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ENVIRONMENT DIRECTORATE
ENVIRONMENT POLICY COMMITTEE

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Cancels & replaces the same document of 30 March 2011

Working Group on Waste Prevention and Recycling

ANNEXES

RE: CRITICAL METALS AND MOBILE DEVICES - A SUSTAINABLE MATERIALS MANAGEMENT CASE STUDY

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NOTE FROM THE SECRETARIAT

In addition to aluminum, wood fibres and plastics, critical metals have been identified as important materials for which a sustainable materials management approach might provide valuable insight. The objective of this case study on critical metals is to analyse the environmental impacts of critical metals throughout their lifecycle and to explore policy opportunities and barriers for SMM, as a way of demonstrating the utility of the SMM concept for policy-making.

This document includes all annexes to the critical metals case study that was presented at the OECD Global Forum on Sustainable Materials Management held in Belgium from 25 to 27 October 2010, together with other policy and case study materials.

The Government of Canada case study project team involved participants from three federal departments: Natural Resources Canada (NRCan), Industry Canada (IC) and Environment Canada (EC). The project team was led by Alain Dubreuil and Rob Sinclair in the Minerals and Metals Sector of NRCan.

Project support was provided by Orlando Dinardo (NRCan), Philippa Huntsman-Mapila (NRCan), David Koren (NRCan), Peter Campbell (IC), Patrick Huot (IC), Cheryl Beillard (NRCan), Duncan Bury (EC), Dennis Jackson (EC) and Andre Martin (EC).

Alberto Fonseca and Steven B. Young (University of Waterloo) conducted a literature review and developed an analytical framework for advancing research into the social aspects of sustainable metals management.

Nokia, Umicore, the US National Research Council of the National Academies and many other players have provided valuable information that was used in the preparation of this case study.

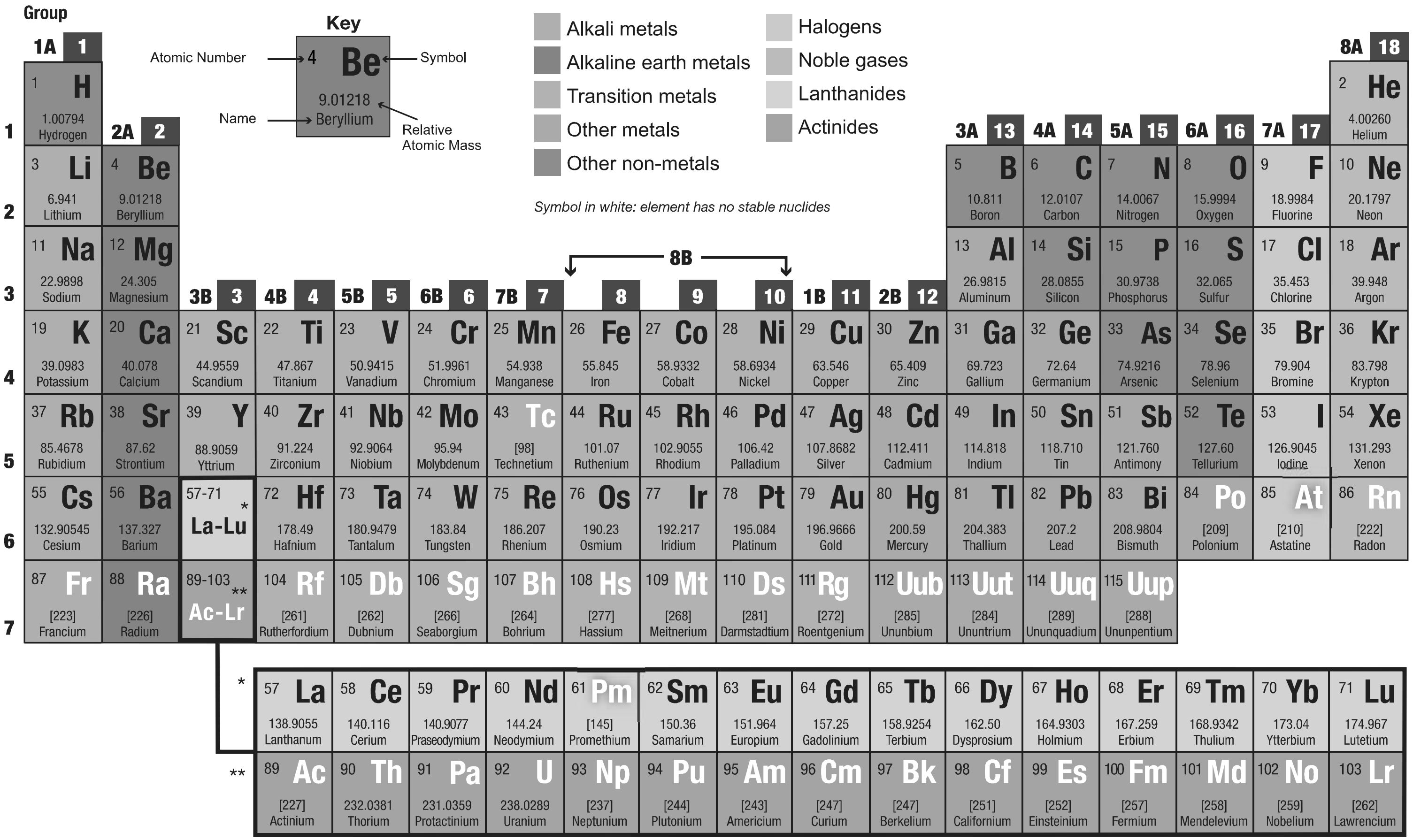
The secretariat would like to thank Canada for the contribution of this case study.

ANNEXES

RE: CRITICAL METALS AND MOBILE DEVICES – A SUSTAINABLE MATERIALS MANAGEMENT CASE STUDY

TABLE OF CONTENTS

ANNEX 1: THE PERIODIC TABLE



ANNEX 2: FACT SHEETS FOR ANTIMONY, BERYLLIUM, PALLADIUM AND PLATINUM

1. Antimony (Sb)

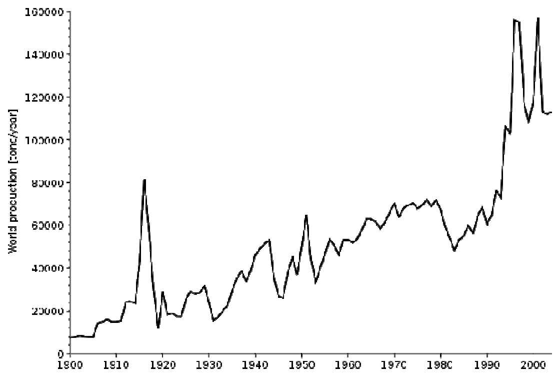
Summary description

1. Arsenic, antimony and bismuth all belong to group 15 of the periodic table. The stable forms of these elements are crystalline, have a grey metallic lustre and are comparatively soft but brittle. The principal antimony-containing mineral, stibnite, (Sb_2S_3) has a relatively low melting point (546^{o}C) which results in a simple recovery method from other minerals in an ore body. Antimony is also found as various antimonides of metals such as nickel, copper, silver and mercury. Examples of these include breithauptite (NiSb), dyscrasite (Ag_3Sb) and pyragyrite ($3Ag_2S.Sb_2S_3$). The principal source of palladium occurs as an antimonide, stibiopalladinide (Pd_5Sb_2). Where stibnite is weathered, it is converted to oxides such as valentenite (Sb_2O_3) and cevantite ($Sb_2O_3.Sb_2O_5$).

Global production

2. China is the major producer of antimony globally having produced over 150 000 t in 2007, or over 87% of the world's total mine production. Canada produced 0.1 % of the antimony as a co-product associated with base metals production. Four other countries (Russia, South Africa, Bolivia, and Tajikistan) together contributed about 10% of world primary mine production. In the USA, ores of the complex deposits are mined primarily for lead, copper, zinc, or precious metals; antimony is a by-product of the treatment of these ores.

Figure 1: Antimony world production trend (tons/year)



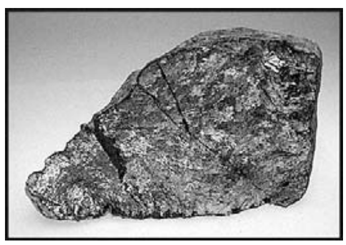
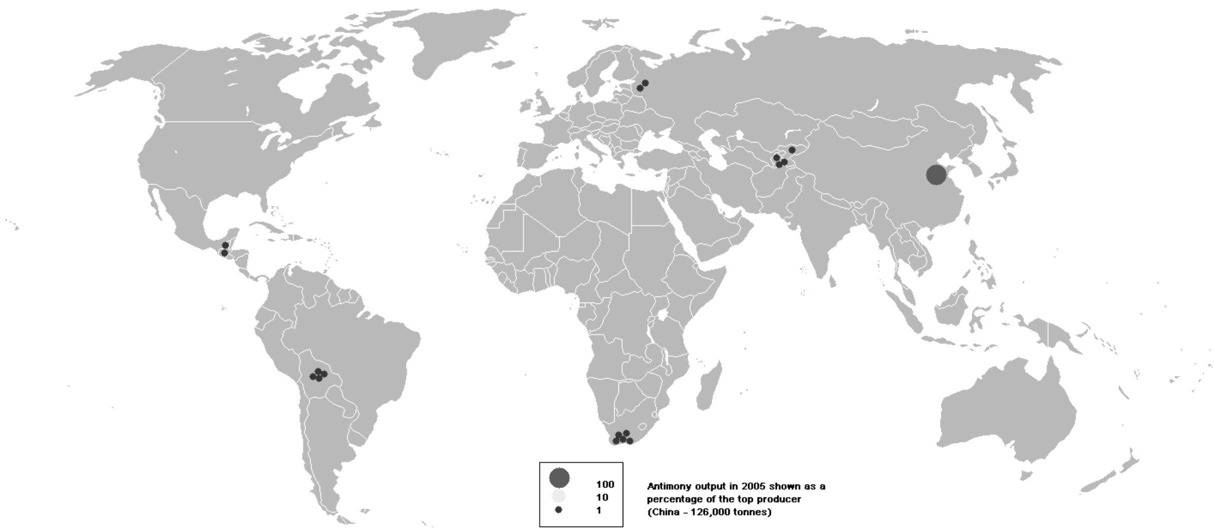


Figure 2: Antimony metal mine distribution in 2005



Supply risk

3. The rate to which the price rise continues will depend upon demand, the availability of antimony supply, and the availability of substitutes for antimony on the market. China has historically been and continues to be the largest producer of antimony globally and therefore an interruption of that supply will impact prices.

Uses

4. World consumption of antimony has increased over the last 20 years, a trend which will continue as more stringent flammability standards and an increased demand for plastics and IT-related products will result in higher demand for flame-retardants. The greatest use for antimony is in the production of flame retardants used in plastics, vinyl, and synthetic fibres. Flame retardants account for about 70% of primary antimony demand and 90% of the demand for antimony trioxide. The rising demand for digital devices has resulted in increased sales of antimony metal for semiconductors and electronic components. The demand for antimony by the electronic and electrical equipment (flame retardant, cathode ray tube glass) represents about 50% of the primary production. It is also used as an alloying element for making lead acid batteries.

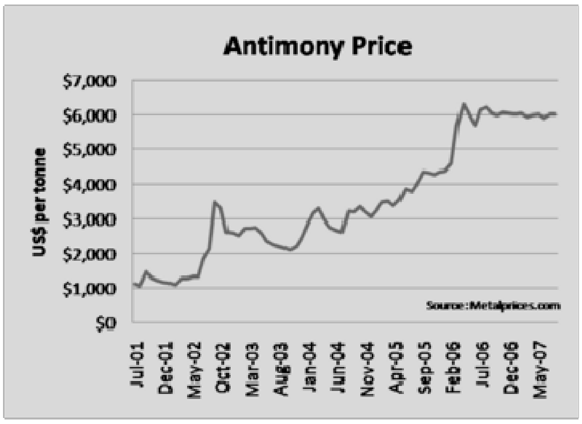
Substitutability

5. Elements which can be used as substitutes to antimony to harden lead in the manufacturing of batteries include cadmium, calcium, copper, selenium, strontium, sulphur, or tin. In addition, hydrated aluminum oxide and some organic compounds can be used as substitutes for antimony in the processing of flame retardants, the principal use of antimony. Compounds of chromium, tin, zinc, or zirconium can be used in place of antimony in the manufacturing of paints and enamels.

