Following the restructuring of the OECD's Environmental Policy Committee, WGWPR was upgraded to a Working Party. The successor body of WGWPR is the Working Party on Resource Productivity and Waste (WPRPW), which had its first meeting in June 2011.

can improve their environmental performance using ICTs— and its work in ICTs, the Environment, and Climate Change (OECD 2010).[4]

- Incorporates relevant information from OECD's work on Trade Policy concerning the effectiveness of import/export restrictions, and from the Committee on Information and Communications Policy on mobile device collection and handset bundling[5].

5. The outcome of this report is a case study that: (i) explores environmental, economic, social, international, and cross-sectoral issues associated with SMM in the mobile device industry, (ii) provides an overview of existing policies relevant to SMM in the mobile device industry, (iii) discusses existing mobile device market and regulatory failures and policy coherence issues, (iv) identifies promising or best-practice policy efforts towards SMM goals, and (iv) recommends measures that member countries could pursue to align the incentive structure of actors to achieve the objectives of SMM. The results of this case study will be presented to the Working Party on Resource Productivity and Waste (WPRPW).

2. SCOPE AND METHODOLOGY

2.1 Scope of Analysis

2.1.1 Critical Metals

6. Rapid advances in electronics and telecommunications over the past 20 years have greatly increased both the number and supply of metals needed to manufacture[6] increasingly complex consumer electronics in order to meet the growing global demand. Countries have classified certain metals as "critical" to identify supply risks to strategically- or economically-important metals, some of which are used in the manufacturing of mobile devices. As Figure 1 shows, there is no one definition of "criticality" (OECD 2011d). Criticality is a country-specific value judgement based on factors such as: (i) availability and security of supply of the metal; (ii) existence and availability of substitutes for the metal; (iii) the consequences of shortages; and (iv) the strategic importance of a metal's applications. Critical metals are often necessary for industrial processes or manufacturing, yet may be limited by geological availability or economic factors.

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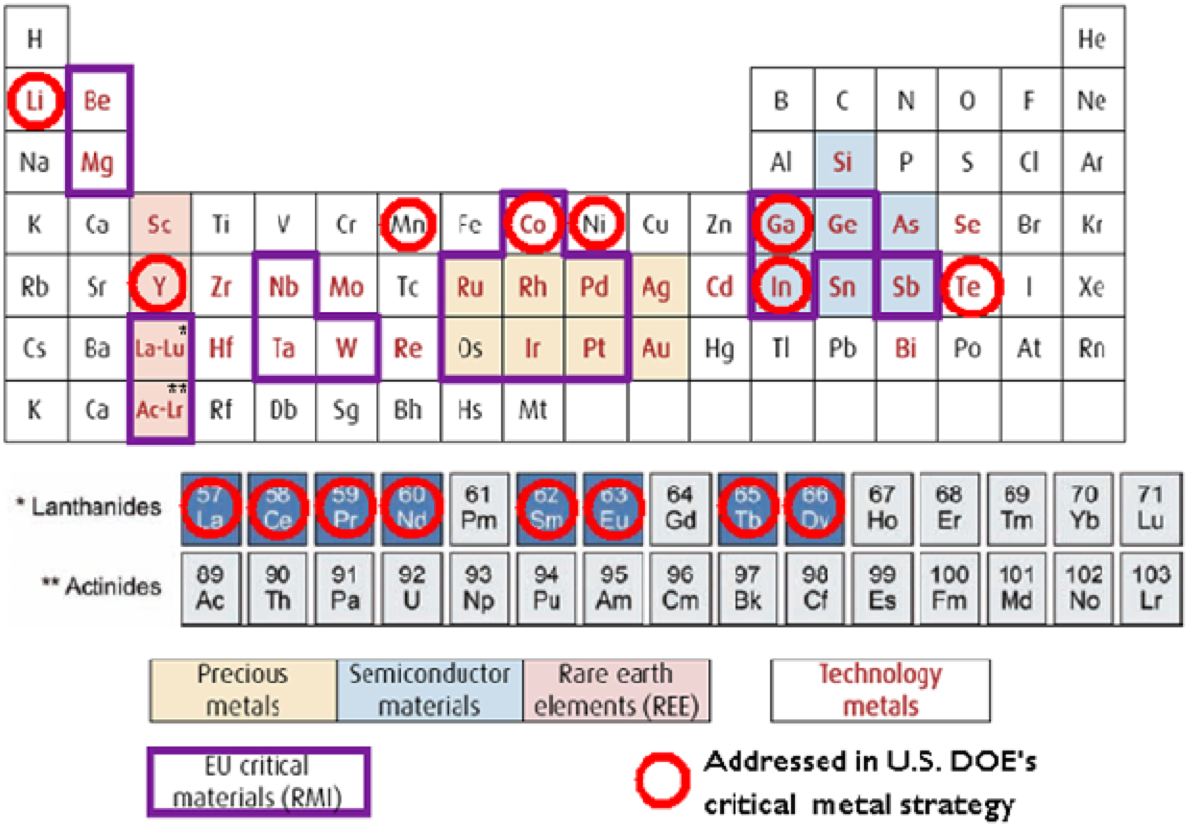
[4] Additional information available is at: http://www.oecd.org/sti/ict/green-ict.

[5] Handset bundling refers to the practice by wireless network providers of selling a mobile device at a discounted rate in return for the customer accepting a minimum subscription period, during which the customer must buy certain network services (Okholm et al. 2008).

[6] In this case study, manufacturing is assumed to include production of mobile device components and the assembly of components into a final, marketable product. As defined, mobile device manufacturing includes the actions of both component manufacturers and original equipment manufacturers, which assemble the mobile device and market it under their name or trademark (BSI 2011).

Figure 1. Categories of "critical" raw materials that have been addressed in studies by the European Union and the U.S. Department of Energy (DOE) (DOE 2011; EC Ad-hoc Working Group 2010)



7. The "criticality" of metals changes over time in response to the availability, supply, demand, and uses of these metals (OECD 2011d). For example, in recent years, concerns over the availability of "rare earth" metals[7] has increased in a number of countries—including the United States, the European Union, and Japan—due to concerns over the reliability of exports from China, which accounts for nearly 95 percent of global supply (Bradsher 2011). These materials serve essential functions in mobile devices, lithium-ion batteries, and other applications (ICF 2011b). A detailed review of rare earth materials are beyond the scope of work in this study, but the recent risks associated with their global supply emphasize how quickly the "criticality" of metals can change; this issue is noted in the discussion on trade policy impacts in section 4.2.

8. The scope of the original OECD case study focused on issues relevant to four critical metals: antimony, beryllium, palladium, and platinum. This scope has been retained for the purposes of this study, in order to expand the existing analysis. These critical metals were selected because they: (i) perform an

[7] Rare earth elements come from a specific area of the periodic table. All but two come from (and constitute) the lanthanide series of elements (numbers 57 through 71), which are located in the sixth row of the main body of the periodic table (see Figure 1). Scandium (21) and yttrium (39), which occupy the two spaces above lanthanum in the third column of the periodic table, are chemically similar to other rare earth elements and are typically included. Although rare earth elements are relatively abundant in the Earth's crust, they are rarely concentrated into mineable ore deposits (Long et al. 2010, p. 3). There are non-rare earth elements that are rarer than rare earth elements, so the name can be misleading.

essential function for which there are few or no satisfactory substitutes; (ii) pose the risk of causing either economic or social disruptions in relevant industries in the event of a supply shock; (iii) command significantly higher prices if supply of the material is restricted; and (iv) demand for key applications represents a relatively high proportion of the overall supply of material.

9. An important caveat: Our focus on specific critical metals is most-applicable to raw material extraction externalities, trade, material substitution, and end-of-life management issues. Within these issues, while the report focuses on specific critical metals, useful information that applies to precious metals and other critical metals has been included. Furthermore, it is noted where information is specific to the four critical metals, where it is specific to other metal fractions but representative of critical metals, and where there is uncertainty in the applicability of this information to critical metals.

2.1.2 Mobile Devices

10. The scope of this study is focused on mobile devices, which may include mobile phones, smartphones, and other handheld telecommunications devices in consumer markets. From a policy perspective, mobile devices are of interest because of their wide usage, critical metal constituents, and end-of-life management. Furthermore, sufficient data on the composition and sales of mobile devices are available to assess many of their life-cycle flows and impacts (OECD 2011d). The approach taken in this study to examine policies relevant to the sustainable materials management of mobile devices could serve as a framework for the analysis of SMM of other electronics utilizing critical metal components.

11. Although mobile devices were selected in part due to their representativeness of other consumer electronics and electrical products that contain printed wiring boards (PWBs), there are characteristics specific to mobile devices that are not broadly applicable to EEE:

1. Mobile devices are small in size and easily stored for longer time periods than other large EEE (see section 4.4); consequently, mobile device hoarding is a larger issue than for EEE in general.

2. Depending on local circumstances and the presence of collection programmes, used mobile devices can frequently be economically reused or recycled. There are existing markets for used mobile devices; similar markets do not exist for most other types of used EEE (Grant et al. 2012). Similarly, unlike other EEE that contain hazardous substances or other materials that are difficult to recycle, the material content of mobile devices is of a relatively high value, making recycling economical. The value of WEEE is often grouped based on its gold content; Umicore has found that mobile devices typically fall into the medium value (100 to 400 parts per million [ppm] of gold) or high value (over 400 ppm of gold) ranges. Low value WEEE (less than 100 ppm of gold) includes TV-boards, monitor boards, calculators, and shredded bulk material after aluminium and iron separation (Hagelüken 2006). Thus, if collected, due to their higher value compared to other types of EEE, it is less likely that mobile devices will be disposed of without material recovery (Ahonen 2012).

3. The material content of mobile devices also differs from other EEE as different materials are required for equipment with network connections like mobile devices (Ahonen 2012).

4. Mobile devices are unique from other types of EEE in that they require wireless network service in order to remain functional; this creates an ongoing relationship between network service providers and consumers that does not necessarily exist for other EEE equipment (particularly residential EEE use). This issue is explored in section 4.4.3.2 in particular.

12. Finally, much of literature relevant to managing used and end-of-life mobile devices is representative of Used EEE (UEEE) or Waste EEE (WEEE) rather than mobile devices in particular. In

this regard, mobile devices may not represent a good proxy for WEEE due to the wide variety of equipment that is considered EEE. For example, the EU's WEEE Regulations define ten categories of EEE. Mobile devices are considered "IT and telecommunications equipment", but other categories—such as "large household appliances", "lighting equipment", and "automatic dispensers"—include equipment that significantly differs from mobile devices in composition and end-of-life management (EC 2012c). Consequently, some results of this report address UEEE and WEEE management issues rather than mobile devices in particular. Throughout this case study the report notes instances where the management of mobile device differs from other EEE.

2.1.3 Key Issues in the Life Cycle of Critical Metals in Mobile Devices

13. This report focuses on the interactions between the different life-cycle stages of mobile devices and their relevant geographical regions (see section 2.1.4), policy frameworks, and data gaps. Separating the life cycle into these areas of focus allowed for targeted research into the unique policy or economic challenges of implementing SMM in each stage and investigation of the specific policies that could affect change within that specific geographic region or economic sector.

14. As discussed in section 2.2, OECD convened an Expert Meeting to identify four specific examples of regulatory or market failures, policy incoherencies, and policy gaps within the life cycle. The issues were selected because they: (i) are relevant to the life cycle of critical metals in mobile devices; (ii) represent potential sources of regulatory or market failures, policy gaps, or policy incoherence issues; (iii) are relevant to SMM concepts in that they involve multiple stages and different actors along the life cycle, and benefit from taking a life-cycle approach; and (iv) address policy areas where information is believed to be available, but which have the potential to offer new insights for how SMM policies may be operationalised.

15. These four areas form the scope within which this report assesses SMM policy issues, interactions, and best practices:

10. **Externalities associated with raw material extraction and end-of-life management.** This issue investigates the: (i) types of externalities that are not fully-accounted for in the price of mobile devices; (ii) existing policy frameworks that help to internalize externalities; (iii) how externalities and policies influence actors along the life cycle, and (iv) additional opportunities to internalize external costs.

11. **Trade policies**. Import and export bans, restrictions, and tariffs affect the flow of new, used and waste mobile devices, and materials between countries. This issue investigated trade policies that enhance or impede SMM policy goals at different life-cycle stages.

12. **Material substitution and hazardous materials policies.** International and domestic chemical and hazardous material policies and market forces influence the use of materials in mobile devices. From a life-cycle perspective, restricting one material for another may result in environmental or human health trade-offs, so it is important to ensure that material substitution does not shift the burden from one type of environmental or health impact to another.

13. Used mobile device considerations, with a focus on:

    - Collection and triage practices. This issue focuses on collection of mobile devices that are no longer in use, and the ways in which mobile devices are diverted to reuse, recycling, and disposal.

- Collection via wireless network service providers. This issue investigates the role that network service providers can play in enhancing collection rates and appropriate triage of mobile devices.

- Economics of informal secondary markets. This issue investigates market dynamics between formal and informal UEEE and WEEE markets.

2.1.4 Geographic Distribution

16. The geographic scope of this report is global, and was informed by the profile of the critical metal and mobile device life cycle, as outlined in section 3.2. Where relevant information is available, this report focuses on one or more specific countries which contain concrete examples of at least one of the four key issues and the potential for policies to encourage SMM practices. The rationale for each country's inclusion was informed by evidence of environmental or social risks, examples of strong policies, or examples of poor policies and market failures.

17. For each geographic country or region of focus, this report seeks to identify: (i) the high-level existing policy framework for regulating environmental and social impacts from critical metals; (ii) the actors involved in the system (e.g., government bodies, manufacturers, telecommunications companies) and how they interact; and (iii) evidence of social or environmental concerns.

2.2 Methodology

18. This report explores the key issues related to critical metals and mobile devices, as defined in Section 2.1, using the steps listed below.

1. **Establish the life cycle and geographic scope** of critical metals and mobile devices. This report builds on the original OECD case study to develop a concise description of the mobile device life cycle. A key difference between the original OECD case study and this report will be a focus on policy-oriented tools and guidance, rather than technical issues. Consequently, this report develops a solid life-cycle framework upon which opportunities for SMM and related policies can be discussed.
2. **Isolate "key issues"** related to regulatory or market failures, areas of policy incoherence, and policy gaps. To narrow the scope, the OECD convened an expert workshop to identify specific regulatory and market failures, issues of policy incoherence, and policy gaps along the life cycle. This report describes and evaluates four "key issues" identified in the expert meeting (see section 2.1.3).
3. **Characterize the key issues.** For each key issue, this report qualitatively evaluates and describes: (i) the current situation, including relevant actors, relevant policy frameworks, and impacts on environmental effectiveness[8], economic efficiency[9], resource productivity[10],

[8] Environmental effectiveness is the extent to which an activity fulfills its intended purpose or function in mitigating impacts and increasing benefits to the environment (Harvey 2004).

[9] Economic efficiency refers to the degree to which resources, such as land, labor, and capital, are deployed in their uses relative to the goods and services they create (Boardman et al. 1996).

[10] Resource productivity refers to the effectiveness with which an economy or a production process is using natural resources. It can be defined with respect to: (i) the economic-physical efficiency (i.e. the money value added of outputs per mass unit of resource inputs used); (ii) the physical or technical efficiency (i.e. the amount of resources input required to produce a unit of output, both expressed in physical terms); and (iii)

competitiveness[11], and social outcomes[12]; (ii) the desired outcome of any proposed policy intervention; (iii) steps already being undertaken to address these issues; and (iv) an examination of existing data gaps within that issue.

Each issue was initially characterized using relevant literature available from academic, industry, governmental, non-governmental, and other institutions. In evaluating key issues, this report uses the following definitions to identify important aspects of the policy matrix surrounding mobile devices:

- *Policy Incoherence* is the product of mismatching, conflicting, overlapping, or otherwise ambiguous policies, particularly with regards to jurisdiction across national borders. It can result in perverse incentives, lack of enforcement or regulatory failures.
- *Regulatory failures* occur when a government policy or intervention results in an inefficient allocation of goods and services. These may occur from unintended consequences of policies, regulatory capture, and market distortions from policy interventions.
- *Market failures* result when the allocation of goods and services as dictated by market activity is inefficient and results in outcomes that are less than socially optimal. They are often associated with externalities, information asymmetries, non-competitive markets, principal-agent problems, or public goods.

4. **Evaluate the key issues with respect to SMM policy goals.** This report evaluates the impacts of each key issue on economic efficiency, environmental effectiveness, resource productivity, competitiveness, and social outcomes. These metrics encompass the OECD's working definition of SMM along economic, environmental, and social considerations.

   To evaluate the key issues, the initial characterization was supplemented by seven expert interviews with private industry, academic, and government actors (see Appendix). These interviews were used to address data gaps in the initial characterization, evaluate the impact of each issue on the economic, environmental, and social criteria, and identify possible best practices and actions being taken to address each issue.

5. **Identify observations, lessons learned, policy levers, and recommendations.** Based on the characterization and evaluation of each key issue, this report identifies observations, lessons learned, policy levers, and recommendations. The findings fall into three categories: (i) observations and lessons learned, activities being taken to promote SMM, and recommendations for achieving SMM goals in the mobile device life cycle; (ii) findings on the usefulness of this approach in advancing SMM, and (iii) key data gaps.

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the economic efficiency (i.e. the money value of outputs relative to the money value of inputs). (OECD 2011i, p. 35)

[11] Competitiveness arises whenever two or more parties strive for something that all cannot obtain; we use this term in an economic sense in this report (Stigler 2008).

[12] Social outcomes are "those that may directly affect stakeholders positively or negatively during the life cycle of a product. Social outcomes may be linked to the behaviours of enterprises, to socio-economic processes, or to impacts on social capital. Depending on the scope of the study, indirect impacts on stakeholders may also be considered" (UNEP 2009c, p. 37).

3. DESCRIPTION OF THE LIFE CYCLE OF CRITICAL METALS AND MOBILE DEVICES

19. In the original critical metals and mobile devices case study, OECD characterized the critical metals and mobile device life cycles with a focus on technical and economic implications along each stage of the life cycle (OECD 2011d). As this case study report seeks to inform the analysis of policy-oriented tools and guidance, this section describes the life cycle of critical metals and mobile devices[13] as a framework for understanding and evaluating policy-related SMM opportunities. This section also seeks to characterize the geographic scope of the mobile device life cycle, identifying the predominant countries where each life-cycle stage takes place and the gaps where information on the geographic scope of the mobile device life cycle is incomplete.

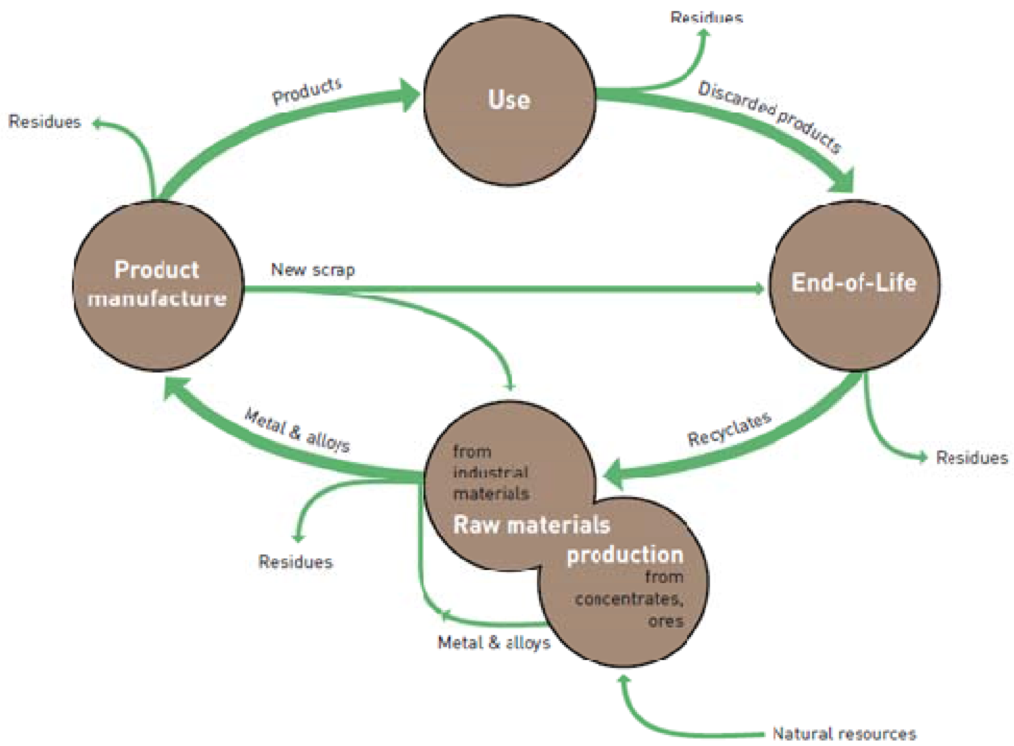
3.1 Critical Metals and Mobile Device Life Cycle Stages

20. Examining the life cycle of critical metals in a mobile device requires an examination of the route that critical metals take from raw materials extraction through their inclusion in mobile devices during manufacturing, use (and potentially reuse), and ending with their fate at the device's end of life (EOL) through recycling or disposal. As such, this section is largely about the intersections between the life cycles of metals and mobile devices, identifying key economic, environmental, and social issues relevant to each life-cycle stage, and exploring correlations and linkages between life-cycle stages.

21. Figure 2 shows a simplified metal product life cycle. The cycle is initiated by choices in product design and engineering (e.g., types and quantities of raw materials selected) to meet both aesthetic and functional requirements of the product where mobile devices represent one product category. The cycle consists of raw material production, product manufacture, use, and end of life and provides a simplified flow diagram of a metal material through the product life cycle. Relevant recycling flows at each stage, across stages, and losses from the system are represented. As shown in the figure, transportation occurs between each stage, denoted by the green arrows that move between each stage and beyond the life-cycle system boundary.

[13] This report discusses the life cycle of critical metals as they are used in mobile devices along with the larger life cycle of mobile devices.

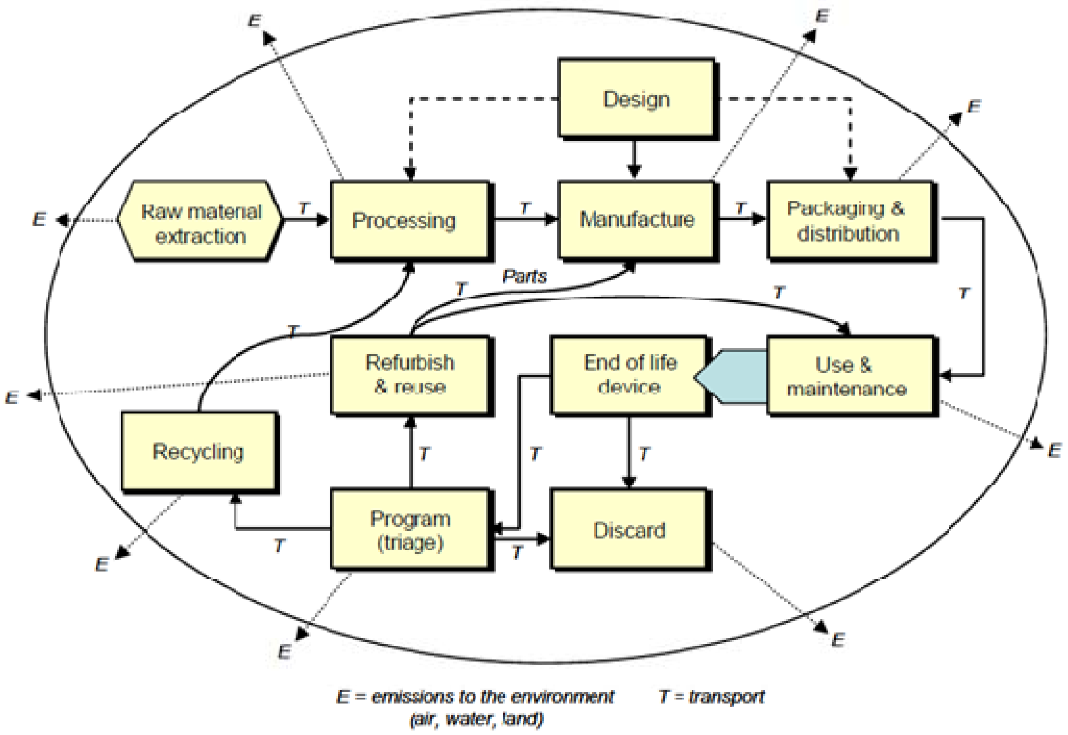
Figure 2. Metal Product Life Cycle



Source: UNEP (2011) Recycling Rates of Metals: A Status Report.