Value

6. Antimony prices have risen from a 40 year low of around US$1,000 per tonne in August 2001 to the US$5-6000 level in 2008.

Figure 3: Antimony metal prices over 5 years in US dollars/ton



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US Geological Survey http://minerals.usgs.gov/

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2. Beryllium (Be)

Summary description

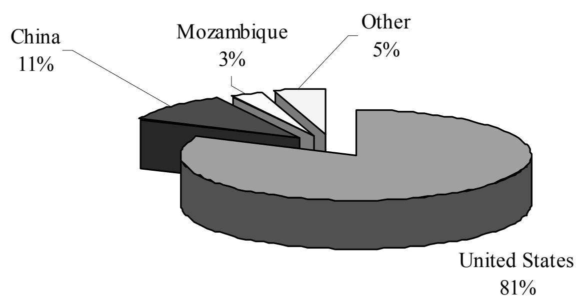
7. Beryllium, an alkaline earth metal with a greyish-white surface, was first discovered in 1798 as a new element in beryl and emeralds, and later isolated in 1828 by reducing beryllium chloride with potassium. Currently, most production of beryllium is through reduction of beryllium fluoride with magnesium metal. Beryllium never occurs in nature as a free element, but as a compound; the most common ore of beryllium is beryl.

8. Beryllium's density is 1.8 grams per cubic centimetre, making it the second lightest metal (lithium being the first) and least dense metal used in construction at two-thirds the weight of aluminium and one quarter of the weight of steel. Beryllium also has high heat capacity and conductivity, as well as being non-magnetic.

Global production

9. The world's reserves of known deposits of beryllium are estimated at 80,000 tons. Approximately 65% of these reserves are in non-pegmatite deposits in the U.S., mostly in the Gold Hill and Spor Mountain areas of Utah and the Seward Peninsula of Alaska. (U.S. Geological Survey [USGS], 2009). In terms of mining production, the majority is also in the U.S. with 155 tonnes, or approximately 81% of the world's mine production. China (20 tonnes) and Mozambique (6 tonnes), are the only other countries currently mining beryllium.

Figure 1: Global Mine Production of Beryllium 2008



Supply risk

10. The market for beryllium is dominated by four firms: Brush Engineered Materials (US), NGK Insulators (Japan), International Beryllium Corporation (Canada), and Ulba Metallurgical Plant (Kazakhstan), leading to potential for supply risk. As beryllium is used in nuclear warheads, as well as in the construction of jet fighters, spacecraft and satellites, it is seen as a strategic metal. As a strategic metal, many countries have policies in place to secure stockpiles rather than be at the mercy of the market. This stockpiling also has the potential to lead to supply crunches in the future.

Uses and issues

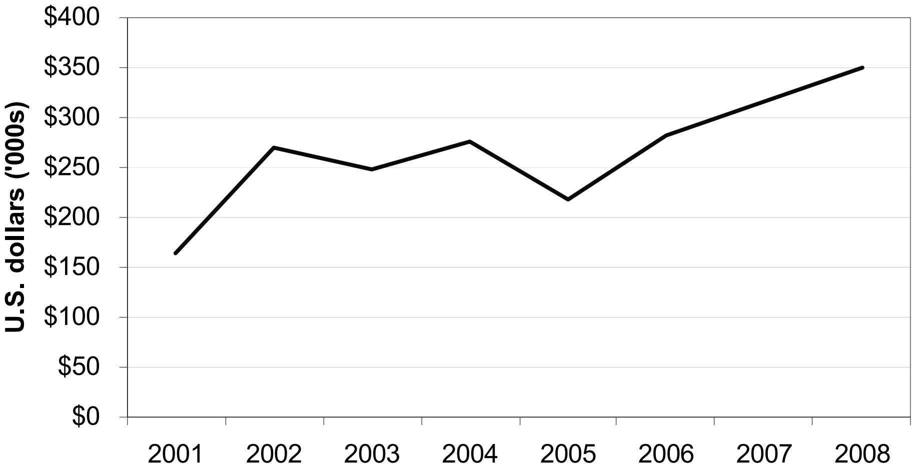
11. Beryllium-copper alloys are the most common use of beryllium. The United States Geological Surveys estimates that approximately one-half of beryllium was used in computer and telecommunications products, where it is used for electrical contacts and connectors. The remainder is used in aerospace and defence, appliances, automotive electronics, and other industrial applications. Because of the toxic nature of beryllium, various international, national guidelines and regulations have been established regarding beryllium in air, water, and other media. The presence of beryllium can impact the recyclability of copper. Some mobile phone producers are phasing out the use of beryllium in new products.

Substitutability (alternatives)

12. In some applications of beryllium, copper alloys containing nickel and silicon, tin, titanium, or other alloying elements may be substituted for beryllium-copper alloys; however, using these substitutes results in reduced performance (USGS, 2009).

Value

Figure 2: Beryllium Unit Value (U.S dollars per tonne), 2001-2007[1]



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http://www.nokia.com/NOKIA_COM_1/Corporate_Responsibility/Environment_/Sustainable_products/Substance_management/Nokia%20Substance%20List%202009.xls Starting on January 1, 2010, all new Nokia devices shall be free of beryllium.

[1] Unit value is defined as the value of 1 metric ton (t) of beryllium apparent consumption. estimation of the beryllium unit value is calculated on an annual basis from the U.S. dollar (expressed as current dollars) value of imports of beryllium-copper master alloy divided by the estimated beryllium content of those imports, which is reported in the MCS

3. Palladium (Pd)

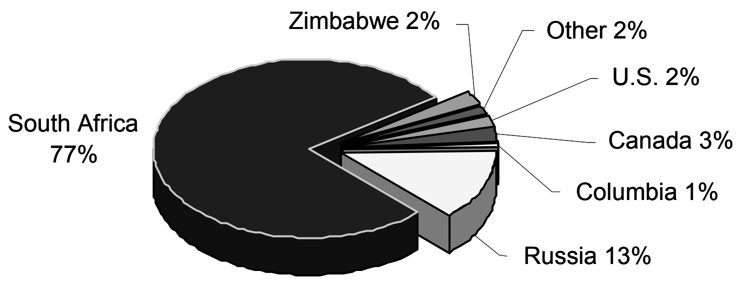
Summary description

13. Palladium is one of the platinum group metals (PGMs). These metals have high melting points and chemical inertness plus exceptional catalytic properties, even under extreme temperature and corrosive conditions. The PGMs were first categorized as a single metal in 1751. Following the identification of platinum, palladium was isolated as a separate elemental metal in 1803 by William Hyde Wollaston. The industrial extraction of Pd from ores is technically complex.

Global production

14. In 2007 world mine production generated 219 tonnes of Pd whereas the recycling of catalytic converters resulted in the recovery of 31 tonnes of Pd. Global economic reserves for PGMs are estimated to be greater than 100 kilo tonnes with almost 90% of that in South Africa: the percentage of PGM reserves that is Pd is not known though a typical deposit ratio for Pd to Pt is 3:1 (USGS).

Figure 1: Global mine production of Pd (219 t) in 2007



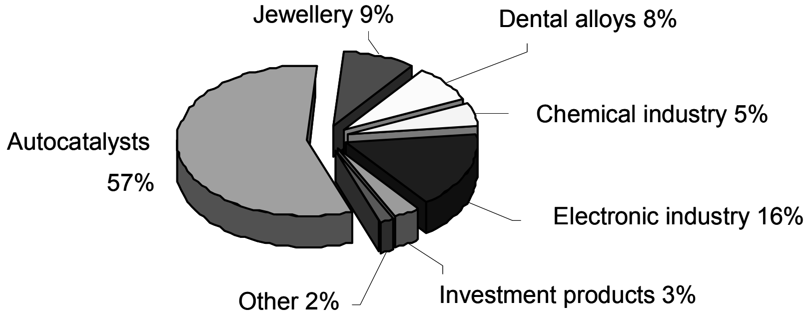
Supply risk

15. Palladium is in demand from a wide range of global industries, yet is supplied by only a few mines across the world. Therefore, an interruption to supply will impact prices. The biggest palladium supplier in the world is Norilsk Nickel in the Russian Federation, and in the year 2000, its deliveries became unreliable. The palladium market then was so tight that supply interruptions resulted in huge price surges. Palladium reached a high of US$1090 per ounce in early 2001 (see Figure 3). Concerns about supply reliability emerged again when a power crisis occurred in South Africa for five days in January 2008 (USGS).

Uses

16. The primary use of palladium is in auto catalytic converters (about 138 tonnes in 2007). The second most important use of Pd is in the electronic industry where half of the 40 tonnes are used to make multi-layered ceramic capacitors found in most electronic devices including mobile phones.

Figure 2: Global sales and use of Pd (244 t) in 2007



Importance of use (or impact of supply restriction)

17. Regulations to increase emissions standards in Europe and Asia are expected to lead to higher Pd loading in catalytic converters. However, reduced sales in the auto and electronics sector plus increased miniaturization and use of cheaper material substitutes may offset any gains. The use of Pd in fuel cells, water treatment and liquid crystal displays and other devices not shown in Figure 2 suggests continued economic importance for this metal.

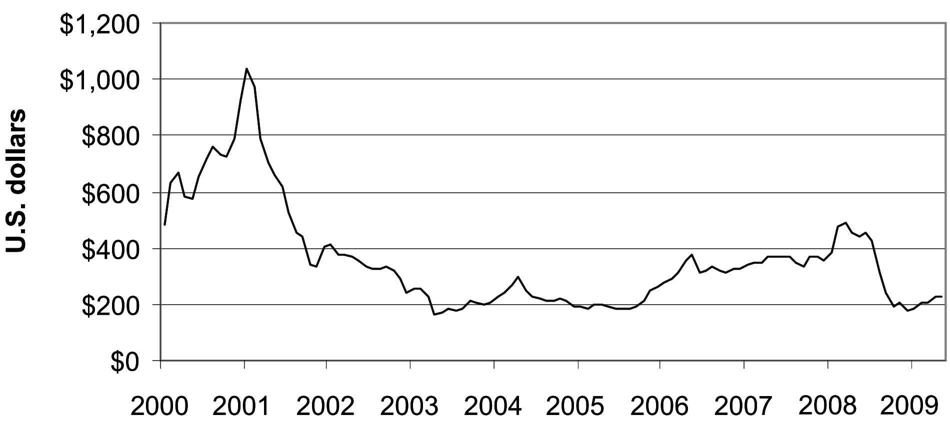
Substitutability

18. PGM metals can substitute for each other (with some efficiency losses). However, Pd is substituting for other PGMs such as the platinum in catalytic converters because of the price advantage (however, Pd is less useful than Pt in the growing diesel market). But, since PGMs are relatively more expensive than other metals, manufacturers are reducing Pd content where possible to reduce costs. White gold and Pd are replacing platinum in some jewellery. Some manufacturers are shifting towards nickel and silver based multi-layered ceramic capacitors, which displaces Pd use.

Value

19. In May 2009, one troy ounce of Pd was valued at US$231 (or US$7,427.65 per kilogram).

Figure 3: Price of Pd, (New York, US dollars per troy ounce), 2000-2009



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Umicore Precious Metal Refining, , *http://www.preciousmetals.umicore.com/*

VM Group, *The white book*, 2008, Vortis (Merchant Banking)

4. Platinum (Pt)

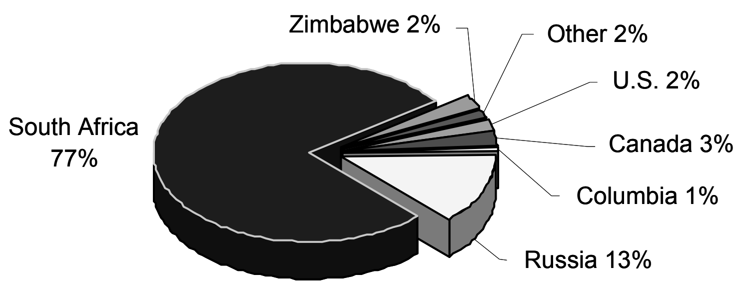
Summary description

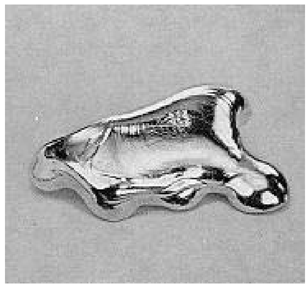
20. Platinum is obviously part of the "platinum group metals" (PGMs) that includes palladium, rhodium, ruthenium, iridium and osmium. These metals have high melting points and chemical inertness plus exceptional catalytic properties, even under extreme temperature and corrosive conditions (*i.e.* it is immune to oxidation). Platinum was independently discovered in 1736 by Antonio de Ulloa and in 1741 by Charles Wood.

Global production

21. In 2007, world mine production was 213 tonnes of Pt while 27.7 tonnes were recovered from autocatalysts. Global economic reserves for PGMs are estimated to be greater than 100 kilo tonnes with almost 90% of that in South Africa.

Figure 1: Global mine production of Pt (213 t) in 2007





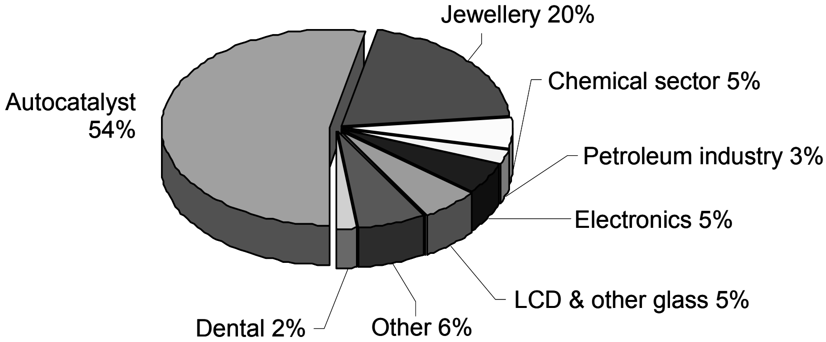
Supply risk

22. A 2007 decrease in the supply of all PGMs from South Africa reduced supply and increased price. The supply of Pt from Zimbabwe is considered unpredictable (USGS). The challenge with mining operations in Developing Countries is securing reliable power supply, retaining skilled workers, resolving labour disputes and managing safety issues – all of these could impact Pt supply.

Uses

23. In addition to auto catalysts, platinum is used in jewellery, wire, and vessels for laboratory use, and in many instruments such as thermocouple elements. It is also used for electrical contacts, corrosion-resistant apparatus, and in dentistry. Interestingly, PT used to control emissions may become lost via automobile exhaust pipes so research to recover Pt from street sweepings has been undertaken in Wales and Germany.

Figure 2: Global sales and use of Pt (246 t) in 2007



Importance of use (or impact of supply restriction)

24. Over the last three decades, the use of PGMs in auto catalysts has greatly improved air quality around the world. PGMs help convert engine exhaust such as carbon monoxide, nitrogen oxides and hydrocarbons into less harmful carbon dioxide, nitrogen and water vapour. Since Pt (and Pd) can also absorb large quantities of hydrogen, it may play an important storage role for hydrogen fuel systems in the future. The global recession of 2008-2009 has lowered the demand for automobiles and therefore the demand for PGMs has been reduced. However, increased air emission standards may increase the demand for Pt in various markets which may offset losses.

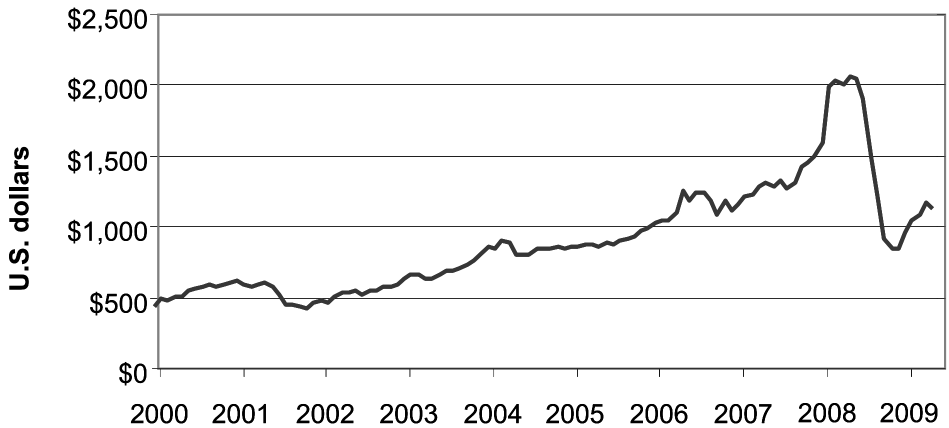
Substitutability

25. PGM metals can substitute for each other (with some efficiency losses). However, Pd is substituting for other PGMs such as the platinum in catalytic converters because of the price advantage. But, since PGMs are relatively more expensive than other metals, manufacturers are reducing PGM content where possible to reduce costs (USGS). For example, white gold and Pd are replacing platinum in some jewellery.

Value

26. In May 2009, one troy ounce of Pt was valued at US$1,134 (or US$36,460 per kilogram).

Figure 3: Price of Pt, (New York, US dollars per troy ounce), 2000-2009



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Platinum-Group Metals [Advance Release], U.S. Geological Survey Minerals Yearbook—2007 *http://minerals.usgs.gov/minerals/pubs/commodity/*

Steve Marsden Chemistry Resources, *http://www.chemtopics.com/elements.htm*

ANNEX 3: PROJECT ADVISORY GROUP

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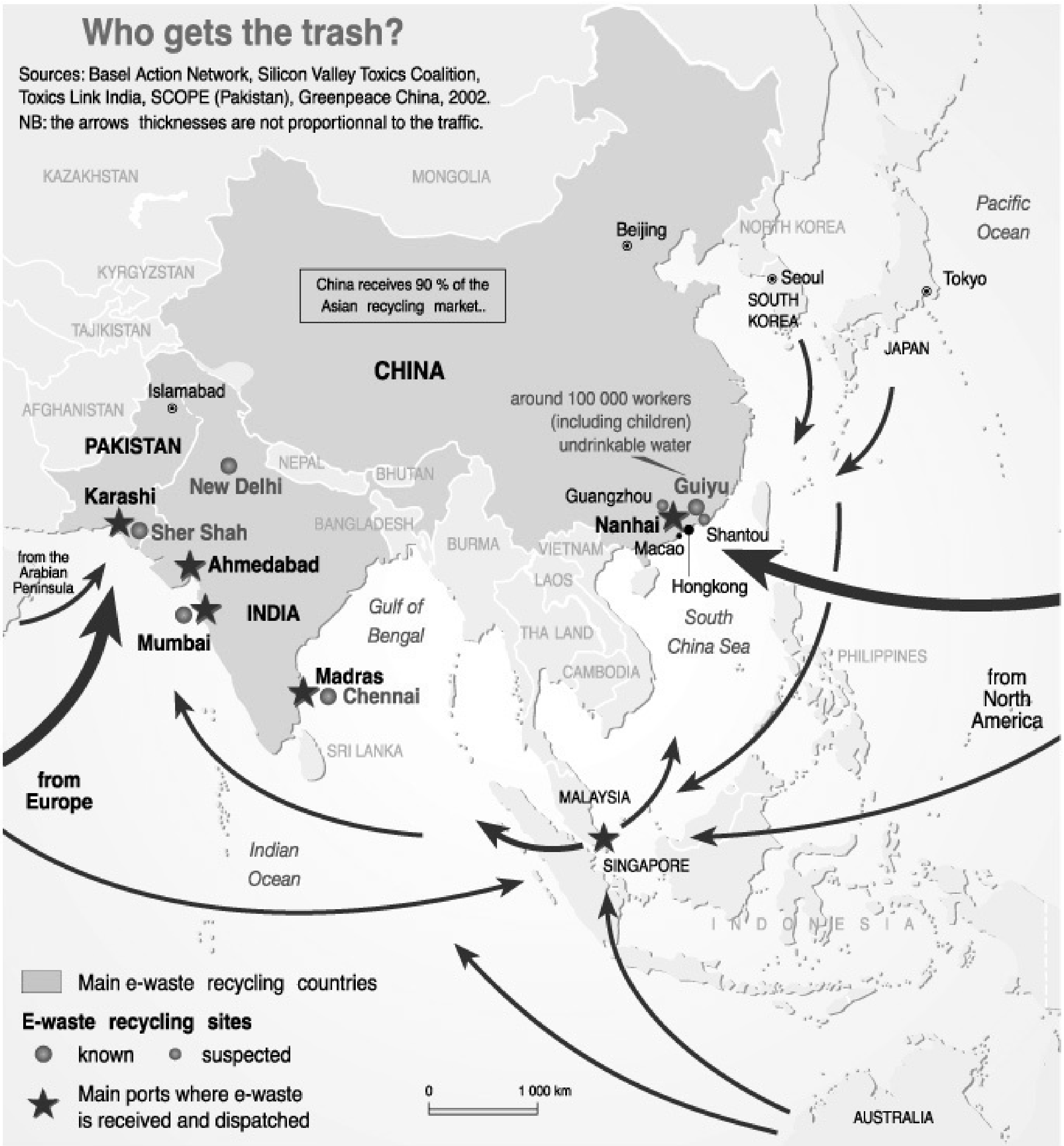
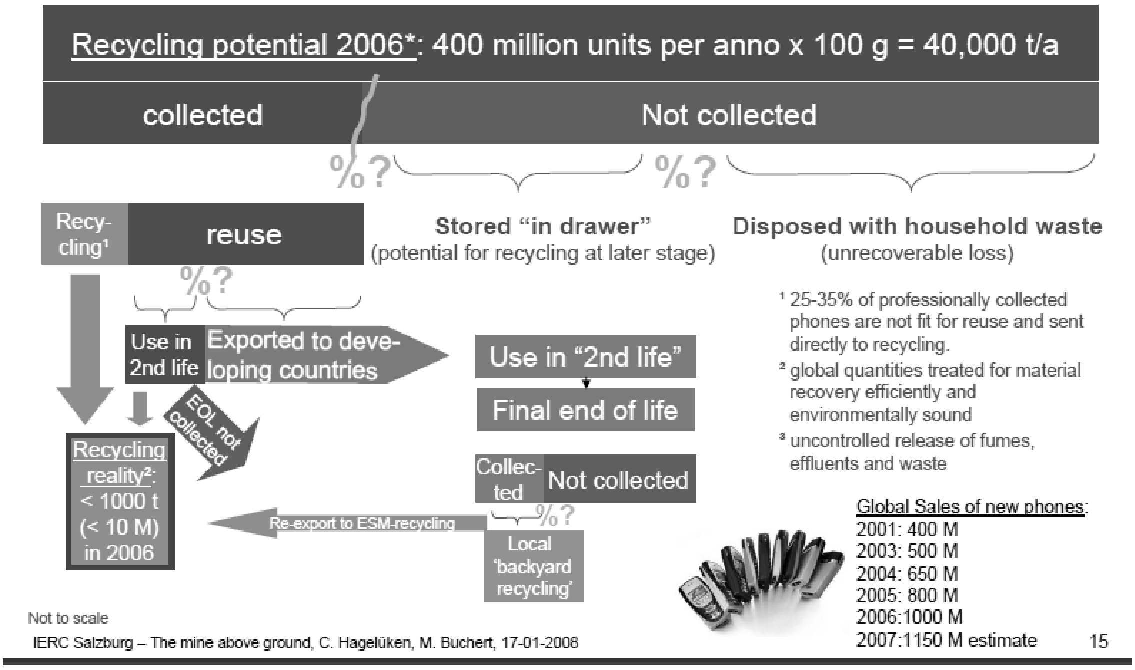
ANNEX 4: FLOW OF E-SCRAP IN S.E. ASIA

27. The following map is taken from a fact sheet produced by UNEP. It illustrates the complexity of the recycling of post-consumer electronic materials. If mobile phones mirror these flows, then Asia (China, Singapore, India and Pakistan) is receiving the bulk of them.



Source: *http://maps.grida.no/go/graphic/who-gets-the-trash*

ANNEX 5: ESTIMATED GLOBAL FLOW OF EXPIRED MOBILE PHONES (NOKIA)



28. Nokia conducted Global Recycling research a year ago and found that up to 40% of spent mobile phones are still "in the drawer" (*http://www.nokia.com/environment/we-recycle/why-recycle*). The estimate of 2.5% for mobile phones recycled at the five largest smelters is illustrated in this figure (40,000 t/a of available devices versus 1,000 t/a recycled: the recycling rate increases if the assumed weight per device is decreased to 70 grams).