22. Figure 2 contains an overview of the mobile device life cycle, showing the flow of critical metals and other raw materials into a manufactured device, followed by the use and management options for a used device once it reaches the end of its useful life. Major sources of emissions to the environment as well as transportation stages are also included in the diagram. Figure 2 is useful for locating opportunities for policy measures that can improve SMM practices for mobile devices, which are discussed in detail later in this report.

Figure 3. Mobile Device Life Cycle



Source: OECD (2011d) A Sustainable Materials Management Case Study: Critical Metals and Mobile Devices

Note: In this figure, the "end of life device" stage can include both devices at end of life (i.e., for recycling or disposal), but also devices at end of one cycle of use that can be refurbished and reused.

23. The following sub-sections provide a description of key economic, environmental, and social issues relevant to each stage in the life cycle of mobile devices and explore correlations and linkages between life-cycle stages. The discussion focuses on the aspects concerning critical metal use in mobile devices.

3.1.1 Raw material extraction and processing

24. The first step in the life cycle of mobile devices is the extraction and processing of raw materials, including critical metals. This report focuses on four key critical metals used in mobile devices: antimony (Sb), beryllium (Be), palladium (Pd), and platinum (Pt) (see section 2.1.1). To include these materials in a mobile device, they must first be mined and processed to be suitable for manufacturing. The types and quantities of raw materials chosen for extraction and how they are processed depend on choices made at the design[14] phase.

25. Acquiring the critical metals and other materials needed to manufacture a new mobile device carries economic issues that conflict with SMM best practices. Critical metals and other raw materials in

[14] In this case study. the mobile device design stage is defined as including both engineering design stages (i.e., selection of the types and quantities of raw materials and components in order to meet the functional specifications of the device) and aesthetic design stages (i.e., deciding the look and feel of the device to meet ergonomic and marketing specifications).

mobile devices are not evenly available throughout the world, necessitating international trade. While the geological challenges of raw material extraction have the largest impact on the cost of materials, taxation, permitting, mining codes, and trade policies can also have a significant impact on the raw material extraction and processing stages, making it difficult and more expensive for manufacturers to acquire the materials needed for new mobile devices; trade policies and their relevance to SMM policy goals are explored in detail in Section 4.2. Additionally, the limited number of companies that mine these critical metals makes their availability susceptible to the supply and price impacts of short-term monopolistic behaviour that are designed to maintain pricing levels and profit margins (OECD 2011d).

3.1.2 Design

26. The design stage influences many other stages along the mobile device life cycle and therefore may offer unique opportunities to integrate SMM practices (OECD 2011d, p. 43). Depending on the level of information they have on their supply chain and the availability of new or alternative materials, mobile device designers can consider the criticality (e.g., availability and supply risk of bottlenecks) in the selection of components. They must also ensure that devices meet required functional and aesthetic specifications, and that material sourcing complies with relevant regulations[15]. The material composition of mobile devices may also affect their recyclability and end-of-life management: "Design for recyclability" or "design for reuse" principles aim to increase the capability of recycling used mobile devices (OECD 2011d, pp. 43-44). It is also important to note the European Commission's Ecodesign Directive, which provides rules for improving the environmental performance of energy related products through ecodesign. The Ecodesign Directive does not currently apply for mobile devices, but computers, TVs, and other EEE are included (EC 2012c).

3.1.3 Manufacturing and packaging and distribution

27. During manufacturing, mobile device components such as batteries, cases, and integrated circuits are fabricated from processed raw material inputs by upstream component suppliers. The packaging and distribution stage includes all steps necessary to bring a finished mobile device to consumers.

28. Mobile device manufacturers assemble these components into devices according to specified established during the design stage (OECD 2011d, p. 46; Ahonen 2012). Manufacturing is usually an important stage in determining the life-cycle cost of the product. Manufacturing also carries significant environmental impacts due to the substantial amount of energy needed to produce high-tech devices (OECD 2011d, p. 47).

29. Materials used to manufacture mobile device components may have hazardous properties. For example, antimony compounds and beryllium—both of which have been phased out of mobile devices by some manufacturers[16]—have toxic properties that can result in worker health impacts without proper protection.[17] However, opportunities exist to reduce impacts at this stage. For example, mobile device manufacturers may exert pressure on upstream suppliers to reduce or avoid certain materials if an assessment demonstrates that the risks of use are unreasonable or unmanageable. Policies that encourage

[15] See section 4.3.1.2 for more information.

[16] See section 4.3 for more information.

[17] An EU risk assessment of diantimony trioxide identified worker concerns for pulmonary toxicity and skin irritation under conditions of perspiration, but no concerns for consumer or other indirect exposures. (i2a 2010) Beryllium is considered to be a carcinogen and inhalation of airborne particles of beryllium metal, alloys, and oxides at the beryllium processing stage can expose workers to risk of chronic beryllium disease. (U.S. ATSDR 2002; U.S. ATSDR 2008)

reuse and refurbishment[18] or which promote increased workplace health and safety practices could also lower the collective impacts from this life-cycle stage (OECD 2011d).

3.1.4 Product use

30. For mobile devices, the product use stage has a large environmental impact due to the high amount of energy consumed across the device's lifetime, although this depends on the vintage of the device, its use profile, and energy efficiency (OECD 2011d; MPPI 2009). The mix of fuels used to generate the electricity that powers mobile devices—and how they vary geographically—influences the magnitude of the environmental impact at the use stage. Therefore, there is the opportunity to reduce the environmental impact of mobile devices by improving the efficiency of the devices themselves and their charging equipment. So far, policies have focused on energy consumption during the use stage, primarily in mobile device chargers (ICF 2011a). The lifespan of a mobile device also has significant economic and environmental impacts; once a device has been manufactured, keeping it in use longer delays the purchase of a new device and the environmental impacts from the production of the new device. Using a simple example, if the average lifespan of mobile devices were increased by 50 percent, this would reduce waste generation by roughly a third; in the United States alone, this would equate to avoiding the generation of 50 million end-of-life mobile devices in 2010.[19]

3.1.5 End of initial use and triage

31. A mobile device typically reaches the end of its initial life when a consumer replaces it with a new one, at which point it is considered a used mobile device (or, when considering all EEE, UEEE). Consumers must then decide what to do with their old device. Official collection rates for mobile devices after use are very low in most countries, outside of a few exceptions in Sweden, Norway, and Belgium (ICF 2011a; Huisman et al. 2008). In place of collection at specified drop-off points, consumers often keep them in storage or pass along to friends and family, making it difficult to track actual rates of reuse and refurbishment.

32. Triage refers to the process of assessing the condition of a used mobile device and directing it towards its most useful fate (OECD 2011d). Effective collection and triage of used mobile devices can significantly reduce the life-cycle environmental impacts of mobile devices and provide economic benefits to resellers, recyclers, and manufacturers. Wireless networks play an important role in both distribution and collection as the "customer-facing" distributors of mobile devices. Therefore, collection and triage is an important target for policies encouraging SMM practices in mobile devices (ICF 2011a).[20]

33. For the purpose of this case study, UEEE and WEEE collected for reuse and recycling are characterized as managed by either the formal or informal processing sectors:

[18] In this case study, refurbishment refers to all steps necessary to prepare a used mobile device for reuse. Depending on the state of the used mobile device, refurbishment could include any or all of the following processes: (1) electronic or manual/visual screening to assess functionality; (2) deletion of all data; and (3) repairs, including the addition or replacement of parts (OECD 2011d).

[19] The reduction in waste generation assumption is calculated using a straightforward ratio of: 1/1.5 = 0.67. In other words, for every one device at end of life under current lifespans, 0.67 devices would reach end of life if lifespan was increased by 50 percent. The United States generated 152 million end-of-life mobile devices in 2010 (EPA 2011, p. 26).

[20] In the expert meeting, participants identified collection of mobile phones as a key barrier to reuse and recycling, while the original OECD case study identified "the extent and nature of interim processing of mobile phones" at end of life as a key knowledge gap related to critical metals in mobile phones (OECD 2011d, p. 68).

- The formal sector refers to mobile device, UEEE, and WEEE collection, triage, reuse, and recycling systems that are legal, licensed entities that are regulated by environmental health and safety legislation, including minimum collection and recycling percentages (Besiou et al. 2010).

- In contrast, the informal sector encompasses "unofficial" mobile device, UEEE, and WEEE collection, triage, reuse and recycling operations, or unregulated and unlicensed actors. In our definition, the informal sector includes unlicensed actors who operate legally and in compliance with health, safety, environmental, and international trade laws, as well as those who do not comply with established regulations. In this study, however, the focus in particular is on informal sector practices that result in environmental and human health impacts, or which decrease resource efficiency.[21]

34. There is evidence that collection rates through informal processes are much higher than "official" collection rates tracked in the formal sector. For example, collection rates vary in countries across Africa, but reach up to 95 percent in Ghana, with nearly all of the collected material reaching the informal sector (Secretariat of the Basel Convention 2011, p. 24).

35. The above definitions of the formal and informal sectors refer to systems for collection, triage, reuse, and recycling of EEE in general but also apply for mobile devices.

3.1.6 Reuse and refurbishment

36. The value of a working second-hand mobile device is greater than the intrinsic value of the components that can be recovered from recycling (OECD 2011d; Geyer and Blass 2009). Consequently reuse and refurbishment—in the form of either second-hand devices or "fake phones" that illegally infringe on brand names—drive the collection system, although primarily through informal channels that are difficult to characterize (ICF 2011a).[22]

37. Mobile devices destined for reuse are processed as follows: "(1) the devices are screened electronically to assess their functionality; (2) if technically sound, all phone data are erased and the phone may be re-sold as is; (3) if the phone is deemed reparable, it will receive "new" parts and be re-sold, virtually as is; and (4) the phone may be cannibalised for useful parts (for other phones or other consumer electronic devices) and the remainder are destined for recycling" (OECD 2011d). Many mobile devices can be refurbished and returned to working order quickly and economically, making reuse an attractive option for mobile device collectors, network service operators, and manufacturers.

38. The PAS 141:2011 standard, developed by the British Standards Institute, is a voluntary standard that is designed to build confidence in the reused mobile device market by setting a benchmark for minimum functionality standards for reusable mobile devices, see section 4.4.3.1 for more detail. Emerging mobile device markets in Africa and Asia have helped increase the demand for reused devices, as consumers in those markets are often unable to afford the higher retail prices for the newest mobile

[21] This definition is broadly consistent with Becker (2004, p. 11), which defines the informal sector in general terms as "the unregulated non-formal portion of the market economy that produces goods and services for sale or for other forms of remuneration", and which "refers to all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements". Becker also discusses various interpretations of the informal sector from activity, employment, location, and economic opportunity perspectives.

[22] At the expert meeting, participants commented that mobile device reuse drives the market due to the high reuse value. Participants expressed that devices for reuse largely flow through informal channels that are difficult to characterize.

devices. However, import bans on second-hand electronic devices may cause distortions in the market for used mobile devices, depending on the size of the domestic second-hand market and share of imports.

39. Reuse also has significant environmental benefits, since each reused mobile device delays disposal of the device, and—assuming that reuse offsets the purchase of a new mobile device—this, in turn, reduces or delays the demand for the manufacture of a new device, saving raw materials, energy, and the environmental impacts of recycling or disposal. Consequently, the environmental benefits from reuse depend in a large part on the extent to which reuse displaces the purchase of new devices (OECD 2011d, citing Geyer and Blass 2009). Mobile device reuse also depends on many factors, including the number and quality of devices collected for triage at the end of their useful life, effective mobile device triage, and the existence of robust reuse markets, both for intact used devices and the replacement parts needed for refurbishment. Older used mobile devices may still contain substances that have since been restricted from inclusion in new mobile devices in the European Union or other countries with hazardous material restrictions for EEE (Ahonen 2012).

3.1.7 Recycling and materials recovery

40. This stage involves recovery of the material components of mobile devices, including precious metals and certain critical metals. The steps involved include pre-treatment (i.e., disassembly of the mobile device into smaller components) and recovery of metals through a variety of processes (Chancerel and Rotter 2009). Technology and capacity exists to safely and effectively recycle mobile devices as part of the formal recycling sector. However, recovery of the critical metals addressed in this report may not presently be feasible or economical for all metals: recovery of platinum and palladium is widespread, with recycled platinum and palladium accounting for an estimated 14 percent of the total supply of those two critical metals in 2007 (OECD 2011d, p. 58). Beryllium, however, forms slag when electronic scrap is smelted, making it unrecoverable; most recycled beryllium is collected off the manufacturer's floor (OECD 2011d, p. 58). Antimony can be recovered from waste mobile devices in a smelter with variable efficiency, and is also recovered from lead acid batteries (OECD 2011d, p. 58).

41. The global trade of used and waste mobile devices and other EEE has also led to the growth of an informal recycling sector, which largely consists of unregulated, dispersed, small-scale operations. The method of recycling affects the material recovery rate, with the final recovery of metals being much higher in the formal sector compared to informal operations. For example, the recovery of copper, palladium, bismuth, and gold at a formal refinery operated by Umicore was shown to be greater than 95 percent; in comparison, informal operations typically only focus on recovering superficial gold, leading to yields under 50 percent (OECD 2011d; Keller 2006).

42. OECD countries have enforced used and waste electronics and WEEE collection and recycling targets, driving the development of a robust formal sector in these nations. However, for a number of reasons including poverty and the employment and livelihood opportunities offered by electronic waste and WEEE recycling, weak enforcement mechanisms, and strong demand for recovered materials, large informal sectors have developed—particularly in developing countries in Asia and Africa, making formal recycling difficult for WEEE collectors and processors, driving the supply of electronic waste—including waste mobile devices—to the informal sector (Widmer 2005, p. 438). Informal systems also exist in developed nations. For example, from 2003 to 2006, around 90 percent of WEEE in Greece was processed by the informal sector, despite the introduction of a law to harmonize Greece's national legislation with the EU WEEE Directive in 2001 (Besiou et al. 2010).

3.1.8 Final disposal

43. While many developed nations, states, provinces, or municipalities have bans on disposing of mobile devices, a small percentage of devices—either wholly or as components after materials recovery—are not recycled and end up in the solid waste stream. From there, they are likely either landfilled or combusted. Disposal of mobile devices effectively means a loss of valuable materials, which could have been recovered and, in turn, a missed opportunity to avoid some or all of the life-cycle environmental impact of the mobile device.

3.2 Geographic Scope of the Critical Metals and Mobile Device Life Cycle

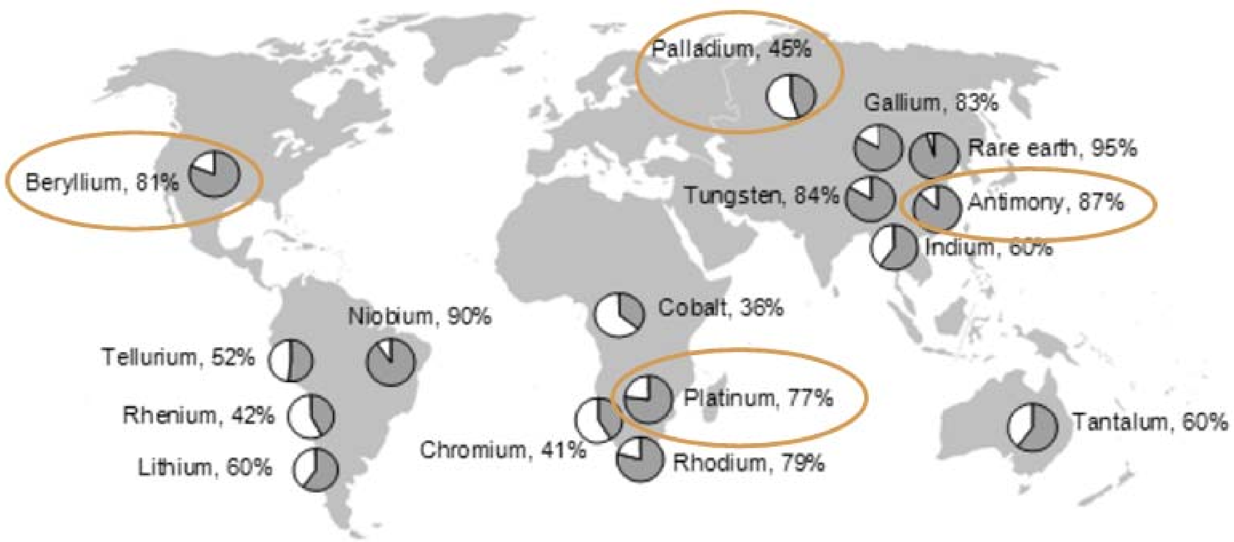
44. This section provides a brief characterization of the geographic scope of a typical mobile device supply chain. For each of the life-cycle stages addressed in section 3.1, an overview is provided of the predominant countries where that stage takes place. This section also includes key data gaps where information on the geographic scope of the mobile device life cycle is limited.

3.2.1 Raw material extraction and processing

45. As shown in Figure 4, certain countries command the dominant share of mining production of some metals used in mobile devices. For the four metals highlighted in this report (USGS 2011):

- 89 percent of antimony production is located in China;
- 89 percent of beryllium production is located in the United States;
- 44 percent of palladium production is located in Russia; and
- 75 percent of platinum production is located in South Africa along with a significant supply of palladium and the capacity to process both metals.

Figure 4. Countries having a dominant mining production of some metals



Source: OECD. (2011). A Sustainable Materials Management Case Study: Critical Metals and Mobile Devices.

Note: The values given in this figure are older than those provided by the USGS and thus differ from those in the bulleted list above.

3.2.2 Design

46. Geographically, mobile device design is dominated by countries in which major electronics manufacturers are headquartered. As shown in Table 1, five companies account for 60 percent of the mobile device market, with most design for those companies conducted in Finland, South Korea, the United States, and China.

Table 1. Geographic distribution of major mobile device manufacturers

Manufacturer	Market Share in 2nd Quarter of 2011(%)	Year over year change (%)	Headquarters (design location)	Main manufacturing locations*
Nokia	24	-20	Finland	China, Europe, Brazil
Samsung	19	10	South Korea	South Korea, Vietnam
LG Electronics	7	-19	South Korea	Korea, China, Brazil
Apple	6	142	United States	China
ZTE	4	36	China	China
Others*	40	42	--	--

Source: IDC (2011) IDC Worldwide Mobile Phone Tracker, July 28, 2011.

Note: Experts have noted that India is also emerging as a large manufacturer of handsets.

3.2.3 Manufacturing and packaging and distribution

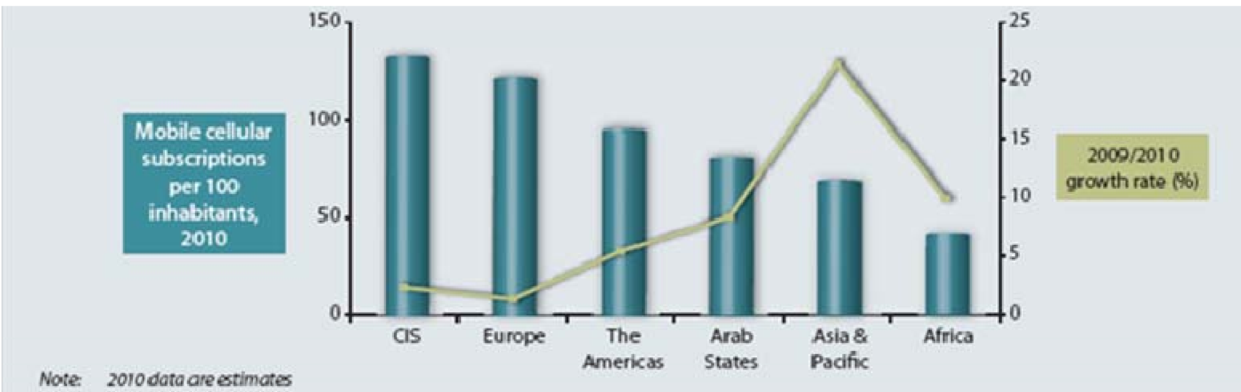
47. Mobile device manufacturing occurs across the globe, although much of it is concentrated in Asia and Central and South America. As shown in Table 1 above, four of the five largest mobile device manufacturers fabricate devices in China. In addition to manufacturing devices in China, Europe, India and Brazil, Nokia also maintains factories in Mexico. Other manufacturers are known to maintain factories in India and Taiwan.

48. By its nature, the packaging and distribution stage involves the transport of mobile devices from their manufacturing location to their point of sale to consumers. As such, the global scope of packaging and distribution is effectively addressed by the geographic scope of those two life-cycle stages.

3.2.4 Product use

49. Mobile device use occurs globally, with high rates of market penetration growth occurring in emerging markets in Asia and the Pacific, Africa, the Middle-East, and Eastern Europe over the past decade (ITU 2010). In 2010, the Commonwealth of Independent States (CIS) and Europe had the highest number of subscriptions per capita, followed by the Americas, Arab states, Asia, and Africa (ITU 2010). Mobile device penetration rates have continued to increase, particularly in developing countries, possibly to the extent where per-capita subscriptions are now becoming largely independent of the development status of a country. Figure 5 illustrates both market penetration and growth rates for mobile device usage across the world. With 5.9 billion mobile-cellular subscriptions in 2011, penetration is estimated to have reached 87 percent globally and 79 percent in the developing world (ITU 2011). Some markets, such as those in Africa, often acquire functional or easily-refurbished mobile devices previously used in other regions and extend the product use phase through the use of one or more pre-paid subscriber identity module (SIM) cards. Because of these practices, subscription statistics in developing nations many not necessarily correlate with the number of mobile devices in use.

Figure 5. Mobile Cellular Subscriptions per 100 Inhabitants and Market Growth Rate by Region



Source: ITU 2010.

3.2.5 End of initial use and triage

50. End of initial use and triage occurs globally wherever mobile devices are in use. When mobile devices complete one cycle of use, they are considered a used mobile device and—if collected—are triaged, or directed towards reuse and refurbishment or recycling. Devices will be refurbished and reused or recycled depending on the condition of the device, availability of reuse or recycling markets, where the collection and triage occurs, and who is performing the collection and triage steps. In Europe and North America, the end of the initial use of mobile devices can lead to triage either in their country of origin, or upon export to a recovery network in another country. In the case of the latter, used mobile devices are often exported for reuse. In some cases, used mobile device exports will include a fraction of non-functioning phones (or disassembled mobile devices) that cannot be reused, and are sent for recycling. Used mobile devices in Africa and Asia are likely recycled for materials recovery, although data on triage in these countries are scarce. Triage practices vary greatly by region, ranging from governmental or non-profit "green" or social or development initiatives to extended producer responsibility (EPR) arrangements or even for-profit informal collection operations. Overall, however, the global scope of mobile device triage is poorly defined compared to other life-cycle stages.

3.2.6 Reuse and refurbishment

51. Similar to the triage stage described above, the reuse and refurbishment phases of the mobile device life cycle can occur in both the country of origin for each device, or upon export to another country. Currently available information shows that refurbishment and reuse is prevalent in the informal secondary markets in Africa and China, which receive used mobile devices and distribute those that can be fixed without the use of specialized parts or machinery to small enterprises for repair or refurbishment and eventual resale (OECD 2011d, p. 54). This allows consumers in Africa and China to purchase mobile devices at lower prices than otherwise possible (Calliafas 2012). The high turnover rate of mobile devices in the United States and Europe ensures a steady supply of used devices to the African market as consumers upgrade to more advanced models. Additional information on the reuse and refurbishment is needed to develop a better characterization of the global scope of mobile device refurbishment and reuse.