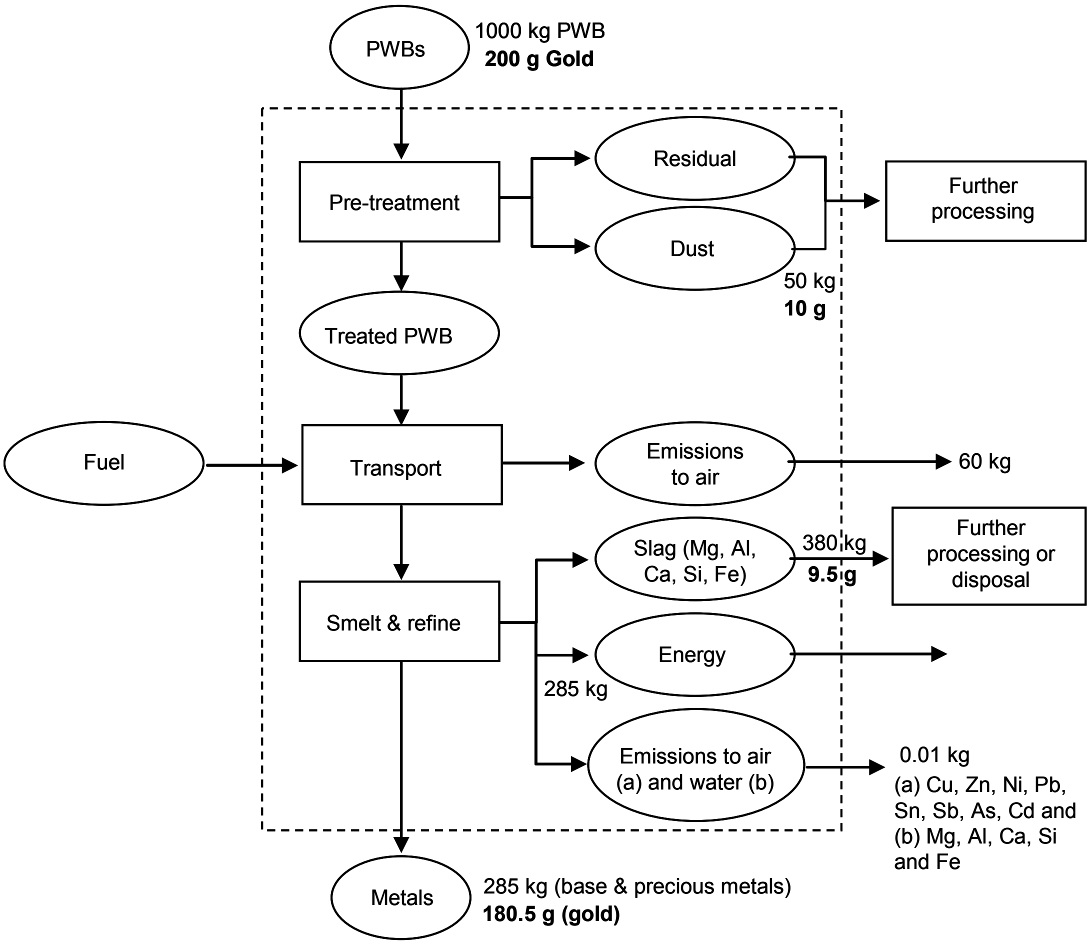
29. Nokia phones can be returned through their global Service Network and this is constantly promoted. The amount of material collected through the Network is relatively small and most of these are recycled. Some components and accessories are extracted during product warranty work (1-2 years) and reused. Some material that is "beyond repair" seems to find its way to Asian markets.

30. Since 2005, there have been national collection systems in the EU for all expired electronics including retail take back and municipal household collection. It should be recognised that consumers have an important role to play. Some national WEEE program information can be found at the following Swiss, Swedish and Spanish web sites: http://www.swico.ch, http://www.el-kretsen.se/, and http://www.asimelec.es/. Also see the WEEE-forum (*http://www.weee-forum.org/*) for more information.

31. The second-hand business in mobile phones is of growing importance. This include charities, special events, trade-in programs and such (all of which are different routes and different players, but they all profit from the resell of the returned devices). Some examples are: http://www.recellular.com/, http://www.regenersisplc.com/, and http://www.mopay.co.uk.

ANNEX 6: INTEGRATED SMELTER PROCESS FLOW

32. This simplified schematic shows the Umicore process used for recycling Printed Wire Boards (PWB).



Source: See Reference 95 (Rochat et al.. 2007)

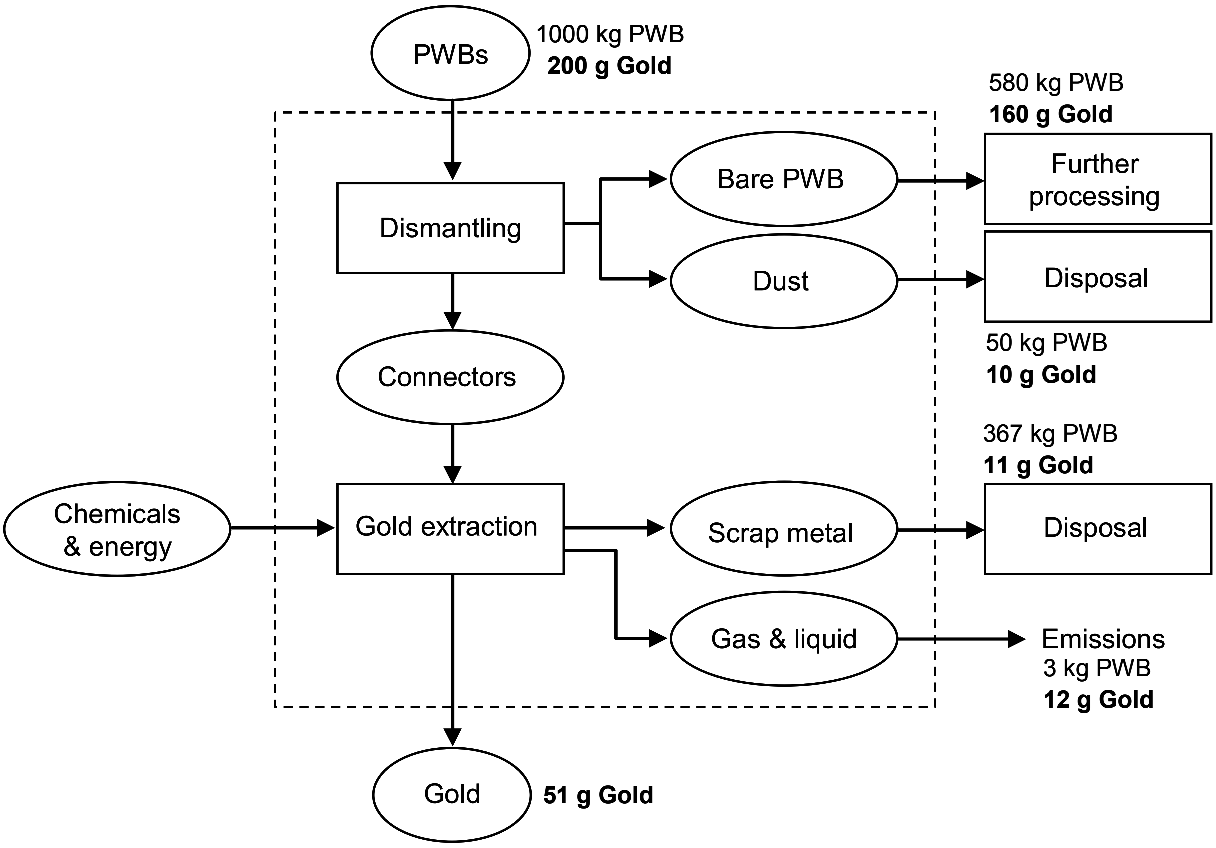
The Horne Smelter is located in Rouyn-Noranda, Quebec. The smelter is a custom copper smelter which uses both copper concentrates and precious metal-bearing recyclable materials as its feedstock to produce a 99.1% copper anode. The anode is shipped to Xstrata Copper's Canadian Copper Refinery in Montreal to produce refined copper, precious metals and other specialty metals and chemicals.

Ongoing capital investments have kept the facility at the cutting edge of technology, with a strong focus on emissions reduction. The Horne smelter has the capacity to process 800,000 tonnes per annum of copper and precious metal-bearing materials.

http://www.xstrata.com/operation/horn/

ANNEX 7: HYDROMETALLURGICAL PROCESS FLOW

33. Material flow for the hydrometallurgical artisanal treatment of Printed Wired Boards (PWB) with cyanide



Source: See Reference [95] (Rochat et al, 2007)

ANNEX 8: ENVIRONMENTAL IMPACT OF MATERIAL PRODUCED

34. This table presents the environmental impact associated with the primary production of several materials per kilogram. It is worth noting that several metals (Sb, As, Be, Cd, In) are not well characterised in terms of life cycle assessment or basic inventory data.

Material	GHG (kg CO2) [i]	Cumulative Energy Demand (MJ) [ii]	GHG (kg CO2) [iii]
glass	1.3	17	
plastic	5	108	
aluminum	12	201	
antimony	missing data	missing data	
arsenic	missing data	missing data	
beryllium	missing data	missing data	
cadmium	missing data	missing data	
cobalt	8	42	
copper	4	102	
gold	missing data	missing data	16 991
indium	missing data	missing data	142
iron	1.2	4	
lead	1.5	21	
magnesium (ref 4)	43	422	
nickel	10	196	
palladium	8 677	181 940	
platinum	13 954	290 770	
silver	missing data	missing data	144
tantalum	missing data	missing data	
tin	16	324	
zinc	2	missing data	

References:

[i] ecoinvent

[ii] Hagelücken, C. and Buchert, M. The mine above ground - opportunities & challenges to recover s scarce and valuable metals from EOL electronic devices. International Electronic Research Corporation (IERC) Salzburg. 2008.

[iii] LCA of magnesium - NRCan

ANNEX 9: PYROMETALLURGICAL RECOVERY YIELDS

35. This table presents the recovery rate for metals in different high efficient pyrometallurgical operations: (a) combined copper and lead collector and (b) copper smelter. Those facilities are able to recover the energy content of the organic material and to recycle several metals from mobile phones to the same grade (quality) as a primary producer. Some metals such as aluminum, beryllium, magnesium, silicon and tantalum report to the slag and are effectively lost.

Substance	Combined copper and lead collectors (Umicore [i] and may be Dowa Ec-Systems [ii])	Copper smelter (may apply to Boliden, Horne Smelter+CCR, Aurubis (Norddeutsche Affinerie))
organic	Energy recovery	Energy recovery
aluminum	slag	slag
antimony	yes	80%
arsenic	yes	
beryllium	slag	
bismuth	>95%	80%
cadmium	yes	
copper	>95%	>99%
gold	>95%	>99%
indium	yes	
iron	slag	slag
lead	>95% (43% Dowa)	>50%
magnesium	slag	slag
nickel	yes	>80%

palladium	>95%	>99%
platinum	>95%	>99%
selenium	yes	
silicon	slag	slag
silver	>95%	>99%
tantalum	slag (lost)	slag (lost)
tellurium	yes	
tin	yes	>50%
zinc	slag (12% Dowa)	>80%

References:

[i] Hagelüken, C. Mobile Phone Partnership Initiative (MPPI)-Study to test the recycling guideline, 2008-02.

[ii] Watanabe, K. and Nakagawara, S. The behavior of impurities at Kosaka Smelter. Kongoli F., Itagaki K., Yamauchi C., Sohn H.Y., Kongoli F., Itagaki K., Yamauchi C., and Sohn H.Y. Metallurgical and Materials Processing: Principles and Technologies Volume II: High-temperature metals Production. 2, 521-531. 2003///. San Diego, CA, TMS (The Minerals, Metals & Materials Society). Yazawa International Symposium: Metallurgical and Materials Processing: Principles and Technologies; High-Temperature Metal Production. 2 March 2003 through 6 March 2003.

ANNEX 10: FORWARD VERSUS REVERSE LOGISTICS

36. The Reverse Logistics Executive Council presents extensive information on their web site (see under table) that illustrates the challenges faced by the private sector when it undertakes the task of taking back old or spent products such as mobile devices.

Forward logistics	**Reverse logistics**
Product quality uniform	Product quality not uniform
Disposition options clear	Disposition not clear
Routing of product unambiguous	Routing of product ambiguous
Forward distribution costs more easily understandable	Reverse costs less understandable
Pricing of product uniform	Pricing of product not uniform
Inventory management consistent	Inventory management not consistent
Product life cycle manageable	Product life cycle less manageable
Financial management issues clearer	Financial management issues unclear
Negotiation between parties more straight-forward	Negotiation less straight-forward
Types of customers easy to identify and market to	Types of customers difficult to identify and market
Visibility of process more transparent	Visibility of process less transparent

Source: *www.rlec.org*

ANNEX 11: OLD OR OBSOLETE MOBILE PHONES IN CANADA

37. The purpose of Annex 11 is to summarize/estimate the flow (sale, use, disposal, storage and/or recycling) of cellular or mobile phones in Canada, which may or may not be typical of other OECD countries. Existing and recent industry stewardship efforts may also be of interest and have been referenced in the main report.

1. How is the telecommunications industry structured and who are the players?

38. The Canadian Radio-television and Telecommunications Commission (CRTC) regulates and supervises these two industries: broadcasting and telecommunications. The CRTC is an independent public agency that reports to Parliament via the Minister of Canadian Heritage (which is a Government of Canada department).

39. The CRTC has a mandate to ensure that Canadians receive reliable and affordable telephone and other related services but this role is changing. Where once there were only a few service providers there are now many, with a plethora of packages and associated prices driving competition. In addition, the lines between broadcasting and telecommunications are blurring as the technology evolves, especially where various Internet services are concerned.

40. Industry Canada manages and licences the use of the radio-frequency spectrum. In this regard, Ttere are a number of national and regional licensed wireless carriers in Canada most of whom are members of the Canadian Wireless Telecommunications Association (CWTA):[2]

- Aliant
- Bell Mobility
- Bruce Telecom
- KMTS Mobility
- MTS Communications Inc
- Nexicom Mobility Inc.
- Rogers Wireless Partnership
- SaskTel
- Sogetel Mobilité Inc.
- TBay Tel
- TELUS Mobility
- Wightman Telecom Ltd.
- Virgin Mobile

41. The three largest carriers (Rogers, Bell and TELUS) account for 94% of the market.

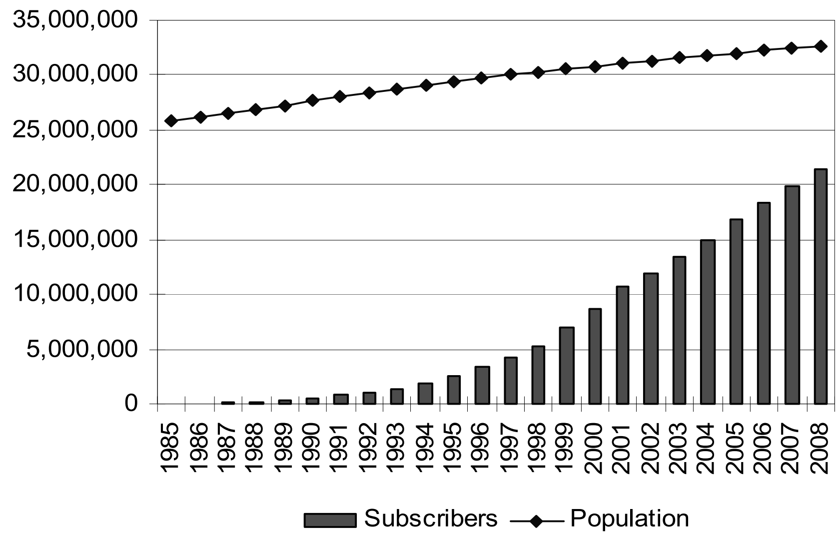
42. Cellular or mobile telephones are available from manufacturers around the world. The big three manufacturers are Nokia, Motorola and Samsung while LG Electronics, Sony Ericsson and BenQ-Siemens cover relatively minor shares of the market. The largest Canadian producer of "smartphones" (Blackberry) is Research In Motion: The parts are from Asia and some assembly work is done in Canada.

[2] Canadian Wireless Telecommunications Association, *http://www.cwta.ca/*

2. How big is the mobile phone market?

43. According to the CWTA, in December 2008, the number of wireless phone subscribers was 21.5 million, which means a market penetration rate of more than 67% (this figure is 70-80% in large urban areas). Over 98% of Canadian households have access to a wireless service, with 72% having subscription (which is low relative to other OECD countries where countries such as Italy have a penetration rate of 151%).[3,4] However, half of all calls made in Canada are from mobile units. Wireless service revenues in Canada totalled $14.4 billion in 2007. Figure A compares Canadian population growth with wireless subscription growth, from 1985 to 2008.

Figure A: Canadian Wireless Subscription (1985-2008)



3. What voluntary stewardship activities are underway regarding end-of-life mobile phones?

44. In Canada, voluntary stewardship activities for end-of-life mobile phones have been initiated by telecommunications service providers, mobile phone manufacturers and an array of other players including retailers, charities, a battery association and security firms.[5] This free market approach to stewardship means that it is very difficult to have a comprehensive set of data. The carriers' recycling programs typically partner with a certified recycler and an environmental or socially oriented charity. Current mobile phone recovery programs by companies affiliated with CWTA include:

- Bell Blue Box (supporting World Wildlife Fund)
- MTS, "Think Recycle" (supporting Resource Conservation Manitoba)
- Rogers Communications Inc. (supporting "Phones-for-Food")

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[3] CRTC Communications Monitoring Report, 2008, *http://www.crtc.gc.ca*

[4] *http://www.oecd.org/dataoecd/24/32/43472431.pdf* (accessed August 2009). The 151% Italian wireless subscription rate means that there are about one and a half subscriptions per person.

[5] CWTA, 2009, Recycle My Cell – CWTA Stewardship Plan for the Recycling of Cellular Phones in the Province of British Columbia, Stakeholder consultation, *http://www.cwta.ca/*

- SaskTel's Phones for a Fresh Start (supporting PATHS)
- TBayTel (supporting "P.R.O. Kids")
- TELUS "Return & Recycle" (supporting Trees Canada)
- Motorola ("Mobile Devices Takeback Program")
- Videotron Allo la Terre (supporting Earth Day Quebec's Allo la Terre)
- Virgin Mobile Canada's Red is the New Green

45. Additional mobile phone collection programs are conducted by outfits not affiliated with CWTA because of the device's intrinsic metal value. These other collection activities are generally not tracked so the size or success of these activities is unknown. This makes national reporting somewhat problematic. Here is a list of other programs operating in Canada:

- Best Buy and Future Shops
- Canadian Diabetes Society ("Project Redial")
- Charitable Recycling Program
- Pitch-In Canada
- Project Redial
- The Rechargeable Battery Recycling Corporation
- Various U.S. based collectors accept mobile phones by mail

4. Are there any mandatory stewardship activities for mobile phones in Canada?

46. Provincial and territorial regulations have jurisprudence over disposal/recovery of mobile phones. EPR programs for waste electronic and electrical equipment (WEEE) are rolling out across the country and are now active in British Columbia (B.C.), Alberta, Saskatchewan, and Nova Scotia, with Ontario coming on-line April 2010 (which is about 67% of Canada's population). In B.C. and Saskatchewan, mobile phones are not included under their WEEE regulations. In the Alberta Electronics Designation Regulation, electronics include mobile phones and other wireless devices.[6] In Ontario, the mobile phones are included as a Schedule 3 item in the OES stewardship plan.[7]

47. In Nova Scotia and B.C., where the CWTA Recycle My Cell program has received regulatory approval, this new stewardship plan is based on their national (no fee) model.[8] Whilst CWTA acts as a coordinating and liaison agent for its members, take back programs that are run by the various companies will continue as is. However, as required by the province, CWTA will track and report all materials collected including quantity returned and the corresponding amounts resold or recycled. The approved CWTA plans identify a set of "performance indicators" for "ongoing evaluation" of their mobile phone collection program. At this time, a recovery target is not specified; rather, the broad based assessment process will include annual consumer awareness surveys, waste audits, web site traffic, toll free number calls or the like.

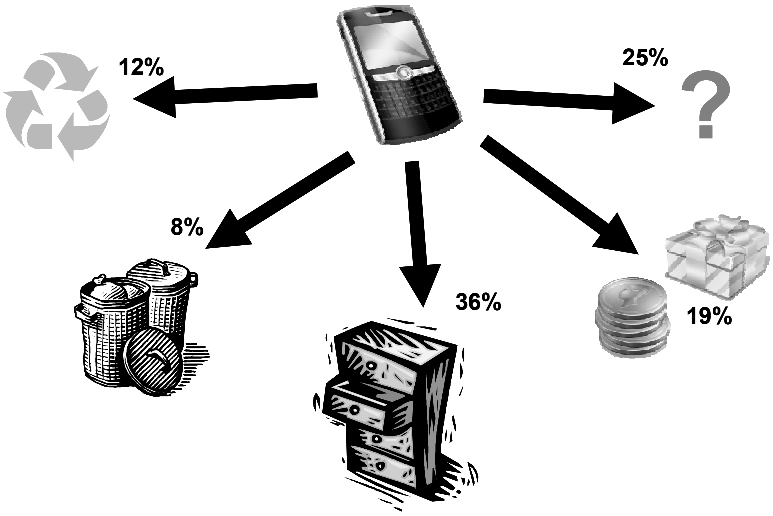
48. Recycle My Cell has also been formally recognized by the provinces of Prince Edward Island, New Brunswick, Manitoba, Newfoundland and Labrador, and Saskatchewan as the official cellular phone stewardship program within those provinces.

5. What is the estimated flow of end-of-life mobile phones?

49. CWTA reported the results of a 2008 user survey in which expected mobile phone lifespan was found to be 2.5 years (which is longer than the 18 months referenced in the main report). What people said they do with old or obsolete mobile phones in Canada is shown in Figure B. The CTWA also reports that in 2008, its member companies collected 360,167 old mobile phones; however, non-member recovery data were not discovered and may be significant.

[6] *http://www.qp.gov.ab.ca/documents/Regs/2004_094.cfm?frm_isbn=9780779725168*
[7] *http://www.wdo.ca/content/?path=page80+item38686*
[8] See *http://www.tourismhrc.com/current-newsletter.php*?article=499 for Jan-2009 news release.

Figure B: CTWA Mobile Phone User Survey, 2008



50. Since mobile devices eventually find their way into a recycling program or be discarded, the 12% recycling number can be adjusted up. For this purpose, it is possible to develop a conceptual flow model for estimating the number of mobile phones reaching end-of-life each year in Canada. However, many **assumptions** are required to bridge the information gaps that exist, as follows (the stages referenced in Figure C appear below in "parentheses"):

- One wireless subscription equals one mobile device;
- One third of mobile phones last 1 year, one third last 2 years and one third last 3 years (for an average of 2 years);
- Mobile phones for which the survey registered null (25%) are probably lost and are assumed to be discarded (total discard at this point equals 25% + 8% = 33%);
- During the first program cycle ("Triage 1" = 12%), it is assumed that 30% of recovered the cell phones are recycled and 70% are refurbished/resold/reused;[9]
- Mobile phones that are given away, sold or hoarded are "delayed" (totaling 55%) and will eventually be recycled or discarded (assumed to be 50/50) in one year (occurring in "Triage 2" – see Figure B).[10]
- Of those mobiles that are reused/resold, it is assumed that 30% are for the North American market and 70% are exported[11] ("Refurbish 1");
- Mobile phones "Delayed" domestically are recycled or discarded 50/50; for those that were reused domestically (following "Refurbish 1"), it is assumed that the split between "Triage 2" and "Domestic Discard" is also 50/50;