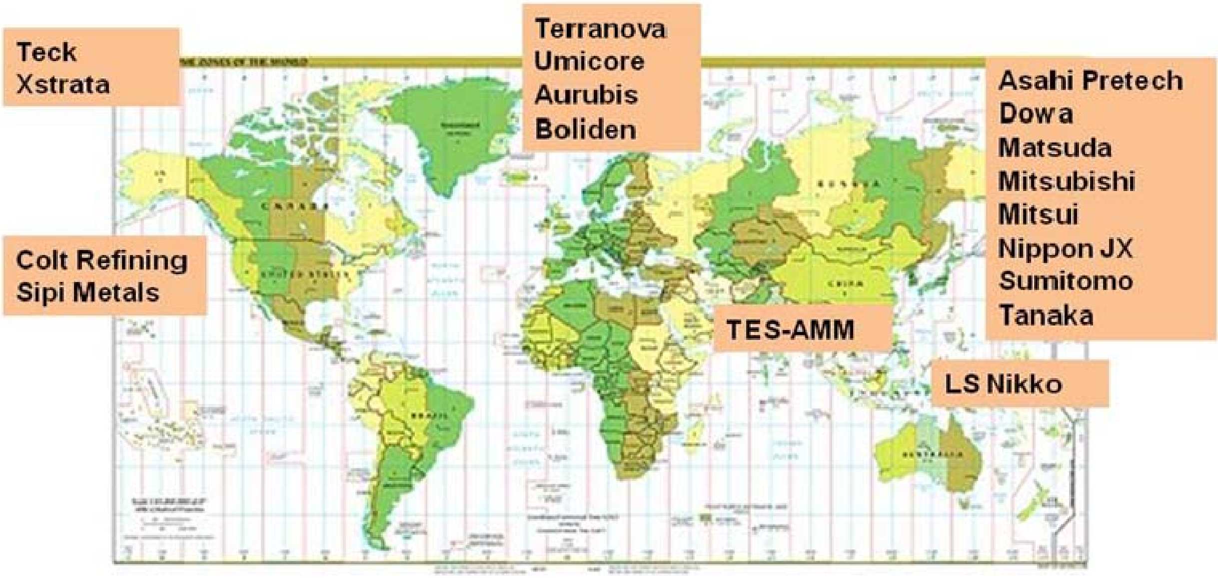
3.2.7 Recycling and materials recovery

52. The recycling and materials recovery segment of the mobile device life cycle occurs in both the formal and informal recycling sectors, as described in Section 3.1.7. Formal recycling practices are established in OECD countries and also occur in developing nations. In particular, there are a number of metallurgical facilities in Belgium, Canada, China, France, Germany, Japan, Korea, Sweden, and the United States, shown in Figure 6. Pyrometallurgical processes melt WEEE at high temperatures to separate metals and impurities into different phases for recovery (UNEP 2009a). Hydrometallurgical methods use chemicals to dissolve and precipitate metals for recovery (UNEP 2009a). Both pyrometallurgical and hydrometallurgical processes are licensed, permitted or otherwise authorised to operate in the formal recycling sector.

53. The informal recycling sector in developing nations also process large quantities of domestically generated WEEE (Schluep 2012; Secretariat of the Basel Convention 2011). In addition, despite the existence of waste shipment regulations intended to prevent international trade of "waste" mobile phones (i.e., non-functioning devices that are not economically refurbishable) and WEEE, some WEEE generated in OECD nations is illegally exported to the informal sector under the guise of reuse. However, the export of consumer electronic devices for reuse or recycling is difficult to track, whether legal or illegal (OECD 2011d). Figure 7 illustrates the flow of exported WEEE through Asia. According to the figure, locations in China, India, and Pakistan are end destinations for WEEE. Singapore may serve as a trans-shipment point: accepting WEEE from Japan, South Korea, Australia, Europe, and the United States and dispatching it to

Pakistan, India, and China. Much recycling and materials recovery takes place in small to medium-size informal enterprises in coastal cities largely reliant on manual labour in place of specialized capital or technology. Overall, there is much data uncertainty associated with the geographic scope of recycling and materials recovery due to the opaque nature of the informal recycling sector and difficulty quantifying the share of WEEE processed in the formal and informal sectors.

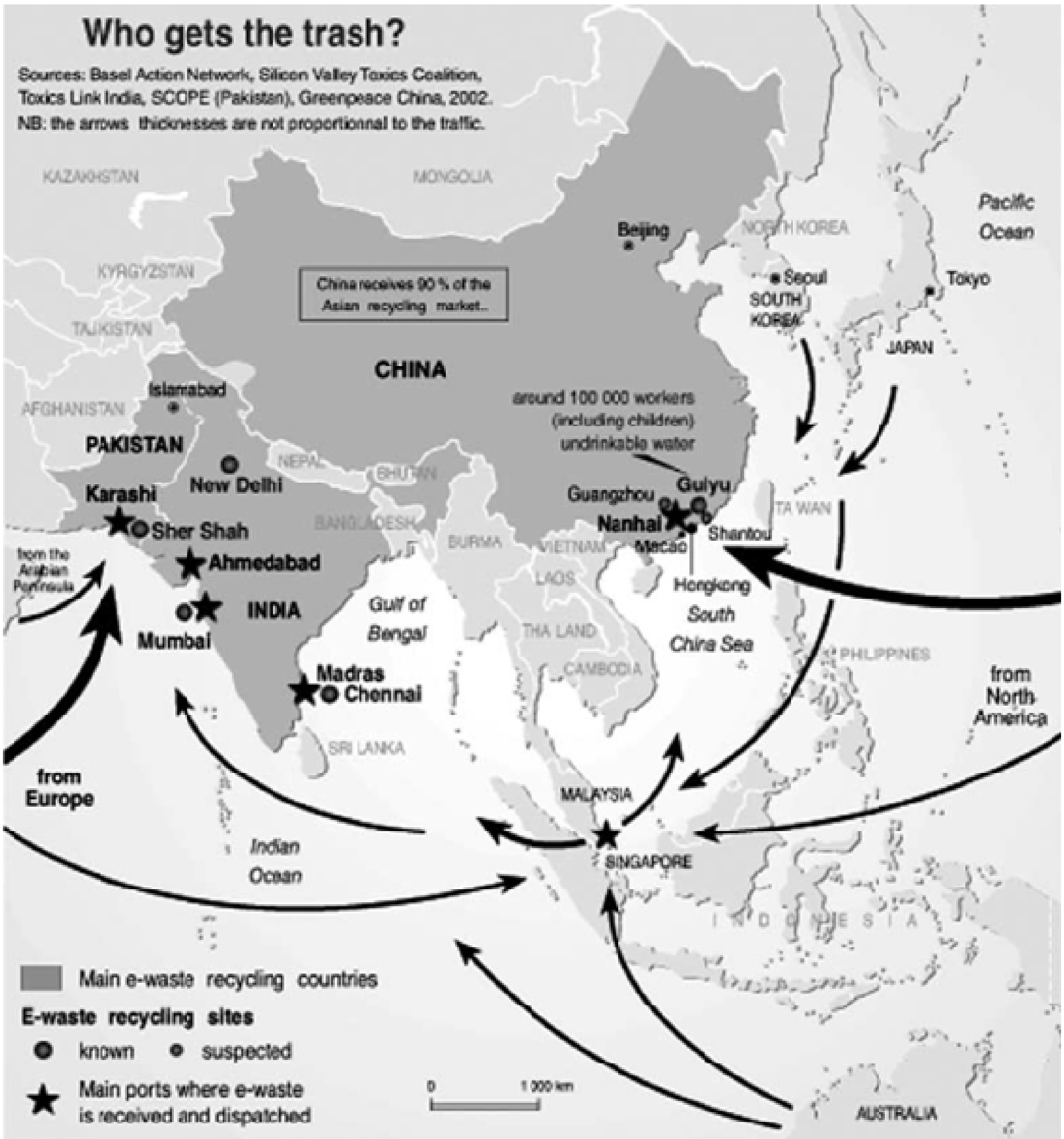
Figure 6. Map of precious metal smelters and hydrometallurgical processors



Source: BIR (2012), Map provided by Ross Bartley of Bureau of International Recycling.

Note: Of the processors known to accept electronic circuit board scrap for base and precious metal recovery, TES-AMM and Asahi Pretech are predominantly hydrometallurgical processors, most others are predominantly pyrometallurgical processors that may also use hydrometallurgical techniques. With respect to mobile phones, some of the operations indicated on this map may not process mobile phones, and some of the operations which process mobile phones may not recover the critical metals addressed in this case study.

Figure 7. The Flow of WEEE throughout Asia



Source: Widmer (2005), citing Schwarzer et al., (2005)

Note: As this figure was published in 2005, it is likely somewhat outdated and may not completely represent the current flow of WEEE throughout Asia. It is also important to note that this figure reflects the flow of WEEE and not just waste mobile devices.

3.2.8 Final disposal

54. Disposal (landfilling or combustion) occurs for mobile devices that have not been collected for reuse or recycling. Mobile devices and other EEE constitute a very small portion of total MSW in North American and Europe. However, efforts to quantify when and where the ultimate disposal of North American and European mobile devices occurs is challenging due to the tendency of consumers to "hoard" or hold on to mobile devices beyond end-of-use, and informal collection practices that are largely untracked. Final disposal of the unrecyclable portions of recovered mobile devices likely occurs in the same regions as recycling, as the material that cannot be recovered is likely combusted or landfilled soon

after recovery. The material that is unrecoverable tends to be the plastic casing and segments of the circuit boards remaining after combustion to remove copper and other valuable metals, however many of these materials can be recovered, either for materials or energy, at state-of-the-art recycling facilities. Overall, however, this is an area where geographic data are incomplete (OECD 2011d).

4. ASSESSMENT OF POLICY ISSUES

55. This section will: (i) summarize key policy issues identified for further research across different stages in the mobile device life cycle, and (ii) evaluate the potential gaps, market failures, or incoherence these issues could cause and the associated impacts on economic efficiency, environmental effectiveness, resource productivity (e.g., waste, eco-efficiency), competitiveness, and social outcomes. Each of the six key policy issues will be described and its potential impacts evaluated in each of the subsections below

4.1 Life Cycle Externalities

56. An externality occurs when the true societal costs that result from an economic activity are not reflected in the market prices associated with it. In other words, externalities result when the true societal costs of the participating firms' actions are not borne by the firms, encouraging them to make different production decisions than they would make if they paid the full societal cost of their operations (Boardman et al. 1996). A common example of an externality is when pollution generated by a firm results in adverse environmental and/or health impacts to others without their consent. If the firm is only responsible for its private costs, and not the other costs it imposes on society, it might make different production decisions. This section examines the life cycle externalities in the use and disposal of mobile devices as related to SMM policies and relevant actors.

57. Across the life cycle of mobile devices, externalities may occur in the raw material extraction, manufacturing, and recycling or disposal processes. Depending on the practices, control measures, and environmental and health and safety policies present at these stages, pollution, health and safety risks, and resource inefficiencies may result in societal costs from environmental degradation, adverse social impacts, and resource depletion.[23] Theoretically, a negative externality is created when the market price for mobile devices fails to account for the environmental and health impacts generated by the raw material extraction, manufacturing, and disposal of mobile devices. Markets may also fail to account for the scarcity and limits to the supply of these materials. (Boardman et al. 1996) There is a geographic imbalance in the burden of these externalities, since trade in used mobile devices generally moves from OECD countries to markets in Africa and Asia (Secretariat to the Basel Convention 2011; Widmer 2005). Previously, the concentration of consumers for mobile devices tended to be in wealthier countries but this picture has changed and the use of mobile devices and other EEE is expected to grow rapidly in developing countries as well, intensifying the extent of current externalities in these areas (Secretariat of the Basel Convention 2011; ITU 2010).

[23] See section 3 for a description of relevant environmental and social impacts along the mobile device life cycle. OECD (2011d) provides a thorough review of economic, social, and environmental dimensions, including environmental and social impacts.

4.1.1 Current Situation

58. The extraction of raw materials—including critical metals—involves processes that produce pollution in the form of air emissions, effluent discharges, land disturbances, mine waste and tailings, and noise (Balkau and Parsons 1999; EC 2011; EPA 1995; Maboeta et al., 2006).[24] If not properly mitigated or controlled, this pollution can result in environmental degradation and adverse health impacts. The literature on mobile devices, other electronic devices, and WEEE in general issues focuses on the externalities resulting from end-of-life processing of electronic devices; some studies have noted that mining generates "severe negative social and environmental impacts" in some countries (Manhart 2010, p.22, citing UNEP 2009b), but have not quantified the specific impacts, nor how these differ in different countries.

59. Manhart also suggests that the prices of virgin resources might play a significant role in the frequency of WEEE and UEEE, noting that "high resource prices provide unique opportunities to introduce more sustainable forms of e-waste management worldwide" (2010, p. 17); in other words, as the price of virgin minerals increases, the incentives to recover precious and other metals from WEEE also increases. This correlation is likely most applicable to metals, such as gold, silver, copper—but also platinum and palladium—and to electronic devices such as computers, TVs, DVD players, and mobile phones, which contain components such as PWBs that have high concentrations of these metals (Manhart 2010, p. 17). Increased recovery of resources through sound extraction methods in end-of-life processing may indirectly lessen some of the environmental and social impacts on mining (Manhart 2010, p. 22), but there are a number of supply and demand factors that influence material extraction, and metals recovery from WEEE may play only a minor role. For example, even for metals where the electronics industry constitutes a large share of global demand, such as indium or antimony, these metals often feature co-dependencies with the production of other base materials (OECD 2011, p. 39-40). Impacts from mining will also greatly depend on the control measures and adherence to existing environmental, health, and safety regulations where the mining is taking place (EC 2010).

60. Many studies of waste electronic devices have focused on the potential impacts of end-of-life stages; particularly the pollution and health impacts caused by poor recycling practices, and the resources lost through disposal of WEEE[25]—including mobile devices (Hagelüken 2008, Heart 2010, OECD 2011d, Robinson 2009). Studies have estimated the volume of WEEE in wealthy countries to be roughly 20 to 25 million tonnes per year, of which roughly 1.6 percent originates from mobile devices (Robinson 2009, p. 184-5). In addition, expected growth in the demand for electronics in developing countries coupled with rapid population growth results in projections for the volume of WEEE in 2020 to be 200 to 400 percent greater than the volume in 2007 (Herat 2010, Table 1, p. 2). Projections for 2020 show the number of discarded mobile devices in China alone to be seven times higher than the number in 2007 (Herat 2010).

61. Theoretically, the costs or inconvenience consumers or processors incur to dispose of electronic goods influences material recovery rates. For instance, if policy in one county attempts to make economic actors pay the full societal cost of their actions (i.e., "internalize the externality") and raise the price for disposal, this can create an incentive to shift the waste to a country that does not have these standards. Evidence suggests that the difference in environmental and labour policies across countries dictate who

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[24] A detailed review of the specific environmental and social impacts of critical metals extraction was beyond the scope of this report, but we have provided information on some of the general impacts that can occur. Several of the literature sources cited here identify impacts from a general standpoint of the mining industry and not from the perspective of critical metals specific to mobile devices.

[25] Disposal practices that adhere to ESM guidelines are an environmentally-sound method of end-of-life management. For example, OECD guidance on ESM of used and scrap PCs acknowledges that components of PCs which cannot be recycled need to be burned or landfilled in an environmentally-sound manner, according to acceptable practices in a given country (OECD 2003, p. 19).

recycles and disposes of WEEE, and how it is handled. For example, Manhart (2010) estimates that in 2007—a period in which copper prices were very high, leading up to the 2008 financial crisis—there was a net savings of €4.50 to €5.00 for a computer monitor that is transported to, recycled in, and disposed of in Vietnam as compared to the same process in Germany. Though this does not apply to mobile devices, it highlights circumstances where the cost of disposal varies by country and is cheaper even when accounting for increased shipment costs. Currently, shipments from China to Europe are at full capacity, whereas the return trip contains unused capacity (Manhart 2010, p.16). This difference drives the price of the return trip down and thus creates opportunities to ship EEE. Studies estimate that China receives some 70 percent of all exported WEEE, but because the flow of goods happens through informal as well as formal channels, the actual volume of WEEE remains unknown (Robinson 2009, p.187).

62. These findings relate to EEE in general, but there are additional drivers in play in the case of mobile devices. For instance, the reuse value of a used mobile device is much higher than the intrinsic value of the materials contained in the phone (ICF 2011a; OECD 2011d; Geyer and Blass 2009). As a result, although cheap recycling in developing countries plays a role, exports are likely driven by reuse, which is the most profitable fate for used mobile devices (OECD 2011d, p. 54). The high value of used mobile devices also means that ensuring collection and effective triage of used mobile devices is a critical consideration from an economic and resource efficiency perspective. These issues are discussed further in Section 4.4.

4.1.1.1 Relevant Actors

63. Several relevant stakeholders and actors influence the mobile device market along different stages of the life cycle. Although externalities may be generated through raw material extraction and end of life processes—depending on the practices employed and regulations and incentives governing these actors—other actors in different stages of the mobile device life cycle have an influence through the interactions of consumer demand and producer supply as well as through their use and disposal practices.

Manufacturers

64. Theoretically, a manufacturer’s objective is to maximize its profit. Because manufacturers generally cannot influence the price at which they can sell their product, they seek to maximize profit by minimizing their costs (Boardman et al. 1996). The desire to minimize costs often leads to manufacturers only paying their private costs and avoiding the social costs associated with extraction and disposal, since they have little incentive to do so (Boardman et al. 1996). In other words, in the absence of regulation, manufacturers have no incentive to pay for the cost of the pollution they generate, since that additional cost would eat into their profit margin (Boardman et al. 1996). There are other influencing factors, however, that can create incentives for manufacturers to reduce upstream environmental or social impacts in their supply chain; for example, considerations such as branding, product safety and workplace health and safety liability, pressure from environmental non-governmental organizations, and consumer demand for “green” electronics, discussed below.

Consumers

65. A consumer’s objective is to maximize their “consumer surplus” (or benefits) by purchasing the best mobile device for the least amount of money (Boardman et al. 1996). Because the market is competitive and consumers have options, if a manufacturer were to charge a fee to account for the social costs of mobile devices, consumer could simply choose to purchase from another manufacturer not charging this fee (Boardman et al. 1996). Some consumers, however, may place a value on the “green” aspect of a company and be willing to pay a premium for a more environmentally friendly product (Harter & Sova 2008).

66. Consumers also influence the end of life stage of a mobile device by deciding how to dispose of their devices (OECD 2011d, p. 52). Although consumers decide how the mobile device is managed at the end of life, they are typically detached from the impact of their decision. For example, if their mobile device were to be exported to an informal recycling or disposal market characterized by low health, safety, or environmental standards, the health and pollution costs of recycling or disposal are not directly borne by the user. In addition, the typical mobile device consumer may not be aware of the value of the extractable materials or benefit in any way from recycling, and thus have little to no incentive to recycle. With this lack of incentive for consumers, how and where mobile devices are recycled often depends heavily on regulatory policies and mechanisms (or lack thereof) within each country to handle UEEE and WEEE.

WEEE and Waste Mobile Device Processors

67. In OECD countries, we observe strict environmental regulations and polices directly related to WEEE end-of-life processes and mechanisms—including waste mobile devices. Due to Environmentally Sound Management (ESM) policies and practices in these countries, formal (i.e., regulated) collection, triage, and recycling systems for waste mobile devices may in fact be paying the full societal costs of end-of-life management.[26] With regard to mobile devices in particular, the costs of collection, triage, and environmentally-sound recycling are recovered by the high value of precious and other metals (e.g., gold, silver, copper) and certain critical metals, such as palladium, in these devices (Grant et al. 2012; Manhart 2010, p. 17).

68. At the same time, however, the several economic factors create an incentive to recover the highest-value fractions in informal, unregulated sectors, or in countries with less stringent regulations: first, mobile devices and other IT and consumer WEEE products, such as computers, TVs, and DVD players, contain a high concentration of high-value metals (Manhart 2010, p. 17); second, less-stringent labour and environmental regulations, and a lack of enforcement enable cheap recovery of the highest-value fractions (Chi 2011, Wendell 2011); finally, demand for recovered materials is high, particularly in Asian countries, which creates a strong market (Chi 2011, p. 737). As a result, developing countries with more lax environmental standards and labour regulations than OECD countries tend to be hot spots for WEEE (Manhart 2010, Robinson 2009, Wendell 2011) , including waste mobile devices.[27] These economic opportunities may also be a driver for countries to develop electronic waste policies in the hopes of developing formal processing industries: legislation concerning waste electronics is in place or under development in several countries, including India, Vietnam, China, Brazil, Mexico, Argentina, Colombia, Venezuela, Nigeria, Kenya, and Ghana (Ahonen 2012; Wendel 2011).

4.1.1.2 Policy Frameworks

69. Several policy frameworks can achieve a common goal of mitigating the pollution externalities associated with WEEE. At the international level, the Basel Convention regulates the flow of WEEE products between countries (see section 4.2.1.2), helping to curb the flow of hazardous materials to inefficient processing activities and requiring transport to environmentally sound treatment facilities (Basel

[26] As noted in section 5, we did not locate data sources that have quantitatively assessed the societal costs end-of-life management of mobile devices. However, environmentally-sound practices seek to mitigate or control harmful environmental and social impacts, thus internalizing the societal costs of end-of-life management practices.

[27] It is important to note that the high reuse value of mobile devices is also a major driver for imports of these devices to developing countries. For example, field studies conducted in Ghana showed that around 70 percent of EEE imports were used EEE; of the 30 percent of second-hand imports that were non-functioning e-waste, half was repaired locally and resold for reuse (Secretariat of the Basel Convention 2011, p. 11, citing Prakash et al. 2011).

Convention 2011). In some jurisdictions the focus is on promoting risk assessment of mineral- or metal-containing products over the full life cycle and discontinuing or prohibiting specific products or product uses where risks cannot be properly controlled or managed (Government of Canada 1996). Other jurisdictions, such as the European Union, regulate the concentration of hazardous materials through policies such as the Restriction on Hazardous Substances (RoHS) (see section 4.2.1.2). An explicit goal of the RoHS framework is to limit the potential for pollution at end of life management stages by preventing the use of hazardous substances in the first place (EC 2012b). Finally, programs that create requirements for, or incentives to encourage, the collection and triage of used and waste electronic devices—including mobile devices—help reduce the number of devices that end up in inefficient recycling operations. These policy frameworks are not necessarily specific to mobile devices: they can apply to used and waste EEE and other materials and wastes as well.

70. The Basel Convention is intended to limit the flow of WEEE to non-OECD countries. This type of policy aims to prevent WEEE from ending up in other countries with more lax environmental or labour policies and to prevent entities from exploiting these differences. The intention is that the country using the EEE will also be responsible for (i.e., bear the full costs of) disposing of WEEE. Despite these efforts, illegal WEEE shipments remain a problem for several reasons:

- The Convention restricts the flow of WEEE but not of UEEE, which—while allowing for the flow of reusable devices to markets (largely in non-OECD countries) where demand for second-hand mobile devices is high—opens a loophole where electronics are shipped regardless of their current functionality (see section 4.2.1.2; Robinson 2009, p. 184).

- Additionally, a lack of monitoring imports that are shipped as UEEE for direct reuse increases the likelihood of illegal shipments (Wendell 2011, p. 4).

- The policy also leaves room for interpretation in the definition of WEEE due to its primary focus on hazardous waste and not WEEE specifically (Wendell 2011, p. 4; Espejo 2010, p. 17).

- Finally, the Basel Convention suffers from a lack of enforcement and reliable, comprehensive flow data, insufficient legal authority given to environmental and customs inspectors, and ambiguity as to protocol when violations have been identified (Wendell 2011, p. 1).

71. The European Union's RoHS regulation attempts to mitigate the pollution potential before the product enters mass circulation. By limiting the concentration of certain materials in EEE, the policy is effectively forcing the producer to "pay" for the externality. Theoretically, in the absence of regulation, a producer will generally use the materials with the lowest cost that meet functional and performance requirements to produce the final product. RoHS requires the producer to use alternative materials that are ultimately less costly to society. The total cost of production, certification, and verification of conformance typically rises with this type of policy; policies of this type, however, can reduce overall societal costs if the production cost increases are outweighed by environmental and social benefits.

72. An additional way in which externalities may be internalized is through tax policies: taxes that are levied to reflect the negative externalities of market activity are called Pigouvian taxes (OECD 2001). The additional amount that a Pigouvian tax on precious or critical metals would add to the cost of a mobile phone may be quite small, however. For example, the value of precious and critical metals in a personal computer—which, like mobile devices, has a relatively high composition of high-value metals—is roughly \$5.21 USD[28] (Manhart 2010, p. 18). Thus, a 100 percent tax would add this amount to the cost of a

[28] 2003 dollars

personal computer; a similar tax on mobile devices might only add $2 to $3 to the cost. No evidence could be found of existing Pigouvian taxes levied on critical metals in mobile devices.

4.1.1.3 Impacts on environmental efficiency, economic efficiency, resource productivity, competitiveness and social issues

73. Information available on the impacts of externalities focused on end-of-life management aspects. In general, there is less of a direct focus on externalities associated with raw material extraction and processing in the literature available on mobile devices.