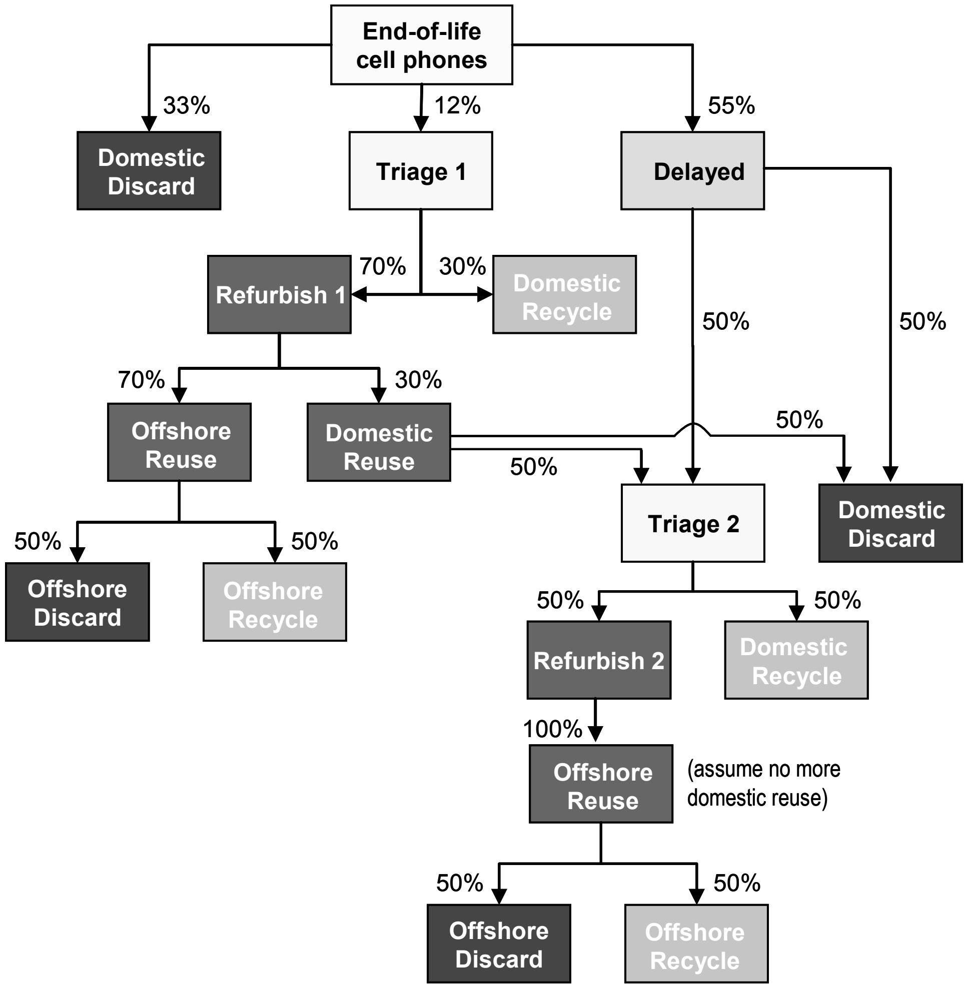
[9] CSR et al., 2005, "Waste Electronic and Electrical Equipment Study," Waste Diversion Ontario, S. 2.4.3
[10] The CWTA survey found that average cell phone storage time was 15 months; in the model this is rounded to one year.
[11] CSR et al., 2005

- Of mobiles processed via "Triage 2", 50% are recycled domestically and 50% are exported for reuse;
- The final offshore fate is assumed to be 50/50 for recycle/discard.

51. From Figure C and based on the assumptions provided, Table B provides a summary of estimates for the fate of Canadian mobile phones. The rows do not add up to 100% because of rounding, estimated cell phone life spans and other assumed delays.

Year	Total subscribers	New or used phones bought	End-of-life	Recycled in Canada	Discarded in Canada	Exported
1990	525,662	344,000	136,000	17,000	68,000	20,000
1991	771,060	474,000	228,000	28,000	114,000	33,000
1992	1,023,810	593,000	340,000	45,000	178,000	53,000
1993	1,321,387	768,000	470,000	66,000	253,000	77,000
1994	1,868,882	1,159,000	612,000	90,000	337,000	104,000
1995	2,584,387	1,556,000	840,000	118,000	453,000	137,000
1996	3,414,711	1,991,000	1,161,000	163,000	625,000	189,000
1997	4,207,019	2,361,000	1,569,000	223,000	852,000	259,000
1998	5,317,247	3,080,000	1,969,000	296,000	1,101,000	341,000
1999	6,883,195	4,043,000	2,477,000	372,000	1,384,000	429,000
2000	8,731,220	5,009,000	3,161,000	470,000	1,756,000	542,000
2001	10,678,560	5,991,000	4,044,000	600,000	2,244,000	692,000
2002	11,934,565	6,271,000	5,015,000	762,000	2,818,000	876,000
2003	13,442,350	7,265,000	5,757,000	928,000	3,342,000	1,060,000
2004	14,984,396	8,051,000	6,509,000	1,062,000	3,804,000	1,211,000
2005	16,809,988	9,021,000	7,195,000	1,195,000	4,246,000	1,359,000
2006	18,425,194	9,727,000	8,112,000	1,327,000	4,746,000	1,512,000
2007	19,919,512	10,427,000	8,933,000	1,488,000	5,281,000	1,692,000
2008	21,455,194	11,261,000	9,725,000	1,635,000	5,779,000	1,856,000

Figure C: Conceptual Flow of Spent Mobile Phones in Canada



52. From the flow model, when 100 mobiles reach end-of-life it is estimated that about 27 are eventually recycled domestically and 73 are disposed of. Of those recycled the model estimates that 18 are recycled in Canada and 9 are recycled offshore. Of those discarded 64 become waste domestically and 9 are discarded offshore. At 70 grams per device, the total weight of Canadian mobile phones recycled in 2008 is estimated to be 167 tonnes with 457 tonnes disposed of. Again, these numbers are very rough and are intended to provide order of magnitude only.

6. How are spent mobile phones recycled in Canada?

53. The processing partners identified in the various provincial industry plans include Global Electric Electronic Processing Inc.[12] (GEEP), SIMS Recycling Solutions,[13] FCM Recycling,[14] GREENTEC International[15] and ReCellular.[16] The firms that are ISO 14001 certified work in complete

[12] *http://www.geepinc.com/*
[13] *http://www.simsrs-na.com/home*
[14] *http://www.fcmrecyclage.com/*
[15] *http://www.greentec.com/*
[16] *www.recellular.com*

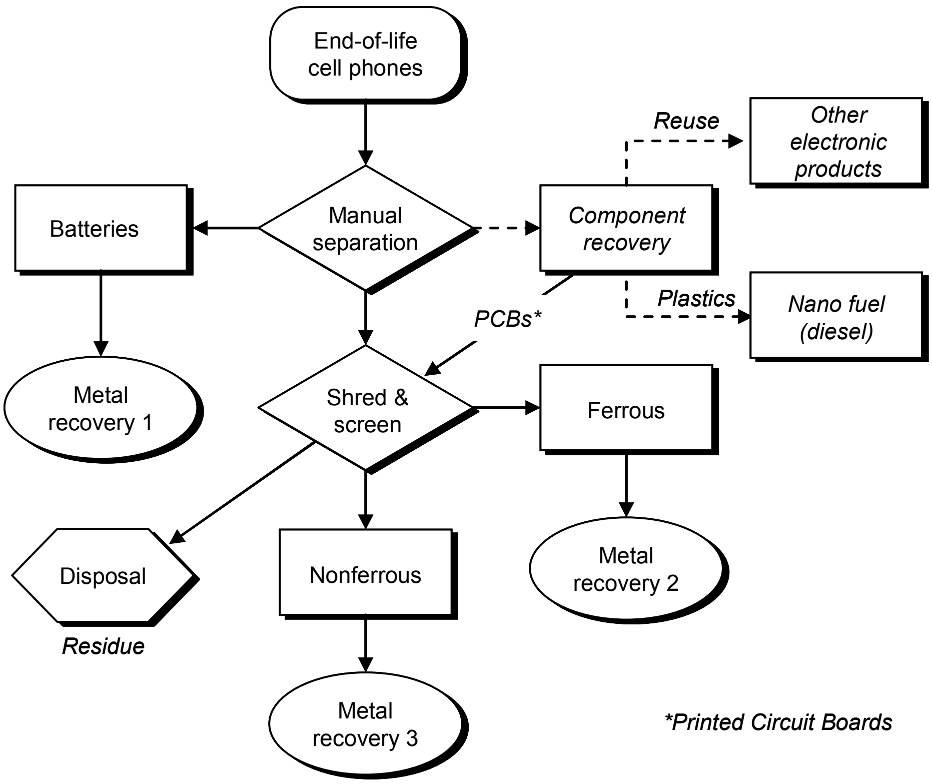
compliance with Basel Convention directives concerning transboundary movement of recyclable materials.

54. As an example of how mobile phones are recycled in Canada, a summary of the GEEP process is provided: At present, GEEP is executing the following processes;

55. **Harvesting of components**: GEEP executes a manual disassembly and the recovery for reuse of certain mobile phone components in other consumer electronic products: printed circuit boards are then shredded and screened (70% of PCBs are non-metallic[17]). This process also allows for the separation of plastic parts from metallic ones. With the plastic components, GEEP is exploring the potential use of nano fuel technologies and the conversion of plastic waste to a diesel product.[18]

56. **Recycling of whole units:** GEEP strips the batteries off mobile phones and then shreds the phones in 18 tonne batches, separate from other e-waste. Three fractions are produced: ferrous, nonferrous and plastics. The primary economic drivers are the copper and gold components but silver, palladium and platinum are recovered as well. The entire nonferrous fraction (screened at 1.9 cm) is shipped to an integrated pyrometallurgical smelter in Europe. GEEP prides itself on the generation of only 3.5% process residue with the rest being recycled. Figure D provides a conceptual materials flow for the GEEP mobile phone program.[19]

Figure D: Conceptual Materials Flow at GEEP



[17] Goosey, M., & Kellner, R. (2003). Recycling technologies for the treatment of end of life printed circuit boards (PCBs). Circuit World, vol. 29, no 3, 33-37.
[18] See *http://www.geepinc.com/nanofueltechnology.php*
[19] Adapted following communication with Dave Huculak, GEEP (March 2009)

7. How does mobile phone collection and recycling compare with other end-of-life waste electronic and electrical equipment (WEEE) management programs in Canada?

57. As noted previously, where a recycler like GEEP or SIMS process both WEEE and mobile phones, because of the proportionately high content of valuable metals, mobile phones are not mixed with other items. Therefore, to establish proper context, it can be estimated that if there are 20.1 million mobile/wireless devices in operation in Canada, at 70 grams for the body plus 30 grams for the battery, this represents about 1,840 tonnes of product. With 9.7 million mobiles available for reuse/recycling each year, 973 tonnes require end-of-life management. In contrast, based on some estimates from Ontario,[20] the amount of WEEE available for end-of-life collection in Canada is in the 240,000 tonne per year range.[21]

58. Insofar as the amount of WEEE currently being recovered in Canada (excluding mobile phones), Table C suggests that about 33,000 tonnes are being collected via four provincial programs[22] (representing about 30% of the Canadian population). These amounts will more than double when Ontario (with 38% of the population) launches its WEEE program in April 2009.

Table C: WEEE Stewardship Programs (2008 average monthly amounts)

Province	Tonnes/month	Population	kg/cap/yr
British Columbia	950	4,310,000	2.64
Alberta[23]	1,450	3,369,000	5.16
Saskatchewan	161	986,000	1.96
Nova Scotia	200	937,000	2.56

59. The amount of large appliances recovered across Canada via municipal, retail, multi-unit, scavenger and reseller programs was estimated in 2002 to be between 150,349 and 194,580 tonnes (representing between 74 and 92%).[24] Regardless of these high recovery rates, these items are included in future stewardship “schedules”, which also include small devices (that operate with a plug or a battery).

[20] Ontario Electronic Stewardship, 2008, Preliminary Waste Electrical & Electronic Equipment (WEEE) Program Plan, *http://www.ontarioelectronicstewardship.ca/*

[21] In Canada, WEEE generally excludes large household appliances.

[22] Data sourced from the four provincial WEEE stewardship web sites.

[23] Alberta is in its fourth year of operation whereas the others are in their first year.

[24] Hanson Research + Communications and Hilkene International Policy, 2005, Generation and Diversion of White Goods from Residential Sources in Canada, Electro Federation Canada and Government of Canada Action Plan 2000 on Climate Change

ANNEX 12: INCORPORATING SOCIAL ASPECTS INTO SUSTAINABLE METALS MANAGEMENT

60. The enclosed text provides a literature review and further discussion regarding social issues within the life cycle of metals and, by extension, materials and products. This annex supplements Section 2.4 of the main report. The corresponding author for this work is Professor Steven B. Young, +1-519-822-1660, *s4young@uwaterloo.ca*

1. Introduction

61. The Working Group on Waste Prevention and Recycling (WGWPR) of the Organisation for Economic Co-operation and Development (OECD) is undertaking four cases studies to explore policy opportunities and barriers associated with implementation of the concept of Sustainable Materials Management (SMM). One of the case studies, submitted by the Government of Canada, regards critical metals in consumer electronics.