74. The end of life management process used to handle WEEE determines the environmental, economic, and resource efficiencies as well as the extent of pollution associated with disposal and recycling of mobile devices. Manhart breaks down recovery practices into three categories: (i) low technology, low yield, and severe pollution; (ii) mid technology, medium yield, and extreme pollution; and (iii) high technology, high yield, and low pollution (Manhart 2010, p. 18-20). [29]

75. The first category, low technology, low yield, and severe pollution, is the most inefficient of the three relative to environmental efficiency, economic efficiency, and resource productivity. Low technology processes involve labour-intensive means to dismantle and extract metals and often support backyard industries (Manhart 2010, p. 18). The labour-intensive means of final metal recovery generate the largest cost to society in terms of environmental and health impacts. Labour-intensive extraction of final metals also produces the lowest yield of recoverable materials and thus is inefficient.[30] Sites that process a large amount of WEEE in this manner contaminate the air, soil, and water, resulting in potentially high clean-up costs (Heart 2010, p. 1).

76. The mid-level technology option covers a middle ground in terms of efficiency but is commonly associated with wet chemicals which may or may not be disposed of effectively (Manhart 2010, p. 19). Depending on the operation, if the process is done using environmentally sound disposal techniques of the wet chemicals (mainly acid) the system can achieve a better balance between resource efficiency and environmental efficiency than the low technology process and not involve as high of an initial investment as the high technology process.

77. High technology, high yield, and low pollution processes generate the highest levels of both economic and resource efficiency while generating less pollution (Manhart 2010, p. 18). An example of a high technology plant would be an integrated smelter, or perhaps advanced hydrometallurgical operations that adhere to ESM practices. Integrated smelters involve an extremely high investment, which some sources have estimated to be over $1 billion US dollars (Manhart 2010), and thus favour consolidation of WEEE streams through large recovery contracts (Kopacek 2011). The high technology plants generate a more efficient outcome than both the low technology and mid technology plants in terms of environmental efficiency and resource productivity. In addition, the concentration of metals found in circuit boards is more than tenfold higher than commercially mined minerals (Robinson 2009, p.185-6). Because minerals are a natural resource that could be depleted, from a societal standpoint, extraction from EEE would yield a more efficient solution than solely relying on the mining sector for raw materials.

[29] For more detailed descriptions of WEEE recycling processes, please see Sepúlveda et al. (2010) and UNEP (2009). We recommend this information be included in the final report to clarify and provide additional context to this description.

[30] Low technology, low-yield methods are, however, highly efficient at collection and dismantling and pre-treatment (see section 4.4.2).

4.1.2 Desired outcomes

78. Market failures occur when the market price of a good does not reflect the full cost to society for producing that good. For WEEE—including waste mobile devices—a desired outcome from a social perspective is to process the waste in high technology plants, generating both a high level of extractable materials and low pollution levels. Currently, economic forces are not directing the flow of WEEE to the most efficient process in all cases, and thus policy intervention is needed. Theoretically, although policy options include command and control strategies (i.e., limits on exports of WEEE, limits on hazardous materials in EEE, etc.), a policy can be more successful if it is more directly related to the underlying market failures and it provides economic incentives to address them.

79. Many studies point to the variation in policies across countries that encourage the flow of WEEE and ultimately increase its volume in different locations (Manhart 2010, Robinson 2009, Wendell 2011). The flow of these goods is closely tied to the potential to make a profit from these goods thus highlighting the economic motivations. Theoretically, a policy directed at economic incentives would be useful for two primary reasons: (1) enforcement would be less of a concern because it is in the parties' best interests to comply; and (2) economic incentives can translate across borders. Because WEEE is a global problem with interactions that span several different countries, enforcement and implementation become difficult. Differentials across environmental, health and safety policies generate some of the motivation for poor WEEE practices, and using economic incentives to make better disposal practices more appealing would thus not only help encourage ESM of used and waste electronics wherever they are generated and managed.

80. Because the labour-intensive practices for final metal recovery from WEEE—including from waste mobile devices—can be inefficient and result in adverse environmental and health impacts, a policy that can target one of these inefficiencies could theoretically mitigate against the other. For example, if a country became a destination for WEEE due to their lax environmental regulations, an increase in environmental standards might both prevent environmental impacts and generate higher resource efficiency through better technology. Coordinated increases in standards, or harmonization, across countries would help reduce the incentive to shift shipments from one country to another.

4.1.3 Steps Being Taken

81. Several countries have adopted policy that mirrors the language from the Basel Convention. In Asia, this includes Japan, Korea, India, Hong Kong SAR, China, Cambodia, and Bangladesh (Wendell 2011). In addition, Chinese WEEE policies also adapted regulations on the concentration of hazardous materials in the manufacturing of EEE (Wang 2012). These policies have set a precedent for other countries to develop similar and consistent polices.

82. There are also initiatives focused on increasing efficiency and reducing the high level of capital investment required by high-technology recovery processes. For example, the Austrian Society for Systems Engineering and Automation is leading a three-year HydroWEEE project to recover certain critical metals such as yttrium and indium from WEEE. The project seeks to develop a mobile hydrometallurgical plant that will recover metals at high purities (above 95 percent) from cathode-ray tubes, lamps, liquid-crystal displays, lithium-ion batteries, and PWBs (Kopacek 2011).

83. Information campaigns or product markings and labelling directed at informing consumers' decisions at end-of-life could help bridge important information gaps (MPPI 2009, p. 18). For labels to be effective, however, consumers must be adequately educated about what they mean; for example, a 2008 review of the EU's WEEE Directive found evidence that 71 percent of consumers didn't understand the crossed-out "wheelie bin" symbol that is meant to promote WEEE recycling. (Huisman et al. 2008)

Initially, consumers dictate how and when mobile devices are disposed of. Changing consumer preferences and making them aware of the end-of-life processing implications might dictate which products consumers purchase which in turn could influence manufacturing practices. By sending a strong market signal, consumers also can indirectly influence manufacturers to invest in reducing environmental impacts and designing for recyclability. For example, by tapping into the market for consumers demanding "greener" devices, manufacturers may be able to command a price premium for their products (Harter and Sova 2008).

4.1.4 Data Gaps

84. A data gap in information on externalities associated with raw material extraction and processing was identified in the literature on mobile devices (see also OECD 2011d). Although a detailed review of the specific environmental and social impacts of critical metals extraction was beyond the scope of this report, information on some of the general impacts that can occur in mining operations is provided. Environmental and social impacts will depend on the extent to which they are mitigated or controlled by operators. In the literature survey and expert interviews that were conducted, no information specific to the four critical metals focused on in this report could be located. Some of the relevant actors and interactions are discussed in general in this section; while this is believed to capture some of the most important interactions at a high level, this is an area where limited additional research could be conducted on specific critical metals if there is interest in exploring this further.

85. As with most externalities, the full extent of the social damage of harmful practices in recycling valuable metals from WEEE remains unknown. This is partly due to long term effects that have not yet occurred, and partly due to the fact that a large portion of the externalities are generated by informal markets where data availability is poor. Accurate and reliable data on the levels of pollution and related health impacts caused by WEEE and material extraction would strengthen the case for policy interventions.

86. Information pertaining to informal markets, especially on the volume and flows of mobile devices, could highlight how and where current enforcement policies are failing. In addition, much of the literature focuses on WEEE as opposed to focusing specifically on mobile devices, which could represent a data gap if mobile devices are not a good proxy for WEEE. The literature surrounding WEEE typically focuses on the implications of inefficient disposal practices (e.g., pollution and health impacts) and less on the economic incentives and drivers of WEEE.

4.2 Trade Policy Impacts

87. This subsection investigates the effect that import and export restrictions have on the flow of critical metals, mobile devices, and end-of-life devices and materials between countries. This analysis includes a high-level overview of trade policies relevant to SMM goals throughout the life cycle of mobile devices. This section seeks to clarify if and how UEEE import and waste export policies influence relevant actors along the life cycle and identify lessons learned about the effectiveness of trade policies in achieving SMM policy goals.

4.2.1 Current Situation

88. Restrictions on trade are used by policymakers to respond to social, economic, and political objectives. These objectives include environmental protection, promotion of downstream industries, revenue maximization, and preservation of resource reserves for future use (Korinek 2010, p. 22). Despite the theoretical benefits of trade restrictions, in practice, these restrictions can have unintended and detrimental economic, social, and environmental impacts (see section 4.3.1.3). Trade restrictions relevant

to the mobile device industry include export restrictions on strategic raw materials and import/export restrictions on UEEE.

89. As discussed in section 3.1 of this report, the first step in the life cycle of mobile devices is the extraction and processing of raw materials, including critical metals. To include these materials in a mobile device, they must first be mined and processed to be suitable for subsequent manufacturing of components. Critical metals used in mobile device component production are not evenly distributed throughout the world, necessitating international trade. The production of components for mobile devices requires the input of several critical metals, including palladium and platinum, and in some cases, antimony and beryllium, which are supplied by a small number of countries, and which have few substitutes.[31] For example, China produces over 91 percent of the world's antimony, which can be used in the production of flame retardants for plastic components of mobile devices (OECD 2011d). The production of these critical metals in only a few countries, combined with the dearth of substitutes, results in a high dependence on imports of these materials for non-producing countries (Korinek 2010, p. 22).

90. Export restrictions can have a significant impact on the critical metal supply chain making it difficult and more expensive for manufacturers reliant on imported materials needed for new mobile device components. At the same time, they present opportunities to increase SMM practices at this stage. However, no export restrictions have been identified that are explicitly applicable to the four critical metals considered in this report, which may, in part, be because export restrictions are not notified to any international body and there is therefore no comprehensive list of such measures (Korinek 2010, p. 6).

91. Import and export restrictions also can impact the final stages of the life cycle of mobile devices. As discussed in section 3.1 of this report, when mobile devices reach the end of their useful life, they are triaged, or directed towards reuse and refurbishment or recycling, depending on the condition of the device and availability of reuse or recycling markets. In Europe and North America, the end of the initial use of mobile devices can lead to triage either in their country of origin or upon export to another country. In the latter case, mobile devices are identified as exported for reuse, even though, upon arrival and triage in the importing country, not all of these devices may be reusable and some will be sent to disposal or recycling.

92. Similar to the triage stage described above, the refurbishment and reuse phases of the mobile device life cycle can occur in both the country of origin for each device, or upon export to another country. Currently available information shows that refurbishment and reuse is prevalent in Africa and China, which import used mobile devices and distribute those devices that can be fixed without the use of specialized parts or machinery to small enterprises. The recycling and materials recovery segment of the mobile device life cycle—despite regulations and trade policies intended to prevent international trade in WEEE—largely takes place in Asian countries, such as China and India, with little enforcement of handling regulations. Final disposal of the unrecyclable portions of recovered mobile device likely occurs in the same regions as recycling, because the material that cannot be recovered is locally combusted or landfilled soon after recovery.

4.2.1.1 Relevant Actors

Importers

93. Manufacturers of mobile devices or mobile device components may import certain critical metals that are needed in the manufacturing process, but are not physically or economically available in the country of manufacture. Trade policies can have a significant impact on manufacturers by making it more

[31] Certain handset manufacturers have phased out antimony and beryllium in mobile devices. For more information, please see section 4.3.

difficult and expensive to acquire the materials needed for new mobile devices (Ahonen 2012; Korinek 2010, p. 21-23).

94. Developing countries may benefit from importing used electronics because reuse and recycling offer business opportunities and employment for poor communities. However, these importing countries may also incur environmental and human health externalities associated with hazardous materials in imported WEEE, or with hazardous substances used to recover metals[32], when these wastes are recycled or disposed of improperly (Chen 2010, p.2).

Exporters

95. Countries with economically-recoverable critical metals may use export restrictions to achieve objectives such as environmental protection, promotion of downstream industries, revenue maximization, and preservation of resource reserves for future use (Korinek 2010, p. 22).

96. Developed countries may benefit from exporting UEEE in order to transfer environmental externalities to other countries that have less stringent environmental standards and less expensive processes for handling UEEE.

4.2.1.2 Relevant Policy Framework

97. In general, export restrictions are not notified to any international body and there is therefore no comprehensive list of such measures that one can refer to (Korinek 2010, p. 6). Additionally, the WTO trade agreements do not include any explicit national export restrictions on metals and minerals (Korinek 2010, p. 6). The WTO, however, does conduct periodic trade reviews of countries to increase the transparency of trade practices; these reviews generally include measures affecting exports, such as export charges, levies, prohibitions, and restrictions. (WTO 2012)

98. Although not applicable to the four critical metals considered in this report, one example of an export restriction on the raw materials needed for the production of mobile devices comes from a recent Chinese trade policy. On September 21, 2010, China began a de facto ban on exports of rare earth metals to Japan (Bradsher 2010).[33] At the time, China accounted for about 97 percent of the world's total production of rare earth metals, about half of which were exported to Japan (Ahonen 2012). This ban was in addition to already reduced total export quotas for 2010, which had been reduced by about 40 percent from the previous year's level. The Chinese government rationalized this restriction by arguing that its reserves of rare earths are finite and, therefore, they should be developed for the prime benefit of China's manufacturing industry. (Korinek 2010, p. 20)

99. The Basel Convention is the only international agreement that applies to transboundary shipment of WEEE, including end-of-life mobile devices. The Basel Convention was created to reduce the flow of hazardous waste from developed countries to developing countries by regulating the exports and imports of hazardous waste and their disposal. The Convention provides definitions on waste and hazardous substances, defines the criteria for ESM, and creates an international legal framework to approach this problem. It originally allowed countries to define waste at a national level when the definitions given within the convention were determined to be insufficient; this aspect of the Convention was intended to

[32] In the case of mobile devices, health and environmental impacts likely occur through substances released during the recycling process, rather than the presence of intrinsically hazardous materials in the phones themselves. OECD (2011d, pp. 58-61) describes some of the health and environmental impacts associated with mobile device recycling.

[33] Chinese officials denied that this ban was in effect (Bloomberg News, 2010).

give developing countries access to technology and second hand equipment that would not be available as new equipment (Espejo 2010, p. 16 - 18).

100. However, what actually occurred was that exporting countries defined "waste" in a way that WEEE could be labelled as equipment for reuse and exported, regardless of the reusability or hazardous content of the EEE. In order to close this loophole, the Basel Convention was revised in 1995 to ban all exports of hazardous waste and all exports destined for recycling and recovery. However, this amendment has not yet come into force due to the lack of ratifications from a sufficient number of signatory countries. The amendment will go into force when 68 of the 90 countries that were party to the Convention in 1995 ratify the agreement to amend. As of October 21, 2011, 51 countries had ratified the amendment, leaving just 17 more needed.

101. Additionally, some OECD countries, including the United States, who have signed but not ratified the Basel Convention, simply export UEEE without applying the standards of the Basel convention (Espejo 2010, p. 28).

102. Additionally, on a more local level, the Bamako convention on the ban of the import into Africa and the control of transboundary movements and management of hazardous waste within Africa, aims to prohibit the import of UEEE containing potentially hazardous substances and any other hazardous waste into African countries. The Bamako convention came into force on April 22nd 1998. (Espejo 2010, p. 38) In Asia, Vietnam, Indonesia, and Thailand have banned imports of UEEE even for direct use (Wendell 2011, p. 3; Vietnews 2010).

4.2.1.3 Impacts on Environmental Effectiveness, Economic Efficiency, Resource Productivity, Competitiveness, and Social Outcomes

103. In the raw materials extraction and processing phase of the mobile device life cycle, export restrictions, such as the Chinese de facto ban on rare earth metal exports to Japan, can have a negative impact on economic efficiency, because manufacturers reliant on the import of these metals must spend unnecessary time and money to identify alternate sources of raw materials that also may be more expensive to extract and process (Ahonen 2012). This can lead to the development of mineral resources that would not otherwise be developed if existing supplies were traded freely. It also leads to increased prices throughout the production cycle, which are passed on to consumers (EC Directorate-General for Trade 2009, p. 9). Export restrictions—particularly the threat of restrictions on critical metals—encourage importing countries to investigate substitutes for these materials.[34]

104. Although the country imposing the export ban is able to domestically process the supplies of the raw material for use in domestic manufacturing, this may not be the most economically efficient use of this resource. An export restriction effectively increases the domestic supply of the raw material because international companies are no longer able to purchase domestically produced raw materials. As a result of this increased domestic supply and static domestic demand, domestic prices for the raw material may decrease. The decreased price may then have additional economic impacts, including increased domestic consumption and decreased domestic production of raw materials (EC Directorate-General for Trade 2009, p. 9).

105. Additionally, an export restriction can create long-term risk for the mineral extraction industry and the mobile device manufacturing industry by distorting or even eliminating international price signals

[34] For example, Japan announced in its 2011 budget that it will spend $650 million on securing rare earth elements and other natural resources. Of this, $19.5 million will be spent on developing rare earth element recycling and rare earth element alternative technologies (Maeda, 2011).

that drive efficient production, allocation, and use of resources (EC Directorate-General for Trade 2009, p. 9).

106. Toward the end of the mobile device life cycle, used mobile devices can benefit an economy. Lower-cost reused mobile devices provide greater affordability to low-income populations: this may be particularly true for reuse in developing countries, where reused electronics help to reduce the digital divide (Secretariat of the Basel Convention 2011). If they cannot be reused, waste mobile devices can be a source of revenue for recyclers when recycled properly (Chen 2010, p. 5).

107. On the other hand, waste mobile devices—although they are not, themselves, hazardous—may be recycled in process that releases hazardous substances in order to recover metals from end-of-life devices. If not controlled, these releases can damage human health and pollute the surrounding ecosystem (see section 4.1). This may be particularly true when WEEE is imported illegally into developing countries, despite current import/export restrictions, since these areas of the world are the least likely to have the capacity to safely recycle or dispose of mobile device components (Herat 2010, p. 14). The insufficient treatment structure available in developing countries creates serious concerns because the waste remains untreated or it is treated under poor conditions, putting in danger workers and the environment.

108. The ban on import/export of UEEE has contributed to the development of informal markets in the countries illegally receiving UEEE by forcing these markets to operate outside the formal sector (Herat 2010, p. 14). The specific impacts of the informal markets created by trade policies are discussed later in section 4.4.

4.2.2 Desired Outcome

109. Ideally, the global market for critical metals should support a level and transparent playing field for trade and investment that promotes a sustainable supply (EC Ad-hoc Working Group 2010, p. 50). In its 2009 annual report on raw materials policy, the EC Directorate General for Trade suggested that, from the European perspective, steps required for a fair and sustainable trade policy have three prongs: (1) including rules on export duties in future trade agreements; (2) effective enforcement and tackling of restrictions imposed by third parties; and (3) outreach to third-party countries in order to raise awareness and establish a common interest, with recognition that solutions for raw material trade policy issues must occur at a global level in order to be effective (EC Directorate-General for Trade 2009, p. 5).

110. A global policy framework or any bilateral agreements should support good governance, transparency of mining and extraction practices (including minimum health and safety standards), equal access for companies, and environmental responsibility (EC Directorate-General for Trade 2009, p. 12).

111. At the end of the mobile-device life cycle, although the current framework does not appear to be creating an economically efficient allocation of UEEE among developed and developing countries, a total ban on the export of UEEE is not desirable for the importing countries because the UEEE may be repairable and reusable (see section 4.4). Similarly, there may not be much demand for used mobile devices in exporting countries, making it more economically efficient to export them to those countries that can use them.

112. In theory, an import/export restriction on UEEE that requires that EEE be sent only to places with the capacity to handle it should encourage internalization of externalities in exporting countries and also maximize refurbishment and resale in developing countries while maximizing recycling of dangerous materials in countries with ESM recycling operations. The Basel convention suggests that one would need: (i) a regional level playing field on how to deal with export and import of electronic and electrical wastes

and (ii) sustainable development policies, including policies on the collection, recycling, and recovery of UEEE and the transboundary movements of such wastes (Herat 2010, p. 14).

4.2.3 Steps Being Taken to Address These Issues

113. While there are no known export restrictions on the four critical metals under review in this report, it is nevertheless worth presenting a few recent developments around the broader issue of export restrictions on raw materials. In 2009, the EU, the US, and Mexico requested that the WTO establish a dispute settlement panel between the European Commission and China to deal with quotas, export duties, and minimum export prices for a variety of metals and raw materials. On July 5, 2011, the panel ruled against China's export restrictions of certain raw materials (including bauxite, coke, fluorspar, magnesium, manganese, silicon carbide, silicon metal, yellow phosphorus and zinc). This was confirmed in a final ruling on January 30, 2012.

114. The panel reasoned that export restrictions can create serious disadvantages for foreign producers by artificially increasing China's export prices and driving up world prices. At the same time, such restrictions artificially lower China's domestic prices for the raw materials due to significant increases in domestic supply. This gives China's domestic downstream industry significant competitive advantages and puts pressure on foreign producers to move their operations and technologies to China.

115. The panel was convinced that export restrictions on trading these materials were not effective at ensuring environmental protection because the production of these materials is not similarly restricted. The panel found that China's export restrictions were not justified on environmental grounds and should be removed (EC 2011).

116. In January 2012, the European Parliament passed an updated WEEE Directive (see section 4.4.1.2 for a description of the EU's WEEE Directive). The Directive places requirements on exporters to "test and provide documents on the nature of their shipments when the shipments run the risk of being waste"; these measures are specifically targeted to reduce illegal shipments of WEEE disguised as legal UEEE. (EUROPA 2012) In addition, the Mobile Phones Partnership Initiative (MPPI) and the Partnership for Action on Computing Equipment (PACE) within the Basel Convention are actively working to promote ESM of mobile devices and personal computers. For example, the MPPI has developed guidelines for the transboundary movement of collected mobile devices, as well as guidelines for mobile device design considerations, and the collection, refurbishment, and material recovery of mobile devices.[35]

4.2.4 Data Gaps

117. Further research is needed to determine how trade policies can help to create a scenario in which UEEE and WEEE are allocated between developed and developing countries in an economically efficient manner, including the results/efficacy of import restrictions like the Bamako Convention or domestic bans on UEEE for direct reuse, such as those in Vietnam, Indonesia, and Thailand. Further research is also needed to develop a more complete characterization of the global scope of mobile device refurbishment and reuse.

4.3 Material Substitution and Hazardous Materials Policies

118. This subsection investigates the effects that international and domestic chemical and hazardous material policies have on the use of materials in mobile devices. From a life-cycle perspective, restricting one material for another may result in environmental or human health trade-offs, so material substitution

[35] For additional information: http://basel.int/industry/mppi/documents.html, accessed January 29, 2012.

may not be preferable if the change shifts the burden from one type of environmental or health impact to another, unless the cumulative burden is reduced. Although various factors can influence the use of specific materials in mobile devices, this section focuses on the effects that hazardous material policies have on the substitution process. To investigate this issue, international and domestic regulations that have influenced material substitution of beryllium and antimony in mobile devices were identified. After establishing the relevant policy frameworks, this subsection examines the uses of and substitutes for beryllium and antimony, including how substitutes are selected and whether there are environmental or health impacts associated with these substitutes. The report focuses on beryllium and antimony because these substances can pose health risks to workers without proper preventative measures and they have been phased out by some mobile device manufacturers.

4.3.1 Current Situation

119. When metals are in short supply, create potential environmental or health risks, or are otherwise expensive, design engineers consider alternative materials (OECD 2011d, p. 73). Additionally, international and domestic chemical and hazardous material policies and markets may influence the use of specific materials in mobile devices.

120. Despite the desire or need to substitute materials, several barriers may impede the ease of material substitution. An Öeko-Institut study (2008) on hazardous substances in EEE recognized that although substitutes and/or alternative technologies exist on the market for many candidate substances, the expenses of changes in production machinery may pose a barrier to the introduction of the substitute. The study also states that machinery changes are very sensitive to the time factor of substitution – if substitution does not take place within the timeframe of the periodical renewal of machinery, there may be a significant cost associated with substitution (European Parliament Directorate-General for Internal Policies 2010, p. 8).

121. Additionally, physical barriers to substitution may exist. Specifically, some substitutes may not be feasible due to the interconnected nature of the originally-used substance and its proposed substitute. When ore is mined, it usually contains several, "co-dependent", metals that are produced alongside carrier (e.g., copper, iron, aluminium) and high-value metals (e.g., zinc, silver, gold, and platinum-group metals). Antimony, for example, is produced either from antimony deposits or as a minor metal co-product with copper, lead, or silver (OECD 2011d, p. 40). If the originally used substance and the substitute are produced co-dependently, then production of the substitute would also involve production of the originally used substance. Co-dependence may eliminate the proposed substitute as an option.

122. To investigate this issue, the report considers the use and possible substitution of beryllium and antimony in mobile devices. Antimony compounds—for example, antimony trioxide[36]—are used as a flame retardant in integrated circuit plastics in mobile and other devices (Ahonen 2012). World consumption of antimony has increased over the last 20 years, a trend which will continue as more stringent flammability standards and demand for EEE increase. Antimony is produced either from antimony minerals with negligible concentration of metals or as a co-product of copper, lead, or silver. Hydrated aluminium oxide, as well as several other organic compounds, can be used as substitutes for antimony in the processing of flame retardants, the principal use of antimony (OECD 2011d, Annex p.7).