62. Canada's proposed case study aims to shed light on the use and fate of metals used in consumer electronics, incorporating existing data about related material flows and discussions on the environmental and social impacts of metals over the whole life cycle. It addresses several issues, such as costs and benefits of SMM; consumer and producer interests; international and cross-sectoral dimensions; effects on the competitiveness of firms in the related industries; and the social implications of SMM. Given the many different kinds of consumer electronic devices, the study has been using mobile phones as a proxy to assess the environmental, economic and social aspects of the life cycle of metals.

63. The case study was divided in two phases. The ongoing Phase 1 will be completed by the end of April 2009; Phase 2 is expected to be completed by September 2009, so that it can be discussed at the WGWPR meeting in December 2009. Phase 1 consists mostly of literature reviews that will help identify existing information, approaches, and knowledge gaps. These gaps and the questions they raise will, in turn, inform the focus for developing new and existing approaches for Phase 2.

64. The present report, which is part of the works undertaken in Phase 1, has a threefold objective:

- Propose a framework that may help policy-makers identify barriers and opportunities associated with the management of social aspects in the life cycle of metals used in consumer electronics;
- Present a preliminary literature review related to the social aspects of the proposed framework.
- Illustrate the potential usefulness of the framework.

65. Two relevant limitations of this report should be acknowledged. First, it was based solely on literature reviews. Second, it was completed under a relatively constrained timeframe by two scholars.

Therefore, the information presented here focuses on the most relevant issues in connection to the scope. The authors, assuming that the readers are familiar with the main issues being discussed, have avoided extensive contextualization and conceptualizations.

66. The document is organized as follows. Section 2 discusses the challenge of incorporating social aspects in Sustainable Materials Management initiatives. Section 3 emphasizes the relevance of the emerging methods of Social Life Cycle Assessment (SLCA), and presents a SLCA-based framework that may help in the identification of barriers and opportunities associated with the management of social aspects in the life cycle of metals. Section 4 presents the result of a literature review regarding the framework's social aspects, pointing out knowledge gaps. Section 5 illustrates how the proposed framework can be used in the identification of managerial and policy tools that address social aspects in the life cycle of metals. Conclusions and recommendations for future studies are finally drawn in Section 6.

2. Sustainable Materials Management and the "Overlooked" Social Aspects

67. Sustainable Materials Management (SMM) is a concept that emerged from the need to harness the increasing socio-environmental externalities of materials flows in the biosphere. It is an umbrella term that is being related to the integration of a wide range of actions that may be applied during the extraction, manufacturing, use, transport, recycling and disposal of materials. Unlike the sustainable development concept, which found an influential definition in a particular point in time (WCED, 1987, p. 8), the definition of SMM is still in formative stages. Joseph Fiksel, in one of the most seminal works on this emerging concept, defined SMM as

> *... an integrated approach toward managing material life cycles to achieve both economic efficiency and environmental viability. Material life cycles include all human activities related to material selection, exploration, extraction, transportation, processing, consumption, recycling, and disposal. (Fiksel, 2006, p. 17)*

68. Fiksel's definition emphasizes the integration of actions during the life cycle of materials. However, his approach focuses on the environmental and economic dimensions of sustainability. According to this author, SMM strategies can be separated into two categories: dematerialization (reduction of material throughput in an economic system) and detoxification (reduction of adverse human or ecological effects associated with materials use).

69. A more comprehensive working definition has been proposed by the aforementioned Working Group on Waste Prevention and Recycling and others during the First OECD Workshop on SMM:

> *Sustainable Materials Management is 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. (OECD, 2007, p. 3)*

70. This working definition also emphasizes the integration of actions during the life cycle of materials. However, it does so by referring not only to economic and environmental issues, but also to the need to consider social equity. It thus acknowledges to a certain extent the social dimension of sustainability. Yet the main focus is still on "reducing negative environmental impacts and preserving natural capital".

71. The limited attention to social aspects of those definitions is reflected in initiatives related to SMM. A recent compilation of such initiatives undertaken by the OECD (2008a) makes it clear. Only a few of the 68 compiled initiatives were found to address social issues. The overall majority covered environmental-focused tools related to eco-efficiency, eco-design, green procurement, extended producer responsibility, among others. The same argument holds true for SMM methodologies. An OECD study reviewed ten methodologies that are relevant to assess material use in terms of its potential impacts on the environment, society and economy. It found that nine methodologies were applicable to the assessment of environmental issues; five to economic issues; and only two to social issues (OECD, 2008b). The latter (Total Cost Assessment and Cost Benefit Analysis) had, nonetheless, a narrow approach, as they addressed social aspects primarily through an economic lens. Attempts to apply the principles of SMM to metals have also downplayed non-environmental issues (Gleich, Ayres, & Göbling-Reisemann, 2006; Zeltner, Bader, Scheidegger, & Baccini, 1999).

72. Given the importance of integrating social and economic and environmental dimensions in sustainability strategies (Atkinson, Dietz, & Neumayer, 2007; Dalal-Clayton & Bass, 2002), future years are likely to witness increasing efforts towards the consideration of social aspects in sustainable materials management as well. A significant barrier to be overcome, however, will be the diversity of approaches that can inform this challenge.

73. "Social issues", like SMM itself, is an umbrella term to describe a wide range of matters that affect society. They can involve negative problems, such as violence, conflict, injustice, corruption, racism, war, unemployment; or positive effects, such as job creation, peace, comfort, convenience, and pleasure. These issues can affect society in various scales, from small employee groups, to local communities or the global population in general. Moreover, the effects can overlap, combine and/or change across the life cycle of materials.

74. To date, there is not a single SMM initiative or methodology trying to address the diversity of social issues in the life cycle of materials. As the OECD studies (OECD, 2008a, 2008b) have shown, efforts usually concentrate on particular aspects and life cycle stages. Recent developments in the emerging field of social life cycle assessment are, nonetheless, hinting at comprehensive ways that may help to frame this challenge.

3. A SLCA-based Framework for Incorporating Social Aspects in SMM

75. The emergence of the SMM concept is tied to the realization that "looking only at wastes, i.e. end-of-life materials resulting from human activities, is no longer sufficient" and that "a more creative and far-sighted solutions that employ life-cycle thinking (…)" are needed (OECD, 2007, p. 2). In this context, life cycle assessment (LCA) emerges as one of the most relevant tools to SMM, as it allows for such "far-sighted" approach.

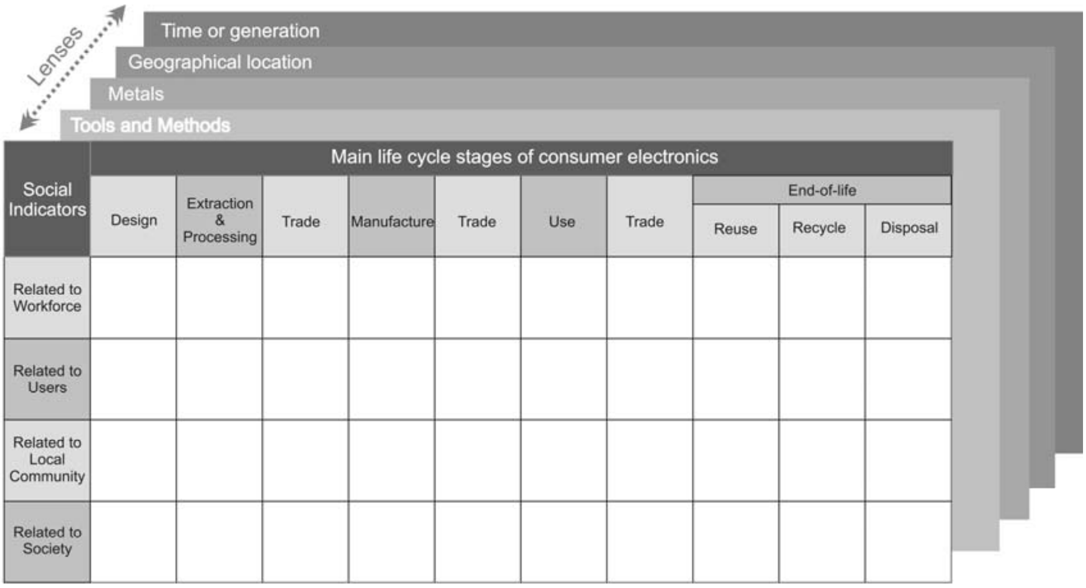
76. LCA is a methodology for assessing impacts throughout the life cycle of a product, material, process or activity, by identifying, quantifying and evaluating environmental and health aspects. This tool has received widespread adoption in decision-making regarding environmental issues. But because it fails to address social issues, its value as a tool to support sustainability-oriented strategies is frequently questioned (Dreyer, Hauschild, & Schierbeck, 2006). In the past years, however, there has been a growing interest in the incorporation of social aspects in LCAs. Such efforts are being referred to as social LCA (SLCA) or, when including environmental aspects, sustainability LCA.

77. SLCAs are particularly important because they have been dealing with many of the challenging questions that are relevant to making SMM more inclusive to society's needs: What social aspects should be considered? How to assess or measure these aspects? Which types of indicators should be used? Should they be quantitative, semi-quantitative or qualitative? Do SLCAs need new areas of protection, such as well-being? A variety of methodologies for SLCA have been developed in the past few years (Barthel, Pflieger, & Held, 2007; Brent & Labuschagne, 2008; Dreyer, *et al.*, 2006; Grießhammer, *et al.*, 2006; Hauschild, Dreyer, & Jorgensen, 2008; Hunkeler, 2006; Kruse, Flysjö, Kasperczyk, & Scholz, 2009; Labuschagne & Brent, 2006; Manhart & Grießhammer, 2007; Norris, 2006; Pedersen, 2003; Weidema, 2006). Each of these carries particular assumptions and interpretations.

78. Andreas Jorgensen and others (2008) recently compared fourteen methodologies and "found a multitude of different approaches with regards to nearly all steps in the SLCA methodology, reflecting that this is a very new and immature field of LCA." In spite of this diversity, their study made clear that there is an emerging trend related to the adoption of social midpoint indicators in connection with stakeholder categories. That is, the social indicators in most of the evaluated methodologies were being addressed in the context of impacted stakeholder groups, such as workforce, local community, users/consumers, and society in general. As for the specific indicators, they have been drawn from international norms and standards such as the Global Reporting Initiative (GRI, 2006) and the International Labour Organization Conventions. The sense-making power of such approaches to categorizing social aspects has been corroborated by its adoption in the UNEP/SETAC's Task Force on the Integration of Social Criteria into LCA (Grießhammer, *et al.*, 2006; UNEP/SETAC, 2008-2009), which gathers several of the world's top specialists in this emerging field.

79. The present report followed the same rationale in designing a framework that may help policy-makers identify barriers and opportunities associated with the management of social aspects across the life cycle of metals used in consumer electronics. The proposed framework, shown in Figure 1, correlates the main life cycle stages of metals used in electronics with 26 social indicators arranged according to 4 stakeholder groups. Given the context of the proxy research focus on mobile phones, under which the present study has been undertaken, the framework's selected life cycle stages mirror the stages emphasized in studies on the life cycle of mobile phones (GSMA, 2006; McLaren, Wright, & Parkinson, 1999; Scharnhorst, Hilty, & Jolliet, 2006). They include design, extraction and processing, manufacturing, use, trade, reuse, recycle and disposal. The categorization of impacted stakeholder groups and social indicators was, in turn, based on the most commonly found approaches in the aforementioned methodologies of SLCA. Selected stakeholder groups encompass workforce, users, local community and society. The specific indicators can be seen in Appendix 1, which will be explained further on.

Figure 1 – Metal's Social Issues Identification Framework



80. As opposed to SLCAs, the proposed framework does not aim at "assessing" social impacts or evaluating trade-offs among life cycle stages or with other environmental and economic issues. Therefore it makes no requirements as to how quantify, normalise and valuate social aspects. The purpose of the framework is simply to (1) help build a qualitative understanding of the most relevant social issues across the life cycle of metals used in electronics; and (2) relate those issues to tools, geographical regions, specific metals, institutions, time, etc. For the second purpose, it adopts a lenses approach similar to the one developed by Beloff and others (2004). Through this approach, the scope of the qualitative understanding of social issues can logically be expanded to include:

- tools that can be applied in the management of social aspects;
- institutions and organizations;
- sensitive geographical regions;
- changes over time;
- metals of concern.

81. The framework was designed to help grasp the "big picture" related to the incorporation of social aspects in sustainable metals management. It can help identify, among others, relevant social problems, knowledge gaps, critical metals, sensitive areas, and opportunities for collaborations among institutions. It can also help to promote the integration of actions across the life cycle, which is a key requirement of the SMM concept. Public or private organizations are likely to find the framework useful as a "first step", before more quantitative and focused actions are taken. The qualitative and exploratory nature of the framework is consistent with the rather embryonic nature of the studies related to the incorporation of social aspects in SMM.