123. Beryllium is used for the manufacture of electrical contacts and connectors in mobile devices. Because of the hazardous nature of beryllium, various international and national guidelines and regulations have been established regarding beryllium in air, water, and other media. Because beryllium is extracted from simple deposits, its extraction and substitution is not limited by co-dependencies with other metals. In

[36] Antimony trioxide with industry standard J-STD-709 specified maximum concentration value.

some applications of beryllium, copper alloys containing nickel and silicon, tin, titanium, or other alloying elements may be substituted for beryllium-copper alloys (OECD 2011d, Annex p. 9 – 10).

4.3.1.1 Relevant Actors

Regulators

124. Countries where mobile devices are produced may be able to regulate the use of materials in manufacturing processes. Environmental or natural resource agencies with a responsibility for environmental stewardship may choose to restrict or encourage the use of certain materials based on the environmental or health risks associated with their use. Regulation can take the form of banning the use of certain substances, reducing the amounts allowed in a product type, or through other restrictions that make the material difficult to use.

Mobile Device and Component Manufacturers

125. In theory, from an economic perspective, manufacturers of mobile devices and their components (e.g., batteries) will likely seek to use the most available and least expensive inputs to their manufacturing processes in order to maximize profit and minimize problems in their supply chains. If forced by regulation to eliminate or reduce the use of a particular raw material, they are likely to select a replacement that is, among other factors, the next most available and inexpensive or that is most compatible with manufacturing processes.

126. Mobile device manufacturers may not have full information of their supply chain and the materials used in components they purchase. Mobile devices, in particular, contain a complex array of components and materials (UNEP 2009a, p. 7, citing Umicore 2008). It can be difficult and time-intensive for device manufacturers to obtain detailed information on the composition of components they purchase. Regulations or consumer demand for products with less hazardous or environmentally-harmful materials can provide regulatory or market-based incentives for mobile device manufacturer to evaluate the impacts of metals in either supply chain (see sections 4.3.1.2 and 4.3.3).

Consumers

127. Consumer demand for improvements in the features and performance of mobile devices may also impact material substitution in mobile devices. Theoretically, if a sizeable number consumers are willing to pay a higher price for a mobile device that can demonstrate lower environmental or health impacts across the life cycle, then a manufacturer may utilize “green” substitutes in their manufacturing process—even if these are more expensive than conventional materials.[37] For example, the MPPI’s guidance on Awareness Raising and Design Considerations explains how consumers have shaped mobile device design through demand for increased portability, longer operating time, and incorporation of multiple functions in a single device. Advances to address these consumer desires have reduced size and weight, material use, energy consumption, the use of toxic materials in mobile devices while providing better performance and utility (MPPI 2009, pp. 5-9).

4.3.1.2 Relevant Policy Frameworks

128. The most direct government regulation that presently affects the design of mobile devices is the European Union’s Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic

[37] For evidence of consumer demand for environmentally-friendly mobile devices, see Harter and Sova (2008) and ABI Research (2009).

Equipment (RoHS) Directive, which bans the use of six substances (lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ethers) in electrical and electronic devices, including mobile devices placed on the European Union market after 1 July 2006 (UNEP 2010, p. 15). The European Union's RoHS Directive has extensively considered and chosen not to restrict the use of beryllium, beryllium oxide, and antimony (Öeko-Institute 2008).

129. The European Union's Registration, Evaluation, Authorisation, and Restriction of Chemical substances (REACH) legislation also impacts hazardous substances used throughout the mobile device life cycle. Unlike RoHS, which regulates substances present in electrical equipment, REACH affects all chemicals including those used to make electrical equipment and chemicals present in finished products of all types. REACH restrictions are introduced only if a risk to human health or the environment can be proven, cannot be controlled, and substitutes exist. Neither antimony nor beryllium are banned under REACH.

130. Currently, no national or international policies explicitly banning the use of antimony or beryllium in mobile devices have been identified. However, by applying the "precautionary principle" Nokia voluntarily committed to phase out bromine and antimony trioxides from all new mobile devices and accessories. Under the precautionary principle, if an action or policy has a suspected risk of causing harm to the public or the environment, in the absence of scientific consensus that the action or policy is harmful, the burden of proof that it is not harmful falls on those taking the action. This principle mandates that industry has a social responsibility to protect the public from exposure to harm. Although not internationally applied, in some legal systems, including Article 174 of the environment title of the EC Treaty, the application of the precautionary principle has been made a statutory requirement.[38]

131. In the European Union, efforts to reduce the environmental impact of products throughout their life cycle are guided by Integrated Product Policy (IPP). The goal of IPP is to minimize environmental impacts across all phases of the product life cycle through a package of policy measures that include economic instruments, substance bans, voluntary agreements, environmental labelling and product design guidelines.[39] In the United States, EPA's Design for Environment Program partners with industry, environmental groups, and academia to identify safer and less environmentally-harmful alternatives to traditional chemicals from a life-cycle perspective.[40]

4.3.1.3 Impacts on Environmental Effectiveness, Economic Efficiency, Resource Productivity, Competitiveness, and Social Outcomes

132. Antimony can cause irritation for eyes, skin, and lungs as well as heart problems during prolonged occupational exposure (U.S. ATSDR 1992). Inhalation of airborne beryllium can have negative impacts on lung health (including acute beryllium disease, which can be fatal) and is considered to be a human carcinogen (U.S. ATSDR 2002; U.S. ATSDR 2008). However, phasing out hazardous materials, such as antimony and beryllium, can have unintended and detrimental life cycle effects on mobile devices.

133. For many raw materials, including antimony and beryllium, substitution is difficult to achieve without deterioration in the quality or performance of products or is not economically viable (EC Ad-hoc Working Group 2010, p. 51). For example, in some applications of beryllium, copper alloys containing nickel and silicon, tin, titanium, or other alloying elements may be substituted for beryllium-copper alloys,

[38] Treaty establishing the European Community. Dec. 24, 2002.

[39] For more information, see: http://ec.europa.eu/environment/ipp/, accessed January 29, 2012.

[40] For more information, see: http://www.epa.gov/dfe/, accessed January 29, 2012.

but using these substitutes results in reduced performance (OECD 2011d, Annex p. 9 – 10). In some cases, plastics are taking the place of metal parts: the benefit of lower costs and lighter weight is offset by the disadvantage of poorer product durability or reduced recyclability of a lower value material (OECD 2011d, p. 73). However, poor performing mobile devices can result in reduced resource productivity because consumers are likely to replace the device more frequently.

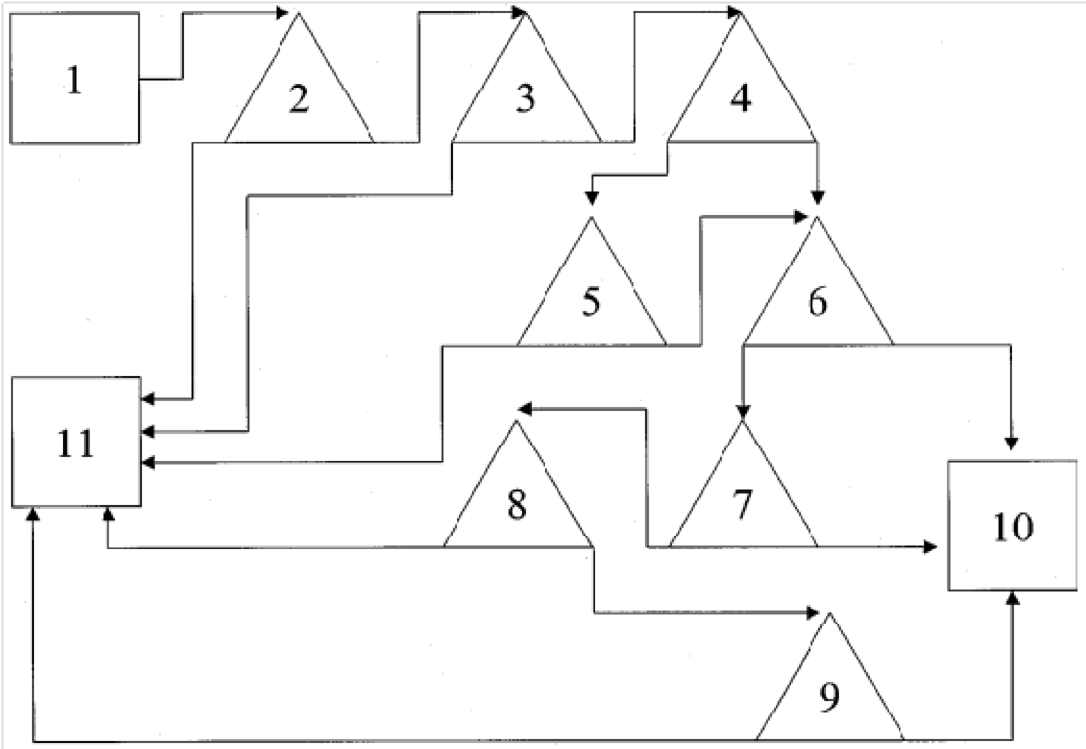
134. Future substitutes for antimony and beryllium may appear environmentally friendly at first because they eliminate the use of an undesirable substance. However, the substitute may have its own negative environmental consequences, or may be scarcer and thus be quickly depleted (Graedel 2001, p. 107). Similarly, as is the case with any raw material, the circumstances surrounding its extraction (pressure on the surrounding populations and the environment) can result in unintended damages.

4.3.2 Desired Outcome

135. Substitution can be used to replace toxic or non-recyclable components but adverse product quality changes are possible and must be carefully scrutinized on a case-by-case basis, using a risk assessment and exposure data with sufficient due diligence to avoid unintended consequences, including adverse social and economic impacts (OECD 2011d, p. 8, 73). Ideally, mobile device manufacturers would begin to produce mobile devices with materials that do not pose negative impacts on human health or the environment, while not reducing the performance of the mobile devices or causing other unintended negative impacts. One driver of materials substitution that can be utilized to reach this goal is regulation. However, before determining that legislation is the appropriate course of action, policy makers should consider the unintended impact of their policy proposals. Through consideration of unintended impacts, policymakers can implement effective policies that encourage SMM practices.

136. Several years ago, Thomas Graedel, a professor at Yale University, proposed an 11-step SMM approach to materials substitution. The logic sequence, found in Figure 8, is described in the numbered list that follows.

Figure 8. Eleven-step SMM approach to material substitution



Source: Graedel (2002). Material Substitution: A Resource Supply Perspective.

1. Action: An EHS problem related to a material in use is identified.
2. Question: Is a potential substitute material available to minimize or avoid the problem?
3. Question: Are chemical and physical properties and anticipated cost of the potential substitute satisfactory?
4. Question: Does the potential substitute raise new EHS issues?
5. Question: Are the new EHS issues potentially more severe than those related to the present material?
6. Question: If the substitution is fully implemented, would this action significantly change the overall use rate of the potential substitute?
7. Question: Do possible supply problems exist for the potential substitute?
8. Question: Could global resources industries accommodate the total anticipated magnitude of use and the rate of increase in use of the potential substitute?
9. Question: Does mining of hitchhiker elements as a result of the change in rate of use contribute significant new EHS issues that outweigh those related to use of the present material?
10. Action: If all the above questions are answered satisfactorily, proceed to implement the proposed material substitution.
11. Action: If any of the above questions is answered unsatisfactorily, minimize the use of the present material to the degree possible, and continue to investigate other potential alternatives.

4.3.3 Steps Being Taken to Address These Issues

137. From a regulatory perspective, many countries have adopted Restrictions on Hazardous Substances (RoHS) regulations in the manufacture of mobile devices. This effort has been made in an attempt to reduce the hazardous substances in EEE, including those used in the production of mobile devices. Such regulations incentivize research and development of less hazardous substitutes for toxic materials in mobile devices (Kishore 2010, p. 3). Trade may be a driver promoting dissemination of this policy to other jurisdictions: for example, the Chinese government has introduced a RoHS regulation and other WEEE legislation in response to EU regulations, which have a large impact on Chinese EEE exports (Chi et al. 2011, p. 731). See the box item for further details.

138. Additionally, material substitution may also occur through voluntary commitments by industry participants. For example, several years ago, Nokia made a voluntary commitment to phase out from all new mobile devices and accessories not only brominated flame retardants, but also other compounds of bromine, chlorine, and antimony trioxide as defined in Nokia Substance List (NSL). Additionally, Nokia has banned the use of beryllium oxide since 2004 in all new products, and placed restrictions on the use of all other beryllium compounds since 2010.

139. Increasingly, mobile device manufacturers are also incorporating supply chain sourcing into their sustainability strategies. For example, both Nokia and Samsung have programs focused on supply chain sustainability, including requirements for reporting and compliance with substance control lists.[41] In 2011, Apple was ranked as one of the top four information technology firms managing social and environmental issues in their supply chain (Wheeland 2011).

140. Similarly, the global acceptance and application of the extended producer responsibility (EPR) theory can help to encourage producers to take steps to manage their products properly at the post-consumer stage. EPR involves sustainable product design (less use of toxic materials, use of recycled and replaceable materials, upgrade potential, and ease of disassembly for repair and recycling), environmental and public health risk management (disposal bans and substance bans), and participation in take-back and recycling programmes (UNEP 2010, p. 16; Toffel 2008).

Box 2. The Role of Trade in Promoting SMM Practices Across Geographic Boundaries and Life-Cycle Stages

Trade is an area where countries can influence the adoption of SMM practices across geographic boundaries and life-cycle stages. The development of EEE regulations by the Chinese Government in response to EU legislation is an example.

According to statistical data, exports from the EEE sector earned China $227.46 billion in 2003, accounting for 51.9% of the country's total export value. Of these exports, approximately 25% went to the EU. Following the adoption of EU WEEE and RoHS, Chinese exporters subject to these requirements had to come into compliance with the standards or face the high likelihood that exports would be substantially reduced.

For example, 70% of the China Electronics Import and Export Corporation's exports to the EU fall under the WEEE and RoHS Directives, and unless full compliance with the new standards was achieved, there was a risk that these exports would be reduced by 30–50%. The economic imperative of complying with EU standards was therefore an encouraging factor in the development of domestic EEE regulations (Hicks et al., 2005, 461).

[41] For example, see http://www.samsung.com/us/aboutsamsung/sustainability/environment/chemicalmanagement/supplychainmanagement.html and http://www.samsung.com/us/aboutsamsung/sustainability/environment/chemicalmanagement/supplychainmanagement.html.

4.3.4 Data Gaps

141. Additional research on voluntary policy frameworks that impact material substitution would be helpful to complete this analysis. Also, additional information on the impacts of antimony and beryllium, their substitutes, and evidence of risk assessment studies on the substitution of antimony and beryllium in components used in mobile devices would be helpful to better understand the case study discussed throughout this section. Finally, further research into drivers, other than hazardous substance restrictions, of material substitution in mobile devices is necessary to better understand how to incorporate SMM policies into the decision process utilized by mobile device and component manufacturers.

4.4 Used and End-of-Life Mobile Device Management

142. This subsection will examine management practices for used end-of-life mobile devices, including collection of used devices, processes for diversion for reuse or recycling, and reuse and recycling economics for informal secondary markets. When relevant, or where information specific to mobile devices is unavailable, information applicable to UEEE and WEEE in general is provided, and noted.

143. This subsection seeks to develop a better understanding of where the current market fails to provide sufficient incentives to ensure mobile phones are recycled efficiently and safely. It investigates the theoretical ability of formal recycling systems to exploit the difference in material recovery rates to pay informal networks to collect and deliver mobile phones for recovery in higher-efficiency operations and reasons why this phenomenon does not occur in practice. To examine this issue, the section reviews available information on the economics behind informal recycling operations. Through interviews, this subsection examines policies that seek to address these issues and identify best practices and opportunities for overcoming these barriers. This subsection includes:

- An assessment of issues related to the current used mobile device and UEEE management situation;
- A description of the actors relevant to these life-cycle stages;
- A high-level overview of policies relevant to used mobile device and UEEE and recycling practices; an examination of the impacts used mobile device and UEEE management has on environmental effectiveness, economic efficiency, resource productivity, competitiveness, and social outcomes;
- The desired outcomes resulting from SMM policies to address these issues;
- An overview of steps currently being taken to address these issues by three issue areas to focus on more specific aspects of used mobile phone management practices; and
- A list of remaining data gaps.

4.4.1 Current situation

144. When mobile devices reach the end of their useful life, the greatest economic and environmental benefits can be realized through reuse or efficient recycling. However, as discussed in Section 4.1.1, there are several factors that drive informal collectors to circumvent the formal mobile phone system and sell mobile devices for triage and recycling or reuse in the informal sector: First, mobile devices have a high reuse and material content value; second, unregulated informal collection and recovery practices are typically lower-cost, and third, there is a strong demand for these devices in markets with large, dispersed

and unregulated EEE reuse and recycling sectors. Informal sector management practices are not regulated, material flows are not tracked, and their environmental, economic, and social benefits are not measured.

145. For example, when the owner of a functioning, used mobile device sells it for reuse, the phone is not considered waste and therefore EU's WEEE legislation is not applied (Kittila-Koeppen 2010, p. 27). This gives collectors the opportunities to export the devices for reuse or recycling abroad, where the vast majority of the used devices will never enter the formal sector (Espejo 2010). Similarly, in Canada, certain collection systems, such as charities, operate outside of existing provincial EPR regulations and thus do not have to track or document the fate of used devices they collect for reuse (Grant et al. 2012).

146. An informal market emerges when disincentives or inefficiencies exist in the formal market, or the formal market does not exist at all.[42] The emergence of an informal market for EEE recovery and reuse indicates that formal channels do not exist, are not operating effectively or that incentive structures are such that the informal market maintains profitability. Theoretically, without a level of profitability higher than formal markets or the presence of other market failures, informal markets will not emerge.

147. Non-functioning mobile devices enter the informal recycling sector in developing nations through domestic waste generation[43], imports of used devices that are used for only a short time before they reach end-of-life, and, possibly to a lesser extent, non-functioning devices imported as waste.[44] Although informal recycling operations encompass legal practices that apply ESM principles, informal recyclers in developing countries often employ low-wage labour and practices that release hazardous chemicals with significant health and environmental impacts in order to recover precious metal fractions from mobile devices and other WEEE (OECD 2011d).

148. Informal markets often have access to a steady supply of workers in rural or impoverished areas, which allows them to recycle a high volume of mobile devices despite detrimental working conditions. In Nigeria, for example, informal WEEE collection and recycling offers job opportunities and immediate cash payment for labour in the rural areas in the north of the country. At these recycling sites, workers are paid at the end of the day for that day's work after the extracted raw materials are sold to local middlemen. Informal workers are also more geographically flexible, having the ability to move to supply sites, collect door-to-door or interact with second-hand shops (Wang 2012). These types of recycling systems are attractive for collectors and recyclers as their workers do not need special training to begin extracting raw materials and the recyclers do not need make large investments in equipment or facilities (Manhart et al. 2011).

149. As discussed in Section 3.1.7, the method of recycling affects the material recovery rate. Informal recycling typically recovers a limited range of metals; in contrast, processes in the formal sector, such as metallurgical recovery, can achieve higher rates of recovery of a wider range of metals—including some

[42] There are also other socio-economic requirements, such as a lack of legislation or enforcement in regulating the sector. In section 4.4.3.3 we discuss the informal sector in China and relevant WEEE regulations that have been introduced in the last few years.

[43] Recent experience in Africa has shown that most mobile devices are imported legally as functioning devices and hence enter the re-use market. This means that most of mobile device waste in the informal recycling sector in African countries is domestic waste (Schluep 2012; Secretariat of the Basel Convention 2011).

[44] For example, field studies in Ghana estimated that imports from developed countries account for 15 percent of WEEE generation. Imports of "near-end-of-life" used EEE—which are repaired, but used for a shorter amount of time before reaching end-of-life—are another source of WEEE generation connected to imports. (Secretariat of the Basel Convention 2011, p. 24) Data is not available for mobile devices specifically, but they likely contribute to near-end-of-life EEE volumes given their high reuse value in developing countries.

critical metals, notably palladium (Manhart et al. 2011, pp. xv, 49). The levels of impurities present will influence the quality of, and ultimate end uses for, the recycled metals. Thus, there are clear economic, social, and environmental benefits to moving recycling from the informal sector to the formal sector. However, barriers to increased formal recycling include: low mobile device collection rates in developed nations, ineffective enforcement of waste export bans, high labour costs for formal recycling, and flexibility of workers involved in informal recycling (e.g., in accessing used mobile devices and selling to second-hand shops) (Wang 2012). This topic is explored in more detail in Section 4.4.3.3.

150. For several actors, including consumers, collectors, and policy makers, a lack of information or data is hindering more effective mobile phone collection and triage. This includes awareness of not only where and when consumers can bring their UEEE but of the environmental impacts of not disposing of mobile devices responsibly (Lindholm et al. 2008, p. 18). In France, mobile device collection by network service providers has been growing, but greater growth has been stifled, in part, by wireless sales associates' inability to answer questions about their collection schemes and customers' confusion about the interaction between the collection operations run by networks service provider, manufacturers, and compliance schemes (Kittila-Koeppen 2010, p. 55). A study of consumers bringing items to Household Waste Recycling Centres (municipal UEEE collection events) in the UK found that 82 percent of consumers at the events could not name other options for getting rid of UEEE without prompt (WRAP 2011, p. 9).

151. An important variable in the process of collecting used mobile devices for reuse or recycling is the period of time they are kept in storage unused by their owner, also known as hoarding. This period of storage is difficult to track, making it harder for policy makers to characterize the flows of mobile devices (Calliafas 2012). In addition, lengthy storage decreases the likelihood that a mobile device can be successfully reused. For example, the Recycle My Cell program in Canada found that the majority of recovered phones are older models that are not useful for reuse and must be sent for recycling, which leads to diminished economic and environmental benefits (Grant et al. 2012).

4.4.1.1 Relevant Actors

152. This subsection introduces and defines the key actors, networks, and markets in the used mobile device system, including upstream actors, collection and triage networks, formal recycling markets and informal recycling markets.

Upstream actors

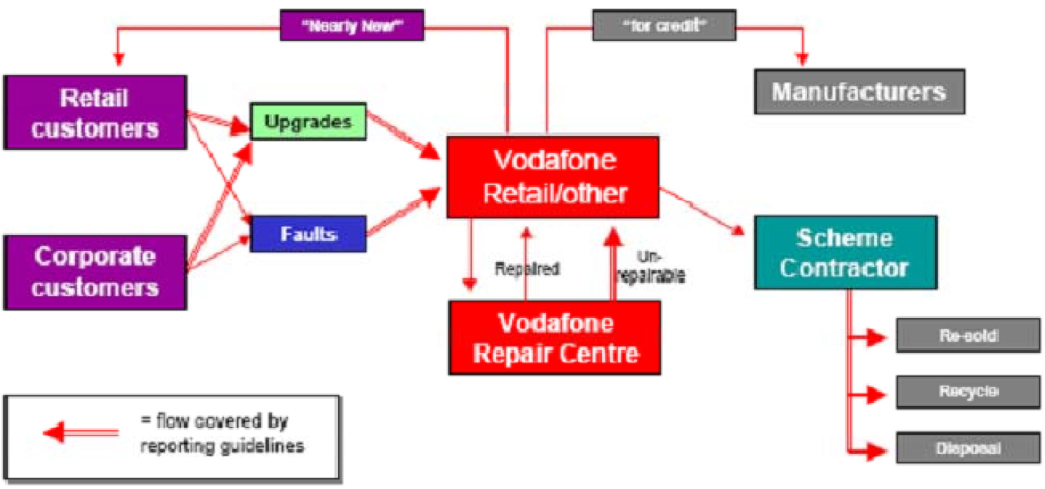
153. Several stakeholders or actors are relevant to issues surrounding used mobile devices before they enter into formal or informal collection and triage networks, or "upstream" from reuse and recycling networks. The report refers to these stakeholders and actors as upstream actors. For this analysis, the most important actors at this stage are used mobile device owners, but mobile device designers and manufacturers and network service providers also play important roles. Most owners realize that their mobile device has value even after it reaches the end of its useful life; however, many owners store their device after it is no longer used. Some of these actors hope to realize this value by passing it along to a family member, friend or using it in the event that their new phone is lost or damaged. In contrast to other EEE, the small size of mobile devices may contribute to the frequency of storage (Wang 2012). As mobile devices sit in storage, their opportunity for reuse and, therefore, environmental and economic benefits, diminish (Grant et al. 2012). This presents an opportunity for network service providers and mobile phone manufacturers to reach out to owners to collect used mobile phones as soon as they are no longer in use. Programs for eventually collecting and processing used mobile devices for reuse and recycling are further explored in the following two sections on formal and informal networks.

Collection and triage networks

154. As noted in section 4.4.1, used mobile device "hoarding" must be overcome before devices can be collected and sent for reuse or recycling. Mobile device collection and triage networks consist of parties that collect used mobile devices and determine whether to direct them towards reuse or recycling. The parties involved in these networks are quite diverse, ranging from collection schemes organized as part of a regulatory framework (e.g., EPR collection systems) to collectors who gather used mobile devices for reuse and recycling in informal networks in other countries.

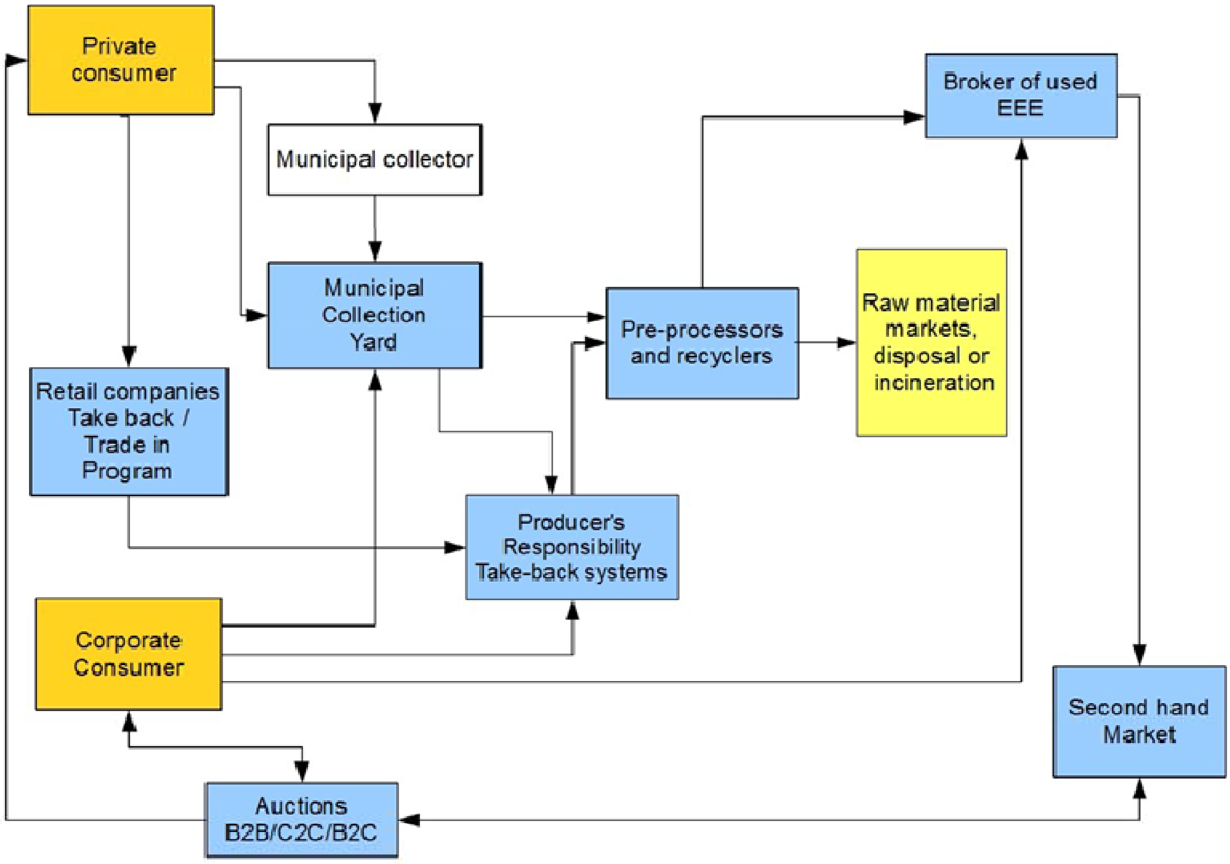
155. Mobile devices are often collected through various networks. These include those set up as part of a governmental regulatory framework, charity or thrift groups, mobile phone manufacturers, network service providers, and private collection companies or individuals. In order to comply with national and international WEEE regulations and/or extended producer responsibility requirements, countries in the EU and other areas require that the manufacturers and network service providers operating in those countries create mobile device collection networks for recycling. These often come in the form of partnerships between government, network service providers, non-governmental organizations, manufacturers, and private collection and recycling companies (Kittila-Koeppen 2010; Calliafas 2011; Grant et al. 2010). In France, for example, used mobile devices are collected directly by network service providers or through collection channels organized by the official Eco-systems compliance scheme (Kittila-Koeppen 2010). Other examples of these types of collection and triage schemes are shown in Figure 9, which provides an example structure for a typical collection and triage scheme run by Vodafone, a network service provider, and in Figure 10, which shows an overview of the flows and actors involved in official collection and triage networks in Germany.

Figure 9. Vodafone collection and triage network



Source: Lindholm et al. 2008.

Figure 10. Diagram of the official flows of used and waste EEE in Germany



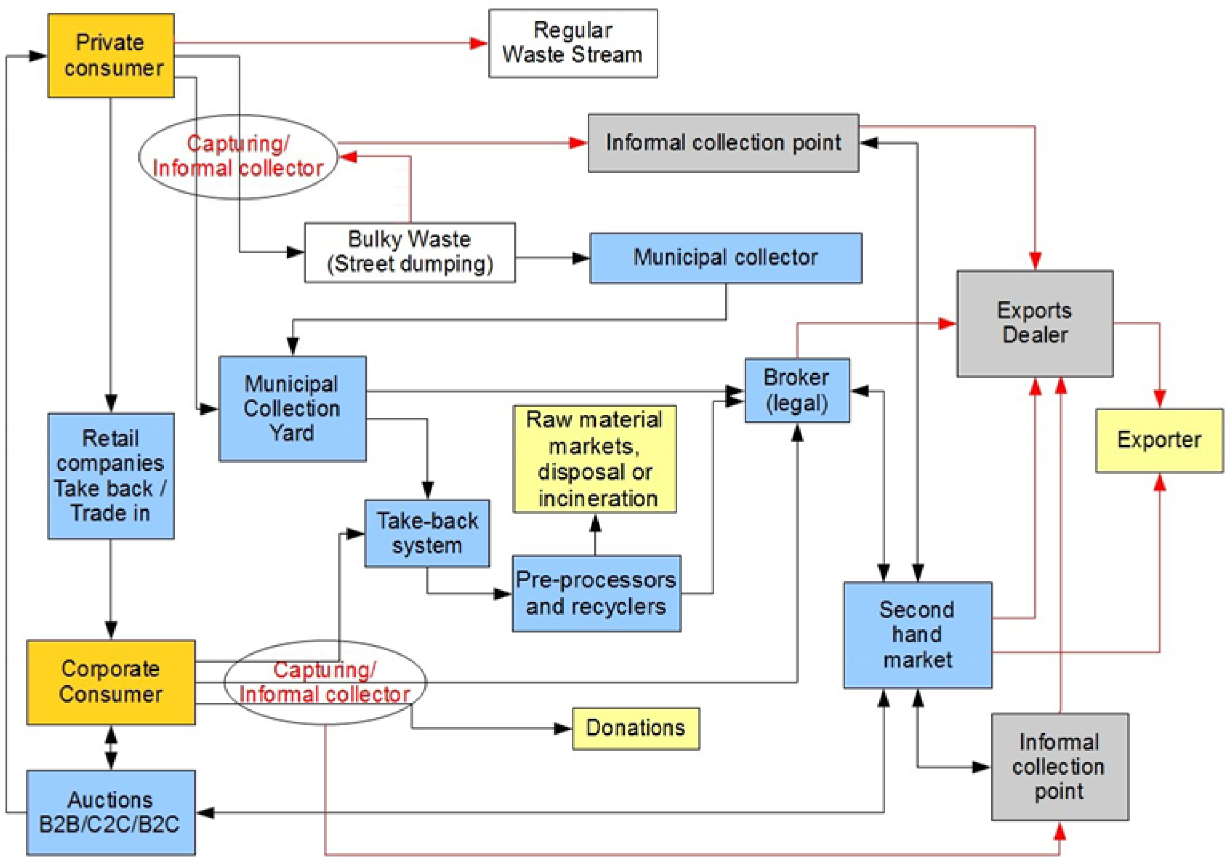
Source: Espejo 2010.

156. Increasingly, used mobile device owners can visit websites that allow them to determine the monetary value of their used phone, mail it to a private collector or drop it off in a designated location, and receive compensation in the form of cash payments, coupons, or gift cards (Calliafas 2012; Kittila-Koeppen 2010; Grant et al. 2012; Let's Recycle 2011; McCaskill 2012). As reusable phones have a higher value for second-hand dealers, owners often receive higher compensation for phones in better condition (Let's Recycle 2011; Kittila-Koeppen 2010).

157. Official collection and triage schemes fail to capture all used mobile devices, however—a lack of compensation to most mobile device owners and regulatory gaps contribute to this failure (Lindholm et al. 2008). For example, official EEE collection schemes in Europe are not required to track the number of used mobile phones designated for reuse, as they are not considered waste. This leaves these reused mobile devices frequently untracked by official schemes and directs their flow to networks of used mobile device collectors operating outside of the formal compliance schemes. These unofficial channels can include sending the device to privately-run, Internet-based, or mail-back schemes; giving the used phone to a friend; or donating to a charity or thrift organization that does not participate in the official EEE collection scheme (Kittila-Koeppen 2010). One important exception, however, is Canada's Recycle My Cell program, which is required to track the number of devices meant for reuse and for recycling. These data are documented via annual reports developed by Recycle My Cell (Grant et al. 2012).

158. In addition, while incentive schemes sometimes direct waste mobile phones towards formal recycling networks, others export mobile devices that cannot be reused to informal recycling networks (Let's Recycle 2011; Espejo 2010). As an example of how this system interacts with official collection and triage networks, a model of the flow of EEE through official and unofficial (indicated by white and grey boxes and red arrows) German collection and triage networks is provided in Figure 11.

Figure 11. Model of official and unofficial UEEE flows in Germany



Source: Espejo 2010.

Formal recycling networks

159. Formal recycling networks involve recycling of WEEE using mechanical pre-treatment and techniques such as metallurgical refining or hydrometallurgical processing to recover ferrous metals, aluminium, copper, and precious metals and other fractions, including antimony, at high recovery rates of a wide range of precious and other metals while minimizing impacts to human health and the environment (Manhart 2010; Hageluken 2008). The mobile devices recycled in the formal sector are usually directed there by official collection and triage schemes. The cost structure of integrated smelting operations favours contracts that can guarantee a large, steady stream of WEEE (Kopacek 2011). Following recycling in the formal sector, reusable components or reclaimed raw materials are redirected towards manufacturers for inclusion in new or refurbished EEE.

Informal recycling networks

160. Small to medium-sized firms, including individual endeavours, dominate the informal markets, and account for upwards of 90 percent of all enterprises (Herat 2010, p. 3). These firms do not have the knowledge, systems, or the budget to guarantee safe handling of WEEE and are characterized by ad hoc or chaotic behaviour leading to poor environmental management (Herat 2010, p. 3). These firms face obstacles gaining legal permits, which force their operations into unregulated, informal sectors (Wang 2012). Regulation of formal markets tends to focus on industrial zones whereas these small to medium-sized firms locate in light industrial sectors in residential zones (Herat 2010, p. 3).

161. Many of these small to medium-sized firms also lack capital and resources and thus rely on outdated technology and labour intensive operations. They typically employ poor people unaware of the dangers of processing of e-waste (Herat 2010, p. 3). Employees in informal recycling networks typically work at a disadvantage compared to their counterparts in developed countries, usually earning lower rates and no benefits. These small enterprises also typically do not feature labour rights in the form of de facto unionization or collective bargaining arrangements (Tong & Wang 2004; Xianbing & Masaru 2006; Jinhui et al 2006; Widmer et al 2007; Manhart 2007).

4.4.1.2 Relevant Policy Framework

162. The EU's Directive 2002/96/EC forms the framework for relevant EEE waste management and take-back policy throughout the EU. This directive, now replaced by the EC recast WEEE Directive, mandates the creation of EEE collection schemes where consumers can return UEEE at no cost (EC 2012a). To comply with this mandate, each country in the EU has its own national regulations that conform to the Directive and that govern the creation and enforcement of WEEE collection schemes. For example, under Germany's ElektroG policy, WEEE owners are required to place their items in collection systems separate from municipal solid waste and municipalities are responsible for creating points of collection for UEEE and WEEE (Espejo 2010). Under ElektroG, EEE importers and producers must register how much EEE, by weight, they bring into the German market and must contract with UEEE and WEEE service providers to collect and process UEEE for recycling or reuse in proportion to their share of EEE brought into the German market (Espejo 2010). Similar policies exist in other countries, including the UK WEEE Directive and the French WEEE Decree.

163. The EU WEEE Directive and its analogous national laws use the concept of extended producer responsibility (EPR) or take-back. EPR policies seek to reduce the environmental impacts of products by placing the burden of managing products at the end of their life on their producers, which internalizes this cost in the price paid by customers (Toffel 2008). By placing the burden of product recovery and recycling on manufacturers, they have an incentive to design products for easier and safer recycling (Toffel 2008)[45]. In addition to the aforementioned EU WEEE policies, EPR policies also exist in other countries at the national and state/provincial level. For example, many Canadian provinces have EPR policies that require mobile device manufacturers or first importers (usually network service providers) to develop collection schemes (Grant et al. 2012). Canadian manufacturers and network service providers have partnered to collect mobile phones through the Recycle My Cell program, which is explored in greater detail in section 4.4.3.2.

164. Policy frameworks—including the Basel Convention, an international agreement that was created to reduce the flow of hazardous waste, including WEEE, from developed to developing countries (see

[45] In practice, this has not yet occurred for mobile devices for two reasons: (i) the guaranteed flow of waste devices for recycling is not large enough to make it economically feasible to further incorporate design for recyclability and (ii) product life spans and design cycles are not synchronized (Ahonen 2012).

section 4.2)—rely on a "command and control" approach rather than using economic incentives to mitigate WEEE. Many critiques of the Basel Convention point to the lack of enforcement as a main obstacle (Herat 2010; Manhart 2010; Robinson 2009).

165. Other policies focus on the end-of-life and end-of-use aspects of the life cycle of EEE. These policies include China's efforts to mitigate WEEE through collection and/or a tax on the sale of products designed to fund disposal practices. These two examples are discussed further in the case study of China WEEE programs in section 4.4.3.3.

166. Finally, policies such as the European Unions' RoHS Directive, limit concentrations of hazardous materials in mobile devices themselves (Hicks 2005; Robinson 2009). These policies limit the hazardous materials that are emitted through poor disposal practices. Design for recyclability or environment programs, such as the U.S. Environmental Protection Agency's (EPA) DfE Program, and efforts by manufacturers to incorporate recyclability and end-of-life considerations into design also contribute to these outcomes.

4.4.1.3 Impacts on environmental effectiveness, economic efficiency, resource productivity, competitiveness, and social outcomes

167. The dichotomy between formal and informal recycling markets at different stages in the recycling process highlights the strengths and weakness of formal markets for EEE end of use and end-of-life processing. These differences can inform how SMM could align with economic incentives to produce more efficient and effective policy.

168. First, at the collection and triage stage, collectors in the informal sector are motivated by income and employment opportunities to achieve very high collection rates of mobile devices and other EEE (UNEP 2009a, p. 57; Wang 2012; Herat 2010, p. 10). By collecting and triaging mobile devices, informal markets drive higher reuse rates, contributing to environmental benefits in the form of extended product life, less raw material extraction, and less waste generation (Kittila-Koeppen 2010). The informal markets tend to be integrated into local communities, maintaining low overhead through labour intensive process, both in terms of collections and extraction (Wang 2012). In Asia, informal markets function synergistically with the growing high-tech manufacturing sectors in the region fuelling local economies demand for raw materials (Tong & Wang, 2004; Jinhui et al 2006, Manhart 2007).

169. Once mobile devices have been collected and triaged, the non-functioning devices are dismantled and sorted into component parts. In informal recycling practices, this is done by hand dismantling the devices and separating out components such as metal fractions, PWBs, and plastic casings. Hand dismantling may also occur in formal systems, but has higher cost than mechanical methods and there is a trade-off between the extent of hand dismantling possible relative to the cost of labour (Meskers et al, 2009). Manual dismantling achieves a high level of material separation. In contrast, mechanical dismantling through smashing, crushing, and shredding WEEE can prevent recovery of a large fraction of precious metals in final, end-processing steps (Chancerel and Rotter et al. 2009; Meskers and Hagelüken, 2009).[46]

170. Final processing of WEEE involves recovery of precious metals and other metal fractions. Formal processes involve high-technology facilities, such as integrated smelters and some hydrometallurgical processes that achieve the highest yield from WEEE with the least amount of pollution. In contrast, final metal recovery in the informal sector focuses on gold and copper fractions predominantly,

[46] Note that Meskers and Hagelüken (2009) and Chantrell et al. (2009) focused on precious metal recovery in personal computers.

and discards the remaining fraction once these metals have been recovered. Labour-intensive processes, most common to informal markets, extract only 6 to 30 percent of potential yields at this stage while recovery rates for mechanical pre-treatment and metallurgic refining can achieve 76 to 96 percent yield for precious metals (Manhart 2010, p. 19-20). Informal markets do not adhere to environmental or workplace standards and regulations, which results in pollution and human health impacts during material extraction at this stage. See section 4.1 above for a further discussion on these environmental and human health externalities.

171. Chi (2010) observes that formal markets are "priced out" by informal markets. Government attempts at take back programs for UEEE and WEEE have not been successful in collecting sufficient amounts of electronics. For example, Hangzhou Dadi, an engineering plant in China, received 133 metric tons of WEEE and 1,325 units of discarded appliances in one year. It was able to dismantle 92 tonnes and recover 59 tonnes of steel, copper and plastics. However, the plant was vastly underutilized with its 36 collection points and a treatment plant of 7,000 tonnes annual capacity (Chi 2010). Informal markets are so effective at collection that their existence prevents the formal processing plants from obtaining enough supply to be profitable. Incidentally, the cost to formal sectors to perform collection might be too high to sustain profitability (Chi 2010).

172. An economic solution to this problem could involve the formal sector paying informal WEEE collection networks to provide WEEE. This, however, only occurs in rare instances, illustrating that the issues may be more complex than just a simple transfer of payment to the informal sector. One obstacle preventing this type of transaction could be that the value of additional precious metals recovered from WEEE in formal recycling is not high enough to compensate the informal sector for delivering WEEE to formal operations. Compared to WEEE in general, however, mobile devices have a greater concentration of high-value metals that can be economically recovered in formal recycling processes. This should enable the formal sector to pay the informal sector more for collecting these devices than informal actors would make recycling devices themselves (OECD 2011d, p. 59; Manhart 2010). Consequently, the economic incentives for informal collectors to provide waste mobile devices to formal recycling operations may be higher than for other types of WEEE. A second possible obstacle is the dispersed and ad-hoc nature of informal collection systems, which make it difficult for formal systems to exchange collected and triaged materials in steady, sufficient quantities—especially since these plants prefer few large contracts over many small contracts (Wang 2012; Chi 2010). Finally, another possible explanation for this market failure is asymmetric information; if actors in the informal markets do not have access or information to complete the transaction, the market becomes distorted. No specific evidence on the extent to which asymmetric information plays a role in this market failure was located.

4.4.2 Desired outcome

173. Ideally, effective policies could encourage SMM practices for UEEE and promote increased and timelier collection of mobile phones for reuse or recycling. This would require increased consumer awareness, more robust collection schemes, and decreased used phone storage. Numerous resources have cited mobile device storage as a major impediment to effective collection and suggested it as a target for policy actions (Lindholm et al. 2008; Grant et al. 2012; Calliafas 2012). Consumers typically hold onto their used mobile devices because it may be of value in the future. Increased awareness of collection options and the benefits of turning in used mobile devices as soon as possible would likely reduce hoarding. Theoretically, monetary or other incentives that exceed the residual value consumers attach to used devices may also be effective at convincing consumers to turn them in (Grant et al. 2012). These issues are addressed further in section 4.4.3.2.

174. Development and implementation of reuse and recycling standards and specifications would also help achieve SMM goals. When used individually or collectively by governmental bodies, companies, or

organizations, reuse and recycling standards address consumer concerns that UEEE and WEEE will be handled efficiently, safely, and in a system that minimizes environmental impacts. Certification systems can also overcome regulatory gaps that lead to the illegal export of WEEE disguised as UEEE. Reuse standards are explored in greater detail in section 4.4.3.1.

175. For UEEE and WEEE that flow through informal channels, the formal sector would ideally establish mechanisms such that the informal sector collects and pre-processes UEEE and WEE and the formal sector extracts the metallic elements. For example, leveraging the high collection and pre-treatment rates in the informal sector alongside final metal recovery in formal recovery operations could increase the overall recovery rate by as much as 170 percent compared to a highly efficient formal-sector recycling system.[47]

176. One attempt to demonstrate this concept is the “Best-of-Two-Worlds” approach (Manhart 2010). The formal sector is generally less successful at collection than the informal sector,[48] but can gain a significantly higher yield in the extraction process (Manhart 2010, OECD 2011d, p. 59). An optimal solution would occur if the formal sector pays the informal sector the same amount the informal sector could yield from labour intensive extraction. This is particularly relevant to mobile devices, which contain a relatively high concentration of economically-recoverable materials compared to other types of WEEE.

177. To address the lack of coordination between formal and informal sectors, Chi (2011) recommends developing capacity and structures within the informal sector through: (i) incentives—both financial and non-financial—to change current economic structures that cause health and environmental impacts; (ii) implementing appropriate recycling techniques and designs to optimally separate and recover materials, and (iii) building capacity for recycling infrastructure and training programs to increase job security and the skill of recyclers.

178. One approach to achieving these outcomes is through national and regional capacity building: for example, institutions such as Solving the E-waste Problem (StEP), UNEP, and the Basel Convention—as well as national governments in OECD countries—have implemented e-waste stakeholder forums in African countries (UNEP 2012; StEP 2011). Projects to demonstrate the “Best of Two Worlds” approach have also been undertaken in China, India, West Africa, and elsewhere to investigate this concept (Schluep 2012).

179. The optimal metal material extraction method is through high technology processing plants. These plants require a large initial investment and may struggle to obtain a sufficient supply of WEEE. Policies structured to: (i) generate investment into these technologies and (ii) utilize the informal sectors ability to successfully collect EEE could facilitate the desired outcome. In addition, activities such as the

[47] This assumes the following recovery efficiencies at collection, pre-processing, and metal recovery stages: (i) for the formal sector, 60, 25, and 95 percent respectively (UNU 2007, Chancerel et al. 2009); (ii) for the informal sector, 80, 50 , and 50 percent respectively (Keller 2006). The overall rate of recovery for formal and informal processes is therefore 14 and 20 percent, respectively. Combining informal collection, pre-treatment, and formal metal recovery increases the overall recovery rate to 38 percent—a 170 percent increase in the rate of recovery compared to formal recycling.

[48] For example, collection rates in the best-performing European countries with strong EPR systems (e.g., Sweden) are around 80 percent (Huisman 2008); in comparison, collection rates in Ghana are as high as 95 percent, with almost all of this occurring within the informal sector (Secretariat of the Basel Convention 2011, p. 24).

HydroWEEE project[49] could lower the capital cost of safe, efficient metals recovery from WEEE (see section 4.1.3).

4.4.3 Steps being taken to address these issues

180. This section presents three examples of steps being taken globally to address market failures, policy incoherence, regulatory gaps, and other issues identified in section 4.4. Each example includes a discussion of the policy or scheme, the effect it has had on the issues discussed above, and the remaining issues not yet addressed.

4.4.3.1 More effective triage through the UK PAS 141:2011 standard

181. Mobile device reuse postpones raw material extraction, leads to lower waste generation, and increases economic benefits as compared to recycling by expanding the product life cycle and is usage across more than one consumer. However, ineffective triage can divert used mobile devices and other UEEE that could otherwise be refurbished and reused (REEE) towards recycling instead. On the other hand, non-functioning EEE that cannot be reused is often improperly labelled as "fit for reuse", allowing it to be exported for recycling in the informal sector (see section 4.2.1.2; Calliafas 2012). The WEEE Directive, for example, permits the exports of items for reuse but, due to a lack of clarity on his aspect in the present Directive, this leads to the illegal exports of WEEE under the guise of reuse. The WEEE Directive does not specify what process steps are necessary to determine when an item is fit for reuse and when it is not (Calliafas 2012).

182. To address this regulatory gap, the British Standards Institution (BSI) (under contract to the Department of Business, Innovation and Skills (BIS) and under guidance from the former WEEE Advisory Body) developed the "Reuse of used and waste electrical and electronic equipment (UEEE and WEEE) – Process management – Specification," also known as the PAS 141:2011 specification. PAS 141:2011 was originated by the Reuse Task Group of the UK WEEE Advisory Body (WAB), an independent body that provided impartial advice to the UK Government on issues related to the EU WEEE Directive and the UK's WEEE Regulations (Calliafas 2011). PAS 141:2011 is intended to be a voluntary standard that any organization can use to help ensure that items of UEEE and WEEE are properly assessed and determined as being fit for reuse (Calliafas 2012). The stated goals of PAS 141:2011 are to:

(a) encourage reuse as promoted by the WEEE Directive (2002/96/EC), Article 1;

(b) provide a framework for assuring consumers of the quality and safety of REEE;

(c) provide a framework for assuring manufacturers that the placing of REEE on the market for will not adversely affect their brands or the placing of their EEE on the market; and

(d) discourage the illegal export of WEEE under the guise of reuse by providing a tool to the Environmental Agencies for differentiating between REEE and WEEE (BSI 2011).

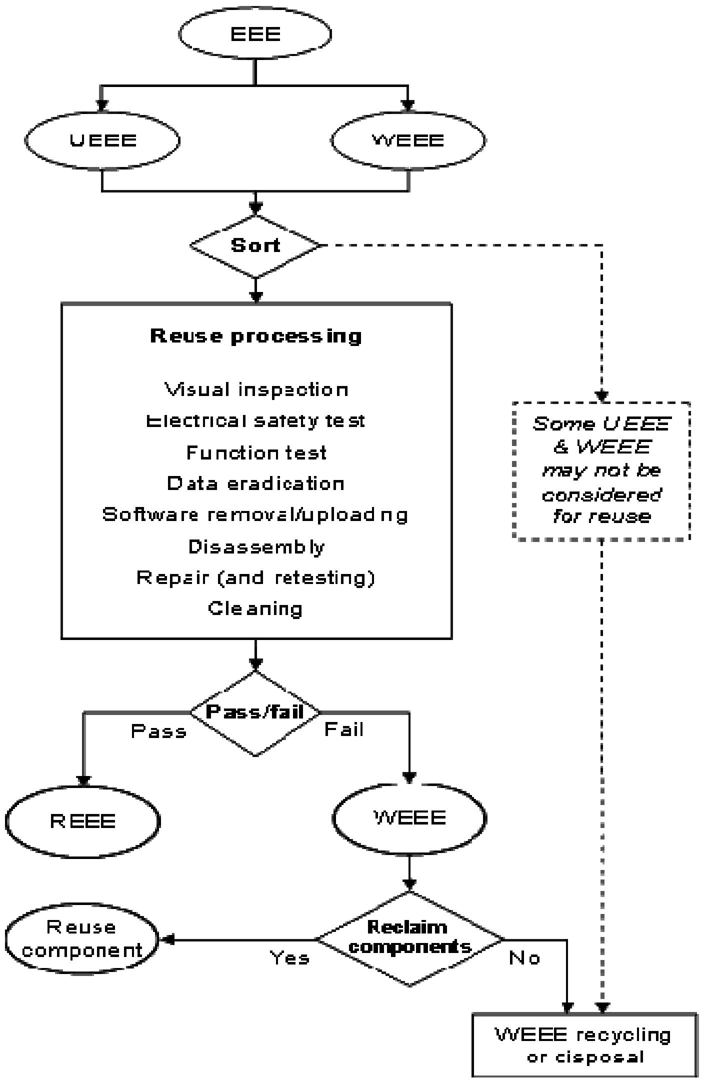
183. While it is possible for organisations to self-certify against PAS 141:2011, it is envisaged that the market will insist upon independent verification for the reasons and goals outlined above. In parallel to PAS 141:2011, scheme guidelines are currently being finalized to enable certification bodies to assess and

[49] The HydroWEEE project seeks to develop a mobile hydrometallurgical plant that will recover certain critical metals such as yttrium and indium at high purities (above 95 percent) from cathode-ray tubes, lamps, liquid-crystal displays, lithium-ion batteries, and PWBs (Kopacek 2011).

independently certify organizations involved in reuse against PAS 141:2011, providing additional safeguards (Calliafas 2012).

184. Figure 12 provides an overview of the process PAS 141:2011 process to evaluate whether UEEE and WEEE derived from EEE is suitable for reuse. The standard sets out and details the process steps by which an item of equipment can be determined as being fit for reuse (Calliafas 2012).

Figure 12. Overview of PAS 141:2011 process



Source: Calliafas 2011. Note: REEE = "Reuse EEE", or refurbishable or reusable EEE

185. Although it is a relatively new, voluntary standard still in draft form, the interest in the use and application of PAS 141:2011 is growing in the UK and in other countries. A number of government departments and businesses have expressed interest in developing contracts with specific reference to PAS 141:2011as a potential requirement. Businesses are recognizing the economic benefits offered by the secondary mobile device market. For example, manufacturers and network service providers can maximize additional profits from the same product item by recovering their devices, refurbishing them, and reselling them, especially into new and developing markets where the latest models are unaffordable. Large

technology firms have also expressed interest in protecting their reputation by ensuring their products are not illegally sent for recycling in developing nations. For both of these instances, PAS 141:2011 is an option for providing clarity and reliability to the mobile device triage process. However, as it currently stands as a voluntary standard that is not mandated by government regulation, the impact of PAS 141:2011 is limited to those organizations that choose to use it and is predicated on the number of mobile devices that are collected by those organizations (Calliafas 2012).

186. Federal standards for the management of electronic waste—including mobile devices—may be one such mechanism for uptake. Recently, the U.S. General Services Administration (GSA) announced guidelines that ban federal agencies from landfilling electronic waste[50] and require reuse, or recycling in facilities certified to e-Stewards or Responsible Recycling (R2) standards[51] (GSA 2012). By incorporating e-Stewards and R2 into federal guidance, the GSA policy will increase market demand for certification under these systems. Additionally, relying on existing voluntary standards reduces the complexity of different management systems and can promote consistency across various systems. For example, the U.S. Office of Management and Budget (OMB) Circular A-119 requires federal agencies to use voluntary consensus standards in place of government-unique standards expressly for the purpose of eliminating the cost of developing government-specific standards and "promoting efficiency and economic competition through harmonization of standards" (OMB 1998).

4.4.3.2 Increasing collection through Canadian network service providers

187. Mobile devices differ from many other types of EEE in that the need for continual access to wireless service necessitates an ongoing relationship between the customer and the network service provider (Grant et al. 2012; Paltridge and van der Berg 2012). The nature of these relationships can vary significantly by country and technology. In some countries—especially those where pre-paid subscriptions are common—mobile device users often carry multiple subscriber identity module (SIM) cards, allowing them to switch between network service providers while using the same mobile device (Paltridge and van der Berg 2012).[52] In other countries, particularly the United States and Canada, wireless network service providers discount the upfront cost a customer must pay for a new mobile device (sometimes known as a handset subsidy) as an incentive for customers to agree to a one to three year service contract. This practice, known as handset bundling, is explored in detail in the text box below.

188. The on-going relationship between mobile device users and network service providers, however, also enables network service providers to serve as a point of collection for used but functioning mobile devices at the time of contract renewal through "phone refresh" incentives. These used devices are likely prime candidates for refurbishment and reuse. For example, network service providers in the U.S. and Canada provide "return to retail" collection points at stores for customers to drop off their used devices, although they do not require consumers to trade-in devices for new ones, nor offer monetary incentives for phones upon contract renewal (Lawford 2012; Grant et al. 2012). Network providers in France, in contrast, have been buying back devices from consumers at the point of contract renewal since 2010 (Kittilla-Koeppen 2010, p. 26). Data on the collection rates of these systems does not appear to be readily available,

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[50] Electronic waste is defined in the guidance as "Federal Electornic Assets", which include telecommunications equipment.

[51] e-Stewards and R2 are voluntary standards that establish guidelines for environmentally sound refurbishment and recycling of electronic waste. For more information, see http://e-stewards.org/, and http://www.r2solutions.org/.

[52] Similarly, the integration of mobile communications into other devices, such as automobiles, has further complicated and expanded the types and number of relationships mobile device owners have with network service providers (Paltridge and van der Berg 2012).

but there is evidence that buy-back incentives may be an effective way to encourage timely mobile device collection: for example, a survey of mobile device ownership among UK university students found that monetary incentives had the greatest impact on students' willingness to give their used mobile devices to takeback services (Ongondo and Williams 2011). The opportunities to encourage mobile device takeback through monetary incentives should be further investigated in future studies.

189. In Canada, three wireless network service providers (Rogers, Bell, and TELUS) represent the majority of the mobile phone market in Canada; all Canadian network service providers and manufacturers are represented by the Canadian Wireless Telecommunications Association (CWTA) (OECD 2011d). Extended producer responsibility (EPR) regulations exist in most Canadian provinces and, where mobile devices are deemed an obligated material (i.e., a material to which EPR regulations apply), require mobile device manufacturers and first importers (typically network service providers) to offer mobile device collection schemes. To address this requirement, mobile device manufacturers and network service providers in Canada, under the organization of CWTA, have developed the Recycle My Cell (RMC) program. RMC was launched by CWTA in January 2009 to facilitate sustainable management of used mobile devices and to provide data reporting to provincial governments on behalf of members as part of the EPR approach. The program currently operates in all provinces. Since Canadian EEE regulations are province-specific, RMC has received regulatory approval in two provinces and formal recognition in all others except Quebec and Ontario. RMC uses a "return-to-retail" collection model, offering approximately 3,500 collection locations throughout Canada. Used mobile device owners can find their closest RMC drop-off location through RMC's customer-facing website, recyclemycell.ca. After collecting mobile devices, RMC sends them to processors located in Canada for triage, who then test each device and direct them towards recycling or reuse. Some provinces, such as Ontario specify which processors RMC can use; other provinces are less prescriptive, but still require RMC to use processors with proper and valid certificates. RMC only sends their mobile devices to processors that are ISO certified and meet identified provincial EPR requirements (Grant et al. 2012).

190. The RMC program is free to consumers and fully funded by RMC members. Current RMC members include: Bell, Dell Canada, GEEP, GREENTEC, LG, Lynx Mobility, Mobilicity, Motorola Mobility, MTS, Nokia, Research In Motion, Rogers Communications, Samsung, SaskTel, Sims Recycling Solutions, Sony Ericsson, TBayTel, TELUS, Videotron, Virgin Mobile Canada, and WIND Mobile. A donation to participating charities is made for each device returned through the various recycling programs. While some carriers have begun offering incentives for customers to turn over used mobile devices, most do not. Similarly, RMC does not offer any financial incentives or direct compensation to the customer for mobile phone collection, but instead focuses on keeping the program free to customers and as accessible as possible (Grant et al. 2012).

191. Used mobile phone owners typically keep their old phones even after upgrading to a new one and are often reticent to turn in their old phone right away, believing that it will be of value in the future. RMC views this as a difficult but important barrier to overcome; most mobile devices they receive are four to six years old and are unlikely to be candidates for refurbishment and reuse. CWTA and its members would like to encourage timelier mobile device collection to take advantage of the higher value reusable phones bring; some carriers are exploring trade-in programs for mobile devices, but these efforts have only recently started and are not presently widespread (Grant et al. 2012).

Box 3. Increasing competition in the mobile device market: a win-win scenario for SMM?

Under handset bundling, mobile network service providers sell a mobile device at discounted rates in order to attract subscribers to their network. In return, consumers must accept a minimum subscription period, during which the consumer is required to buy services (Okholm, et al. 2008). Consumers eventually pay for the full cost of the device as part of their monthly service payments throughout their contract (Okholm, et al. 2008; Paltridge and van der Berg 2012). At the end of the contract, customers typically enter a new contract and receive a new mobile device, discounted up-front.

Since the cost of the mobile device is included in the monthly service payments paid by customers throughout their contract, customers have an incentive to renew their contract and purchase a new, discounted mobile device as soon as their contract expires. Otherwise, they continue to pay the same monthly service charges—which include payments towards the cost of the mobile device—for a device they have already purchased across the life of the contract (Paltridge and van der Berg 2012). The prevalence of handset bundling in some OECD nations limits the ability for consumers to purchase an unbundled mobile device without a service contract and to move between service providers more frequently than the terms of their contract allows.

As it becomes easier for consumers to move between service providers, customers may seek to retain their mobile devices for longer, delaying the turnover of phones (Lawford 2012). This assumes a willingness from carriers to allow customers to “unlock” their phones (i.e., bring their phone to another carrier). Theoretically, such a scenario would achieve a win-win result when viewing this issue from an SMM perspective; increased competition between service providers for customers alongside increased material efficiency from longer device lifetimes.

Data was not available to validate this theoretical “win-win” result, and demand for new mobile devices with improved features and performance is likely the main force driving customers to use mobile devices for relatively short periods of time (Paltridge and van der Berg 2012). Further investigation is necessary in order to assess whether increasing competition in mobile device markets where handset bundling is prevalent could decrease the rate of mobile device turnover.

One possible area of investigation is Iliad Free, a new network service provider in France, which requires that customers bring their own mobile devices and does not require contracts while offering significantly lower prices than established network service providers (Paltridge and van der Berg 2012). It could be helpful to note the rate of mobile device turnover among Iliad Free’s customers.

4.4.3.3 Economic incentives through China’s WEEE policies

192. China is a producer and a consumer of EEE, and generates UEEE and WEEE domestically while also receiving imports of UEEE and WEEE from other countries (Yang et al. 2008). Imports consist of legal imports (which include electric motors, electrical scraps, waste wires and cables) and illegal imports. Domestic generation of WEEE originates mainly from the consumption of EEE, however the industrial sector contributes small amounts as well (Yang et al., 2008).

193. The Chinese government has taken the initiative to develop policy measures to mitigate the potential damages that originate from improper disposal habits, particularly in the informal reuse and recycling sectors in the country. To participate in the formal sector in China, a firm needs to be registered at the Ministry of Environment. Currently, around 100 companies are registered (Wang 2012). These companies represent large scale plants that can process large amounts of WEEE. In addition to these companies, several unlicensed medium-sized firms also participate in environmentally sound recycling and disposal practices (Wang 2012).

194. Although the number of permitted firms has grown significantly, informal recyclers still handle the majority of WEEE in China (Yang et al. 2008). In the Guiyu regions alone, around 30,000 to 40,000 people are engaged in treating WEEE in the informal market (Robinson 2009; Yang et al. 2008). Several mechanisms, discussed in section 4.1.1.1, currently exist in China to support these informal markets. For

example: the high material value in certain WEEE products—particularly mobile devices, and less-stringent labour and operating regulations and enforcement. Finally, in developing countries and less mature markets, the informal sector provides a livelihood to segments of the population who are unemployed or uneducated (Wang 2012).

195. As discussed in section 4.4.1.3, several challenges prevent formal recycling facilities from contracting with informal collectors: first, in order to get informal collectors to supply WEEE to formal recycling facilities, the value of additional metals recovered in formal facilities must be greater than what informal collectors would earn by directly recovering metals from WEEE; second, large scale plants need large, steady supplies of WEEE to maintain profitability, but the ad-hoc, small-scale, and dispersed nature of collection in informal markets does not typically sync with formal recycling systems (Wang 2012; Chi 2010); finally, it is likely that there are information-sharing imbalances or barriers between the formal and informal sector, although no specific evidence of this was found.

196. The emergence of informal markets may be closely tied to current policy incoherence, both domestically and globally. Domestically, a policy that works in some regions of China may not generate the same outcomes in other regions, especially in less developed areas compared to developed areas (Wang 2012). On a global scale, inconsistent policies in other countries challenge China's ability to successfully ban the import of WEEE and UEEE. For instance, it is still legal to ship UEEE and WEEE out of the United States while in Europe only shipments of electronics for the purposes of reuse are allowed. Both policies create channels for UEEE and WEEE ending up illegally at Chinese ports (Wang 2012). Finally, though Hong Kong is part of China, the port operates independently and as such funnels large amounts of UEEE and WEEE to the mainland (Wang 2012).

197. China in recent years has trialled a few programs to help mitigate WEEE ending up in informal sectors. Specifically, China has adopted the "Regulations for the Administration of the Recovery and Disposal of Waste Electric and Electronic Products" (No. 511 2009). From 2009 to 2011, China enacted the Home Appliance Rebate Program, which offers consumers a 10 percent rebate on new televisions, refrigerators, washing machines, and computers if they bring in their old product (Yang et al. 2008). This program generated nearly $334 million in subsidies and contributed to both higher collection rates and stimulated demand in a tough economy (China.org.cn, 2012). In addition to the Home Appliance Rebate Program, the Chinese government now opts to charge a tax on the suppliers of these four types of electronics (Wang 2012). The tax will be placed on the sales price of the good and revenue will be directed to a WEEE recycling fund. This tax aligns with the governments' directive of a "producer pays" mechanism.

198. Since the first policy just ended and the second has just begun, findings and estimates are still fairly preliminary. These back-to-back policies create an interesting comparison in terms of economic incentives. The first policy offers an economic incentive to consumers to recycle used EEE while the latter policy charges the producer a fee to cover some of the cost to recycle their product. One policy attempts to address collection and triage while the second policy addresses the lack of investment to support formal markets. These different policy approaches—although not specific to mobile devices—could provide useful frameworks for the development of other approaches using economic incentives to increase the flow of WEEE to formal markets. Attention to the unique characteristics of mobile devices (e.g., their small size) is needed. For example, because consumers can easily store mobile devices, the effectiveness of a take-back policy (such as the Rebate Program focused on large appliances) will depend on consumer willingness to participate (Wang 2012).

4.4.4 Data gaps

199. Policy recommendations to encourage higher mobile device drop-off and more effective triage are difficult to make without greater knowledge of the size and success of unofficial collection schemes (i.e., those outside of regulatory schemes). Efforts to more fully characterize the collection and triage of mobile devices is hindered by a lack of data on unofficial collection schemes. RMC has noted that their efforts to gauge the total share of Canadian mobile devices collected is incomplete without an idea of the number of devices collected through other programs (Grant et al. 2012). There is also a lack of information on the effectiveness of different strategies for encouraging mobile device take-back. Data on the success of strategies used by wireless service providers, manufacturers, or private collectors to encourage mobile device take-back (e.g., one-to-one mobile phone take-back, coupons, monetary incentives, free service features) would help inform policy recommendations.

200. Similarly, a more complete characterization of global triage practices is currently unavailable. There is inadequate information available on when and where triage typically occurs (before export to developing nations or after), the percentage of UEEE for which triage takes place, and the percentage of potential REEE which are sent for recycling. It would be especially helpful to know how this information varies across countries and regions.

4.5 Summary

201. Table 2 below provides a summary of the key actors identified in the discussion of policy issues in section 4 and where they may play a direct or indirect role in influencing environmental economic efficiency, environmental effectiveness, resource productivity, competitiveness, and social issues at different life stages. The table categorizes actors according to public (i.e., government, civil society, or general public) and private sectors.

202. Stages where the actor has a direct influence on environmental, social, or economic issues are indicated by an "X". This indicates that environmental, social, or economic outcomes are determined by decisions or actions taken by the actor at that stage. For example, manufacturers' adherence to environmental and social regulations—and additional efforts to reduce emissions or improve health and safety performance at facilities—can have direct impacts on SMM outcomes at the manufacturing stage.

203. Stages where the actor has an indirect influence are denoted by an "O"; this indicates that decisions or actions taken by the actor have subsequent impacts on other life-cycle stages that, in turn, affect SMM outcomes. For example, through their purchasing decisions, consumers can influence manufacturers to change the design of their products, and manufacturers, in turn, influence raw material extraction through supply chain sourcing decisions, and by requiring upstream suppliers to report on environmental and social performance.

204. There are overlapping areas of influence across each life-cycle stage. Some of the key interactions include: (i) raw material markets and suppliers influence the decisions of manufacturers through raw material prices (section 4.1); (ii) manufacturers influence demand for raw material suppliers through design and supply chain sourcing decisions (section 4.3); (iii) manufacturers and wireless service providers can influence consumers through educational campaigns and ecolabelling (section 4.1); (iv) consumer demand for mobile devices influences design decisions made by manufacturers (sections 4.1, 4.3); (v) consumers influence collection and triage practices by deciding where to send their phones at end of use (sections 4.1, 4.4); (vi) wireless service providers can incentive phone collection through relationships with consumers (section 4.4); (vii) formal and informal processors have a direct impact on SMM outcomes from triage, reuse, and recycling of mobile devices (section 4.4), and (viii) manufacturers can influence the recyclability of mobile devices through design (section 4.4).

Table 2. Summary of Key Actors Across the Critical Metal and Mobile Device Life Cycle

			Life-cycle Stage					
			Upstream		Downstream			
Sector	Group	Actors	Raw materials	Design & manufacture	Use	Collection & triage	Reuse / refurbishment	Recycling
Public	Government	OECD members*	O	X	X	X	O	O
		Other state/provincial, national, or multilateral regulators and actors	X	X	X	X	X	X
	Civil society	ENGOs, human rights organisations	X	X	X	X	X	X
		Consumer advocacy groups			X			
	General public	Consumers		O	X	X		
Private	Raw material providers	Mining companies, refiners, exporters	X	O				
	Manufacturers	Component manufacturers, mobile device engineers, designers, and manufacturers, importers of raw material or components	O	X	O	O		O
	Service providers and retailers	Network service providers, device retailers			X	X		
	UEEE and WEEE processors	Formal collectors, refurbishers, recyclers, certifiers		O		X	X	X
		Informal collectors, refurbishers, recyclers		O		X	X	X

Notes:

X = Direct or primary role or influence

O = Indirect or related role or influence

* Influence of OECD member states varies based on geography, domestic resources, and industries. In general, OECD member states will have less direct influence over raw material extraction, and reuse, refurbishment, and recycling of exported mobile devices.

205. Government and civil society groups have overarching interactions at each life cycle. Even so, OECD member countries may only have indirect influence over several key stages, depending on their geographic location, domestic resource based, and industry structure. OECD countries are less likely to have direct influence over raw material suppliers (who are concentrated in specific countries, some of whom are not OECD members), and reuse/refurbishment and recycling practices of UEEE and WEEE exported to non-OECD member countries.

5. LIMITATIONS OF THE ANALYSIS

206. This section summarizes the findings on the usefulness of the approach, challenges and data gaps that were encountered in this work. These findings are provided to inform further efforts by WPRPW and OECD member countries to operationalise SMM approaches, either through case studies or alternative approaches.

207. It was found that the following aspects demonstrate the **usefulness of this approach**:

- **Focusing on actors, their interests, priorities, and incentives, and the alignment of these drivers with existing policies and market structures.** The key elements of investigating and understanding policy interventions involved: identification of key actors related to the issue, their interests, incentives, and areas of influence, and the interactions between relevant actors and the existing policy framework. Understanding the interests of actors and how they aligned or misaligned with policy interventions across the life cycle was very useful for identifying opportunities to promote SMM goals.

- **Employing a life-cycle perspective and evaluating economic, environmental, and social considerations in tandem.** This was essential in approaching the issue from an SMM perspective. Application of this approach was aided by: (i) a clearly-defined life-cycle boundary, and relatively distinct life-cycle stages; (ii) information on important issues related to all three considerations (i.e., economic, environmental, and social considerations); and (iii) contact with experts from government, academic, and industry who are knowledgeable in life-cycle concepts and thinking.[53]

- **Identifying a limited set of issues across the life cycle to explore.** Using an Expert Workgroup in the initial phase of the project to specify several key policy issues for further focus was useful in bounding the scope of the work and ensuring that the analysis concentrated on areas of existing concern. This approach provided clarity and agreement on the scope of the assessment, established a structure for discussing actors, policy frameworks, and their interactions, and enabled a “deeper dive” into each issue. This case study focused on a number of issues across the life cycle, but other case studies might benefit from a specific focus on one or two key policy issues. This would enable an even more rigorous analysis of key gaps along the life cycle.

208. In contrast, it was found that the following aspects of the approach worked less well and informed **lessons learned** for future studies:

- **Specifying a geographic focus within each key policy issue at the outset of the study.** For some issues that were well-defined and well-studied within a particular jurisdiction, this was a suitable approach; but it was not suitable for other issues. For some issues, relevant examples of best practices and activities in various areas of the world were found (e.g., collection and triage practices in the United Kingdom). In other cases, data gaps prevented a more in-depth exploration of specific areas (e.g., raw material externalities in China). Certain actors are based in multiple locations around the world and do not fit neatly into a particular jurisdiction (e.g., mobile device manufacturers). Finally, it was necessary to include other regions where there were important connections through trade and international conventions (e.g., the Basel Convention).

[53] See the appendix for a list of experts who provided input to this report in the initial expert workshop or through phone and email interviews.

Lesson learned: The geographic focus of an assessment should be guided by: (i) the relevance of a country, or location, to involved actors and the life cycle of the material or product in question, (ii) the connections and interactions between relevant locations, (iii) the availability of data specific to a given location, and (iv) evidence of strong or weak institutions that can provide examples of either best practices or specific failures.

- **Adopting a strict material- or product-based perspective.** Although the focus of this case study was on the life cycle of four critical metals and mobile devices, it was not possible to strictly adopt this perspective throughout the entire case study.

  The focus on specific critical metals was useful at raw material extraction, trade, and material substitution stages, while the focus on mobile devices was useful at the manufacturing, use, and collection and triage stages. At the reuse/refurbishment and recycling stages, however, much of literature focused more broadly on UEEE and WEEE in general. In addition, relevant policy measures and activities were identified that—while they did not apply specifically to mobile devices or the four critical metals in focus—offered excellent examples of good practices and interactions that informed our lessons learned and recommendations. This outcome could also make the findings from this case study more useful to other electronic and materials management challenges.

  Lesson learned: A material- or product-based perspective is useful for establishing the scope and relevance of the analysis, but the specific products and materials must be representative of broader classes of materials and products they are chosen to represent. This enables the analysis to incorporate broader information to address data gaps and identify higher-level policy recommendations.

209. The following **key data gaps** that limited the extent to which concrete SMM recommendations in the four policy areas could be developed were encountered. Several of these data gaps correspond with the "inventory of knowledge gaps" that was identified in the original OECD case study (OECD 2011d):

- Life-cycle externalities:
  - **Information characterizing specific externalities associated with raw material extraction and processing of critical metals:** No quantitative information on specific environmental or social impacts attributable to the extraction of critical metals used in mobile devices could be found. The report, however, discusses the relevant actors, their incentives, and interactions at this stage in general. While it is believed this captures some of the most important interactions at a high level, this is an area where limited additional research could be conducted on specific critical metals if there is interest in exploring this further.
- Trade:
  - **Information on the results and efficacy of import restrictions:** The report identifies relevant policies, such as the Bamako Convention in Africa, and UEEE import bans in place in Vietnam, Indonesia, and Thailand. However, it did not identify sources that investigated the impact of these policies on economic efficiency, environmental efficiency, social outcomes, or competitiveness, although Wendell (2011, p. 3) suggests that Indonesia's import ban on UEEE helps support the country's domestic electronics industry.
- Material substitution:

  - **How different manufacturers make material substitution decisions:** Several voluntary industry initiatives to eliminate the use of beryllium and antimony in mobile devices were identified. This may be an area where there is further information on the specific steps mobile device manufacturers have taken to phase out these materials. The extent to which findings specific to antimony and beryllium can be applied to other metals, however, is uncertain. This likely depends on factors such as the availability and cost of substitutes for other metals and the impacts substitution would have on product functions and performance. Decision-making processes likely differ by manufacturer as well.

- Used and end-of-life mobile device management practices:

  - **Available information on informal recycling markets focuses on WEEE in general rather than mobile devices in particular:** This could represent a data gap where mobile devices are not a good proxy for WEEE. Consequently, the results of this report that address UEEE and WEEE management in particular are most representative of EEE in general rather than mobile devices. Several instances where mobile devices might differ from both UEEE and WEEE have been noted: the small size of these devices, their high reuse and recycling value, their value as a "back-up" in case a new device breaks and the value of data contained in the phones likely increases hoarding times, and the need for wireless network access creates an ongoing relationship between consumers and network providers.

  - **Information on triage practices in different countries.** There is inadequate information available on when and where triage typically occurs (e.g., before export to developing nations or after), the percentage of UEEE that is triaged, and the percentage of potential REEE that is sent for recycling. This information would help to assess overall resource productivity, and the whether collected mobile devices are handled efficiently. It would be especially helpful to know how this information varies across countries and regions.

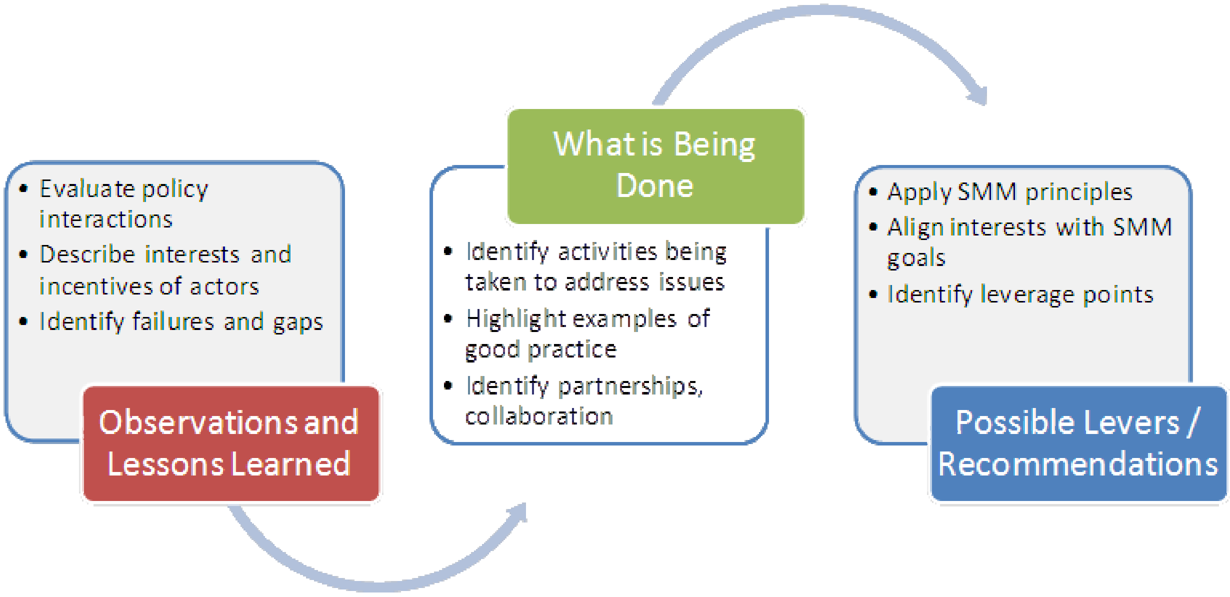
  - **Information on the effectiveness of different strategies for encouraging mobile device take-back:** Although it was possible to identify a number of different take-back schemes and systems, only little information on the effectiveness of these strategies could be found. Specifically, information on which systems collect the most mobile devices and at what cost would be useful. This information could be gathered through further studies on existing collection systems, such as those in France. Many collection systems are relatively new and only have data covering a few years. Information on the cost and success of strategies used by wireless service providers, manufacturers, or private collectors to encourage mobile device take-back would help inform policy recommendations.

  - **Conclusive information on the impact that handset discounts or phone refresh incentives have on mobile device turnover rates:** While evidence that device refresh incentives increase device turnover could be found, the overall impact of this on SMM outcomes is still unclear: The impacts on resource productivity depend on whether devices are reused, stored, or disposed of. High turnover rates may also provide benefits, such as promoting innovation and increasing the speed with which new technologies and device functions enter the market. Finally, in certain markets where up-front device discounts are common, there are strong consumer expectations that handsets will be offered at reduced cost in exchange for term contracts. Further research on how these factors interact and their impact on resource productivity and environmental outcomes is required.

6. OBSERVATIONS, LESSONS LEARNED, POLICY LEVERS, AND RECOMMENDATIONS

210. This section summarizes a set of observations, lessons learned, priorities, and recommendations from the assessment of policy issues along the critical metals and mobile device life cycle (section 4). As shown in Figure 13, to identify SMM recommendations, first observations and lessons learned from each policy issue were considered (i.e., life-cycle externalities, trade policy impacts, and end of use management). Next, in each area, what is being done was identified—i.e., promising activities or examples of possible good practices that are being undertaken to address these issues across the critical metals and mobile device life cycle. This in turn, informed a list of priority recommendations that OECD member countries might consider to leverage or promote SMM goals.

Figure 13. Framework for identifying levers and recommendations to promote SMM goals



211. The findings are presented below using the following structure: first, SMM observations, lessons learned, and "what is being done" are provided, or in other words: concrete activities that are being taken to promote SMM (section 6.1); second, prioritized recommendations for promoting SMM goals are developed (section 6.2).

6.1 SMM Observations and Lessons Learned, What is Being Done, and Possible Policy Levers for Achieving SMM Outcomes

212. The report identified the following observations and lessons learned from each policy issue. This list also includes examples of concrete activities that promote SMM goals. To distinguish observations that are relevant to UEEE and WEEE in general from those specifically relevant to mobile devices, the observations have been sorted into three categories: those relevant to UEEE and WEEE broadly, mobile device-specific observations, and potential inter-linkages between the two. Observations and lessons within each category are listed in the order of their relevance.

Observations and Lessons Learned UEEE and WEEE in General:

1. **The informal sector in developing countries is adept at collection and triage of UEEE and WEEE and at dismantling and pre-processing WEEE, while formal recycling processes are more efficient at recovering metals with minimal environmental impacts and health risks.** Coordination between these sectors could increase the overall recovery rate by as much as 170 percent compared to a highly efficient formal-sector recycling system (see section 4.4.2). Despite these complementary roles, formal recycling operations rarely purchase WEEE from informal-sector collectors due to at least two barriers: (i), the value of the additional metals recovered in formal recycling processes may not be enough to compensate informal collectors for delivering WEEE, and (ii), it is difficult for formal operations to secure a large, consistent supply of WEEE because informal collectors are unorganized, and spread out geographically. Efforts to understand these challenges, such as the "Best of Two Worlds" approach, can provide insight into useful, concrete actions to align these sectors.

2. **Enforcement difficulties, a lack of consistency in defining UEEE and WEEE, and differences between national environmental, health, and safety policies remain challenges for hazardous waste export and WEEE policies.** As a result, WEEE is able to move to locations with low health, safety, and environmental standards or poor enforcement practices. These regulatory failures create externalities that result in inefficient social and environmental outcomes.

3. **The global picture of mobile device use, UEEE, and WEEE has changed.** Mobile device use rates are increasing rapidly in developing countries. UEEE and WEEE generation in these countries is similarly increasing, and now rivals imports—particularly in the case of mobile devices; future management of UEEE and WEEE generation will be just as important as management of transboundary UEEE and WEEE in developing countries.

Observations and Lessons Learned Specific to Mobile Devices:

4. **Mobile devices have a high reuse value and a high concentration of economically-recoverable materials compared to other types of UEEE and WEEE.** There are large existing markets for used mobile devices, and the relatively high concentration of precious metals in mobile devices as compared to other WEEE makes mobile device recycling more economical. Consequently, there is a strong economic incentive for recovery, triage, and reuse or recycling of mobile devices.

5. **Hoarding occurs because consumers perceive residual value in their used mobile devices.** Many consumers tend to hold on to their devices until they no longer have any reuse value and must be recycled. Even with convenient "return-to-retail" collection systems, many consumers appear unwilling to release their old mobile devices and are not inconvenienced by storing small-sized electronics. To compensate consumers, some manufacturers and network providers (e.g., service providers in France) are beginning to offer incentives for returning mobile devices.

6. **Consumers can play an important role in the mobile device life cycle.** First, through demand for devices that are designed for recyclability, and/or which demonstrate reduced environmental impacts from material extraction and manufacturing (e.g., recycled content, energy efficiency), consumers can provide a market signal that encourages mobile device manufacturers (and, through the supply chain, component manufacturers as well) to invest in these areas. Second, consumers influence the quantity of and ways in which mobile devices are disposed; they can achieve better SMM outcomes by avoiding hoarding and ensuring devices enter processes where

they are properly triaged and, if recycled, recovered in a safe, high-efficiency process. For instance, increasing the average lifespan of mobile devices by 50 percent would reduce waste by a third, equivalent to avoiding the generation of 50 million end-of-life mobile devices in the United States in 2010 (see section 3.1.5).

7. **Government policies and industry-led activities are working together to achieve SMM goals.** These policies and activities include government regulations, voluntary programs, private-sector initiatives, as well as market forces. For example, at the mobile device collection and triage stage, national or state/provincial EPR or WEEE recovery targets, reuse and recycling certification programs, and triage standards (e.g., PAS 141:2011) work together to promote proper management of EEE; these activities often occur through government and industry collaboration or prescriptive regulation. Another example is mobile device design, where manufacturers have committed to phase out metals, such as antimony and beryllium, alongside government programs (e.g., the U.S. EPA's Design for Environment), integrated policy packages (e.g., the European Union's Integrated Product Policy), and regulations (e.g., the European Union's RoHS directive).

<u>Interlinkages between UEEE/WEEE and mobile devices</u>:

8. **Trade access can influence SMM policy goals across geographic boundaries and life-cycle stages.** The strongest interactions that was observed across life-cycle stages and geographic locations occurred through trade. Policies enacted in one jurisdiction may influence other countries through trade linkages. Chinese WEEE and RoHS regulations, for example, were developed—in part—in response to WEEE and RoHS regulations in the European Union that impact Chinese exports.

9. **The high value of metals in mobile devices may lower barriers to coordination between efficient collection and pre-processing in the informal sector and efficient metals recovery of the formal sector.** Theoretically, given the high concentration of economically-recoverable metals in mobile devices, formal recyclers should be able to compensate informal collectors for delivering these devices to their facilities. This economic incentive reduces the barriers to coordination between the informal and formal sector, although coordinating with dispersed, ad-hoc informal markets and information barriers may still pose a challenge.

10. **Material substitution choices involve trade-offs with possible effects across the material and product life cycle.** Substitution decisions require—for both the original metal and its substitute—consideration of the cost and availability of materials, the cost of changes in manufacturing processes, the impacts on product design, performance, and function, and an assessment of the environmental and health risks associated with material production, use, and disposal. Existing policy approaches (e.g., IPP and DfE) take life-cycle considerations into account. For example the EPA's DfE program includes human health concerns, environmental considerations, and the performance and cost of traditional and alternative technologies through partnership projects.

6.2 Recommendations and Policy "Levers" For Promoting SMM Goals

213. The observations, lessons learned, and data gaps informed our areas for recommendations. In developing these recommendations, the report sought solutions that could directly address the barriers and failures observed through the application of SMM principles to key leverage points.

214. The report provides recommendations in three areas: priority actions, secondary measures, and further activities. Priority actions represent the areas of highest leverage that decision-makers in the public and private sectors may wish to focus on; they represent the issues where the clearest evidence of market or regulatory failures was located. Secondary measures involve leveraging existing activities that are underway, and ensuring these are aligned with SMM outcomes; these measures may also help reinforce the priority actions. Finally, further activities involve areas for further follow-up due to data gaps and less-clear evidence of market or regulatory areas, policy gaps, or policy incoherence.

215. The recommendations are provided in . Using the same framework applied in the rest of the report, the table identifies how the recommendations address policy gaps, regulatory or market failures, and areas of incoherency or inconsistency. It also denotes which recommendations address economic and trade, resource efficiency, environmental, or social issues, and the relevant actors involved.

216. The two priority actions, listed below, involve improving collection of mobile devices in OECD countries and developing ESM systems in developing countries with large informal sectors.

1. To increase collection, decision-makers could consider: (i) the use of financial incentives to reduce hoarding and increase collection rates; (ii) adopting harmonized standards and terminology to reduce loopholes and inconsistencies between regional policies—PAS 141, for example, seeks to address such issues in EEE reuse markets; and (iii) implement public-sector UEEE and WEEE management requirements that adhere to ESM principles.

2. To develop ESM systems in developing countries with large informal sectors, the report recommends that decision-makers consider: (i) efforts to support capacity development in the informal sector in developing countries—such as those run by Solving the E-waste Problem (StEP) and the Basel Convention; and (ii) supporting the commercialisation of cheaper, high-efficiency metal recovery technologies that minimize health and environmental impacts. Also, measures that help to Reduce the up-front capital cost of high-efficiency recovery technologies would lower the barriers to adoption for smaller-scale recyclers.

217. Alongside these priority actions, decision-makers may want to consider secondary measures to ensure existing or ongoing activities are aligned with SMM goals. These include: (i) performing due diligence on emerging voluntary standards,[54] and adopting these into public-sector management programs; (ii) encouraging the establishment of harmonized take-back systems at the state/provincial level or management systems within large institutional or commercial organisations; (iii) using communication platforms—including government Web sites and social media—to inform consumers about management of used or waste mobile devices; and (iii) incorporating life-cycle thinking into existing policies and programs, such as chemical management programs, product design policies, and voluntary industry programs.

54 In addition to EMS standards such as ISO 14000 and the EU's EU Eco-Management and Audit Scheme (EMAS), as well as the "Core Performance Elements" in OECD's Recommendation C(2004)100 on Environmentally Sound Management (ESM) of Waste, relevant standards include: Canada's Recycler and Electronics Reuse & Refurbishing Programs, the WEEE Label of Excellence (WEEELABEX) in Europe, and e-Stewards and Resource Recycling (R2) standards in the United States.

218. Finally, decision-makers may also wish to undertake further activities in areas where there are data gaps or less-clear evidence of market or regulatory failures. These include: (i) seeking a better understanding of how the bundling of handsets and service contracts increases mobile device turnover rates; (ii) investigating efforts to encourage consumer demand for devices with lower life-cycle impacts, and (iii) conducting further research to characterize the extent of externalities along the life cycle of mobile devices.

Table 3. Summary of Recommendations and Policy "Levers" For Promoting SMM Goals

	Actions/Policy Goals	Recommended Steps	Policy Linkages	SMM Area: Econ/ trade	SMM Area: Resources	SMM Area: Enviro.	SMM Area: Social	Actors Involved
	Priority Actions							
1	Increase collection and triage of mobile devices in OECD countries	Engage with private sector to explore and advance the use of monetary or other incentives to increase collection from device users.	Align financial incentives Extend the useful life of devices	X	X	X	-	Governments in OECD countries Networks & manufacturers Consumers
		Adopt and promote the use of harmonized standards based on internationally- or regionally-accepted terminology and definitions (e.g., consistent definitions of used/waste electronics, UEEE/WEEE, and ESM).	Address gaps/ inconsistencies in policy frameworks Promote ESM	-	X	X	-	Governments in OECD and non-OECD countries International organisations Mobile device and UEEE/WEEE processors Standards developers
		Implement management criteria for used and waste mobile devices, UEEE, and WEEE generated in the public-sector.	Leverage trade & market access Promote ESM Extend the useful life of devices	X	X	X	-	Governments in OECD countries Mobile device and UEEE/WEEE processors
2	Develop ESM capacity in developing countries with large informal sectors	Hold workshops or regional forums and pilot market development projects to expand institutional and private-sector ESM capacity.	Leverage trade & market access Incorporate the informal sector Address information asymmetries/ knowledge gaps Promote ESM Protect human health & safety	X	X	X	X	Governments in OECD and non-OECD countries Non-governmental, international organisations, civil society Formal and informal sector mobile device and UEEE/WEE processors
		Promote/ fund research & development, and pilot-scale demonstrations of high-efficiency metal recovery technologies with low capital costs.	Lower barriers to entry Promote ESM Protect human health & safety	X	X	X	X	Governments in OECD and non-OECD countries UEEE/WEEE processors
	Secondary Measures							

	Actions/Policy Goals	Recommended Steps	Policy Linkages	SMM Area: Econ/ trade	SMM Area: Resources	SMM Area: Enviro.	SMM Area: Social	Actors Involved
3	Encourage development of consistent, harmonized frameworks for collecting, triaging, and managing mobile devices in OECD countries	Perform due diligence on emerging mobile device, UEEE, and WEEE management standards from voluntary, multi-stakeholder, and industry-driven initiatives.	Address gaps/ inconsistencies in policy frameworks Promote ESM	-	X	X	X	Governments in OECD countries Non-governmental and research organizations
		Use existing standards in public-sector used and waste electronics or UEEE/WEEE management programs.	Address gaps/ inconsistencies in policy frameworks Leverage trade & market access Promote ESM	X	X	X	-	Governments in OECD countries
4	Support establishment of and information sharing between state/provincial and industry-led take-back initiatives in OECD countries	Engage with state/provincial or private sector actors about existing standards and lessons learned to develop or harmonize take-back systems in absence of national systems.	Address gaps/ inconsistencies in policy frameworks Promote ESM	-	X	X	X	National, state/provincial governments in OECD countries Manufacturers UEEE/WEEE processors
5	Educate consumers on appropriate management practices of used and end-of-life mobile devices	Use existing communication platforms to increase consumer awareness about options for appropriate management of used and end-of-life mobile devices, and of important environmental attributes of mobile devices to consider when making purchases.	Address information asymmetries/ knowledge gaps Extend the useful life of devices Promote ESM	-	X	X	X	Governments in OECD countries Consumers and consumer advocacy groups Manufacturers and network providers
6	Ensure existing policies and programs consider economic, environmental, and social impacts across the life cycle of mobile devices	Incorporate or ensure that existing chemical management, product design policies, and voluntary programs that are relevant to mobile devices emphasize a life cycle approach.	Address gaps/ inconsistencies in policy frameworks	X	X	X	X	Governments in OECD countries Non-governmental and research organizations
	<u>Further Activities</u>							
7	Better understand potential competitiveness/ resource efficiency linkages in consumer relationships with network providers	Investigate the effect of handset bundling and service contracts on increasing turnover rates to determine the effect on life time and resource efficiency.	Align financial incentives Extend the useful life of devices	X	X	-	-	Governments in OECD countries Network providers and research organizations

	Actions/Policy Goals	Recommended Steps	Policy Linkages	SMM Area				Actors Involved
				Econ/ trade	Resources	Enviro.	Social	
8	Encourage consumer demand for "greener" mobile devices	Investigate the effectiveness of ecolabelling schemes, and evidence of consumer demand influencing mobile device design.	Leverage trade & market access Address information asymmetries/ knowledge gaps	X	-	X	X	Governments and OECD, international organisations Non-governmental and research organizations
		Perform due diligence on existing mobile device eco-labelling schemes, upstream manufacturing standards and labelling programs to assess their effectiveness, rigor, and transparency.	Leverage trade & market access Address information asymmetries/ knowledge gaps	X	-	X	X	Governments in OECD countries Non-governmental and research organizations
9	Identify the extent of externalities across the life cycle of mobile devices	Characterize the nature and importance of specific externalities; determine whether fiscal policies or trade drivers could play a role in internalizing environmental or social costs.	Leverage trade & market access Address information asymmetries/ knowledge gaps Protect human health & safety	X	X	X	X	Governments and OECD, international organisations Non-governmental and research organizations
10	Leverage the results of this case study to further operationalise SMM and apply lessons learned to other sectors	Extend the methodology and structure of this case study to other materials and areas of interest.	Address gaps/ inconsistencies in policy frameworks Address information asymmetries/ knowledge gaps	X	X	X	X	Governments and OECD WPRPW, international organisations Industry stakeholders, and research organizations
		Support further research on data gaps identified in this report.	Address gaps/ inconsistencies in policy frameworks Address information asymmetries/ knowledge gaps	X	X	X	X	Governments and OECD WPRPW Industry stakeholders and research organisations

X = Direct effect of SMM area

ESM = Environmentally Sound Management

SMM = Sustainable Materials Management

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APPENDIX: AFFILIATIONS OF WORKING GROUP EXPERTS AND INTERVIEWEES

Ahonen, Salla	Nokia
Bartley, Ross	Bureau of International Recycling (BIR)
Börkey, Peter	Organisation for Economic Co-operation and Development
Coulas, Maureen	Natural Resources Canada
Calliafas, Peter	WEEE Advisory Board, Past Chair
Derry, Allen	United States Environmental Protection Agency
Faure-Miller, Yvan	MoEnv France
Grant, Ursula	Canadian Wireless Telecommunications Association
Lawford, John	Public Interest Advocacy Centre
Lelièvre, Tania	Canadian Wireless Telecommunications Association
Leith, Angie	United States Environmental Protection Agency
Manhart, Andreas	Öko-Institut
McIntosh, Keith	Canadian Wireless Telecommunications Association
Meskers, Christina	Umicore
Mickoleit, Arthur	Organisation for Economic Co-operation and Development
Morliere, Adeline	Ministry of Ecology, Energy, Sustainable Development and the Sea
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