4. Preliminary Literature Review of Social Aspects in the Life Cycle of Electronics

82. A literature review was undertaken in order to obtain a preliminary understanding of the framework's social indicators that are likely to be relevant in the life cycle of metals used electronics (particularly mobile phones). Given the limitations of this study, the review covered only a few dozen reports and publications that were made available in the English language. The search covered studies in connection with the various metals used in mobile phones. Studies related to electronics in general were considered when their respective discussions were applicable to mobile phones as well. Results were systematically summarized in the Appendix and presented below according to each life cycle stage. Final considerations are drawn at the end of this section.

Design

83. The literature review revealed issues of concern in connection with the indicator "quality of product or service" (to users), as well as with the indicator "prevention of unjustifiable risk" (to society). The academic paper of Han and others (2004) shows how some design features of mobile phones are critical to user satisfaction. Several publications (Boswell, 1999; Brigden, Santillo, & Johnston, 2008; Byster & Smith, 2006; Han, *et al.*, 2004; Rifer, Brody-Heine, Peters, & Linnell, 2009) discuss how the "choices" by electronic companies' of materials and metals can lead to unjustifiable risks to society, insofar as these materials can lead to serious health problems to workers in the end-of-life of electronics. The report of Rifer and Boswell also point out that the lack of life cycle thinking in the design can hamper the recyclability of electronics.

Raw Material Extraction and Processing

84. Many publications, mostly published by NGO organizations, were found to address social issues of concern in the extraction and processing of minerals and metals (CorpWatch, 2007; Cox, 2009; Farrell, Sampat, Sarin, & Slack, 2004; FOE, 2003; Grossman, 2006; GW, 2005, 2006; Hayes & Burge, 2003; Norbrand & Bolme, 2007; Poyhonen & Simola, 2007; Steinweg & Haan, 2007). Those issues were related to almost every indicator of the framework, with the exception of the indicators related to consumer stakeholders. The publications have a diversity of purposes and scopes. Some address the problems of specific minerals, such as the conflicts related to coltan mineral (tantalum) mining (Hayes & Burge, 2003), or the bad performance of specific metal companies (Global Witness, 2006). Overall, the publications suggest that the impacts on the workforce and on local communities hosting mining operations deserve special attention in policy-making.

Trade of Metals

85. Only three publications (SOMO, 2008; Steinweg & Haan, 2007; Young, Dias, Fonseca, & O'Keefe, 2008) were found to address the social aspects of trade of metals. The publications show the relevance of the indicators "transparent business information" and "unjustifiable risks to society" in the trade of metals used in electronics. According to Young and others, the structure of the metal market and the lack of transparency in trade represent a barrier to the consideration of the social problems of extraction in the ethical supply management of metals used in electronics.

Manufacturing

86. Numerous publications were found to address social issues in the manufacturing of electronics. The majority of these discussed labour-related problems/indicators (Astill & Griffith, 2003; CEREAL, 2006; Chan, 2008; Chan, Haan, Nordbrand, & Torstensson, 2008; Chan & HO, 2008; Ferus-Comelo, 2006; ILO, 2007; Manhart, 2007; SACOM, 2006; Schipper & Haan, 2005, 2007;

Seibert, 2007). A few publications addressed indicators in connection with local communities (Brigden, Labunska, Santillo, & Walters, 2007; Byster & Smith, 2006; Manhart, 2007) or with society in general (ILO, 2007; Manhart, 2007; Manhart & Grießhammer, 2006; Poyhonen & Simola, 2007). The review makes clear the existence of significant of labour-related concerns in the manufacturing of electronics, especially in Asia and developing countries.

Trade of New Electronics

87. No publications addressing social aspects in the trade of new electronics were found.

Use of Electronics

88. Only two of the many reviewed publications gave attention to social aspects in the use of mobile phones (Drori & Jang, 2004; Ling, 2004; Scott, Batchelor, Ridley, & Jorgensen, 2004). Particularly relevant is the book of Rich Ling (2004) which presents several aspects (mostly positive) associated with the use of mobile phones, reflected in the indicators “improvement of social and economic opportunities”, “quality of product or service”, and “protection of privacy”. The publications also stress mobile phones as a technology that contributes in several ways to national economies.

Trade of Used Electronics

89. The publications addressing social issues in the trade of used electronics were mostly discussing the risks to society resulting from the trade of e-wastes (BAN, 2002; Cobbing, 2008; Gregory, Magalini, Kuehr, & Huisman, 2009; Johnson & Graedel, 2008; Johnston, 1998; Puckett, 2006; Puckett, *et al.*, 2002; Weston, 2009). These publications discussed issues of transparency, illegal and “hidden” commerce, responsibilities of producers and consumers of electronics.

Reuse

90. No publications addressing social aspects in the reuse of mobile phones were found. It is noteworthy, however, that arguments in two identified publications on the benefits of reusing computers (James, 2001; Williams, *et al.*, 2008) are applicable to mobile phones as well. That is, that the reuse of electronics (thus, mobile phones) can contribute to national economies and to lessening the global digital divide.

Recycling

91. The literature review revealed issues of concern mostly in connection with labour-related indicators (Allsopp, Santillo, & Johnston, 2006; Brigden, Labunska, Santillo, & Allsopp, 2005; Jackson, Schuman, & Dayaneni, 2006; Manhart, 2007). The publications show that the lack of appropriate working conditions in electronics recycling plants impose, for example, risks to the health and safety of employees. The aforementioned publications of James (2001) and Williams and others (2008) also show that recycling can contribute to national economies.

Disposal

92. A few publications made references to the impacts of e-wastes disposal to the health and safety of local communities surrounding landfills that receive e-wastes (Allsopp, *et al.*, 2006; Byster & Smith, 2006; Cox, 2009). Publications addressing other social indicators are likely to abound in the literature but were not discovered during the study.

Final Considerations

93. The Appendix (based on the framework presented in Figure 1) places a reference for each publication reviewed in this study as it relates to the social indicators and the life cycle stages of consumer electronics. It shows that the overall majority of publications are addressing "negative" social indicators in the extraction of minerals/metals, manufacturing of electronics and trade of e-wastes. This table in the Appendix, therefore, "suggests" knowledge gaps related to positive social indicators, as well as to particular life cycle stages, such as trade of new electronics and disposal of e-waste. Additional research would be necessary to confirm these gaps, and to evaluate whether the lack of information on those areas was a result of the limitations of this study's scope and methods. The authors recognize that the classification of publications according to the social indicators is not precise: it reflects their particular interpretations. In spite of these limitations, the Appendix provides an initial and broad-based sense of the diversity of relevant social issues across the life cycle of metals used in electronics.

5. Identifying Relevant Tools to Address Social Aspects in the Life Cycle of Metals

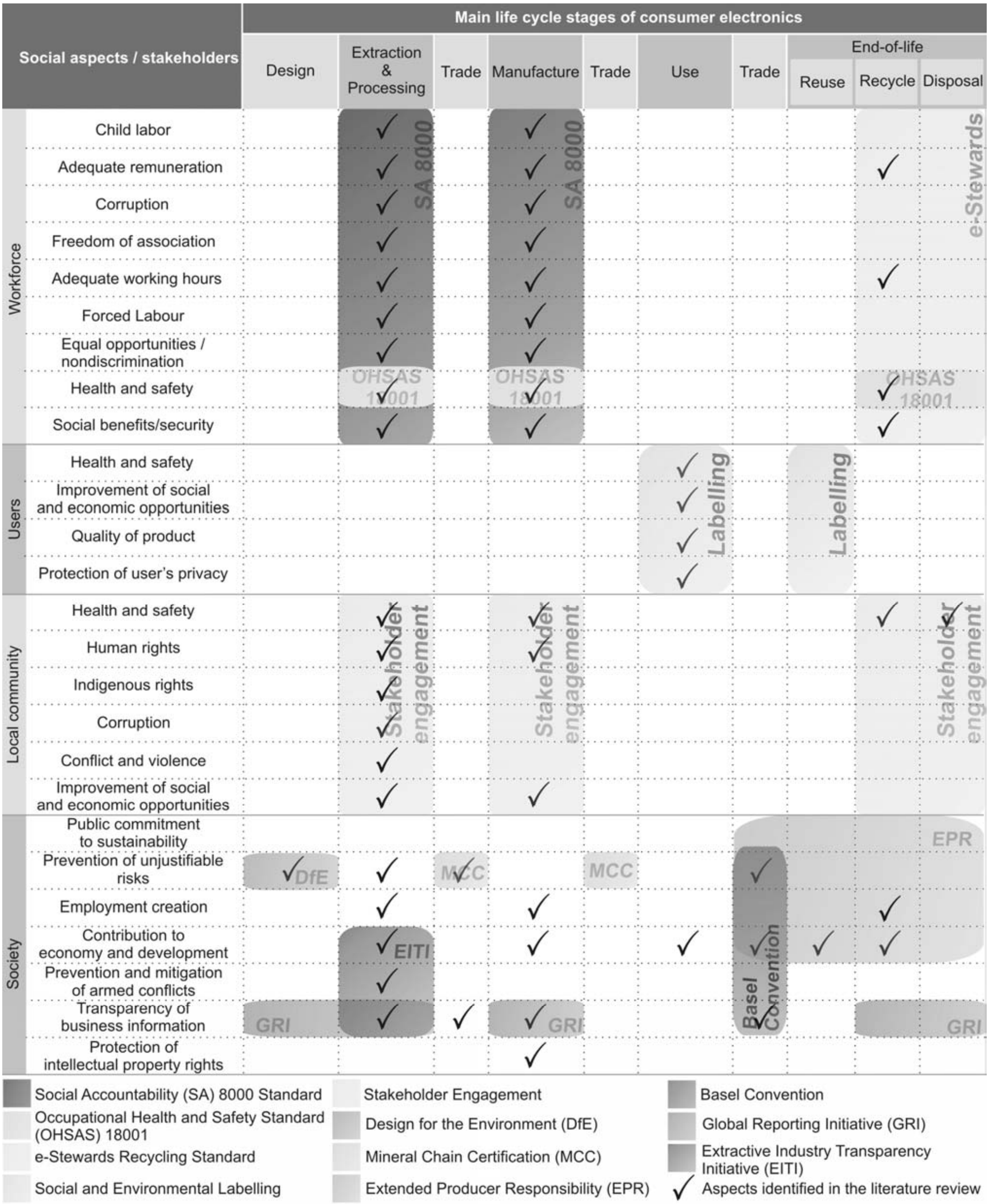
94. The literature review made evident that the majority of the 26 social indicators categories are likely to be relevant in policy-making targeting sustainable metals management. Policy-makers are, however, unlikely to find a single tool that can address this diversity. The challenges imposed by each indicator vary not only according to the nature of the indicator per se, but also according to stakeholder groups and life cycle stages.

95. In order to illustrate the usefulness of applying the lenses of the Framework presented in Figure 1, a set of 11 tools were correlated to the social indicators across the life cycle stages. In undertaking this correlation, tools were broadly defined to include public, private, voluntary or regulated instruments that may positively affect the social indicators. The correlation (shown in Figure 2) considered specific tools or categories of tools. For example, the various instruments that can be applied in initiatives related to "Design for the Environment" and "Extended Producer Responsibility" were considered broadly, as a whole.

96. As Thomas Birkland (2005) explains, policy tools refer to a variety of instruments (economic, regulatory, educational, etc.) whose taxonomies have long been debated. There is not a consensus on how to classify them or on how to rank their relevance in the context of social responsibility. The 11 tools presented in Figure 2 were selected based on the authors' own experience and insights. Many other tools could have been included in the framework. In spite of this limitation, Figure 2 illustrates the variety of actions that are necessary to address social issues in the life cycle of metals. From social certification schemes and international agreements to third-party monitoring and reporting mechanisms, each tool has a particular scope and audience, part of which is illustrated.

97. When correlating the tools, the authors considered their primary scope, highlighting potential overlaps. The main purpose was to show the diversity of tools available to the management of social issues. Another approach to using lenses, to refine future analysis, would be to correlate only specific types of tools, or to correlate tools applicable only to a particular life cycle stage or social indicators. Narrower approaches might be more helpful in identifying opportunities for partnerships and synergies among organizations and social initiatives.

Figure 2 – Primary Scope of Tools that Address Social Aspects in the Life Cycle of Metals



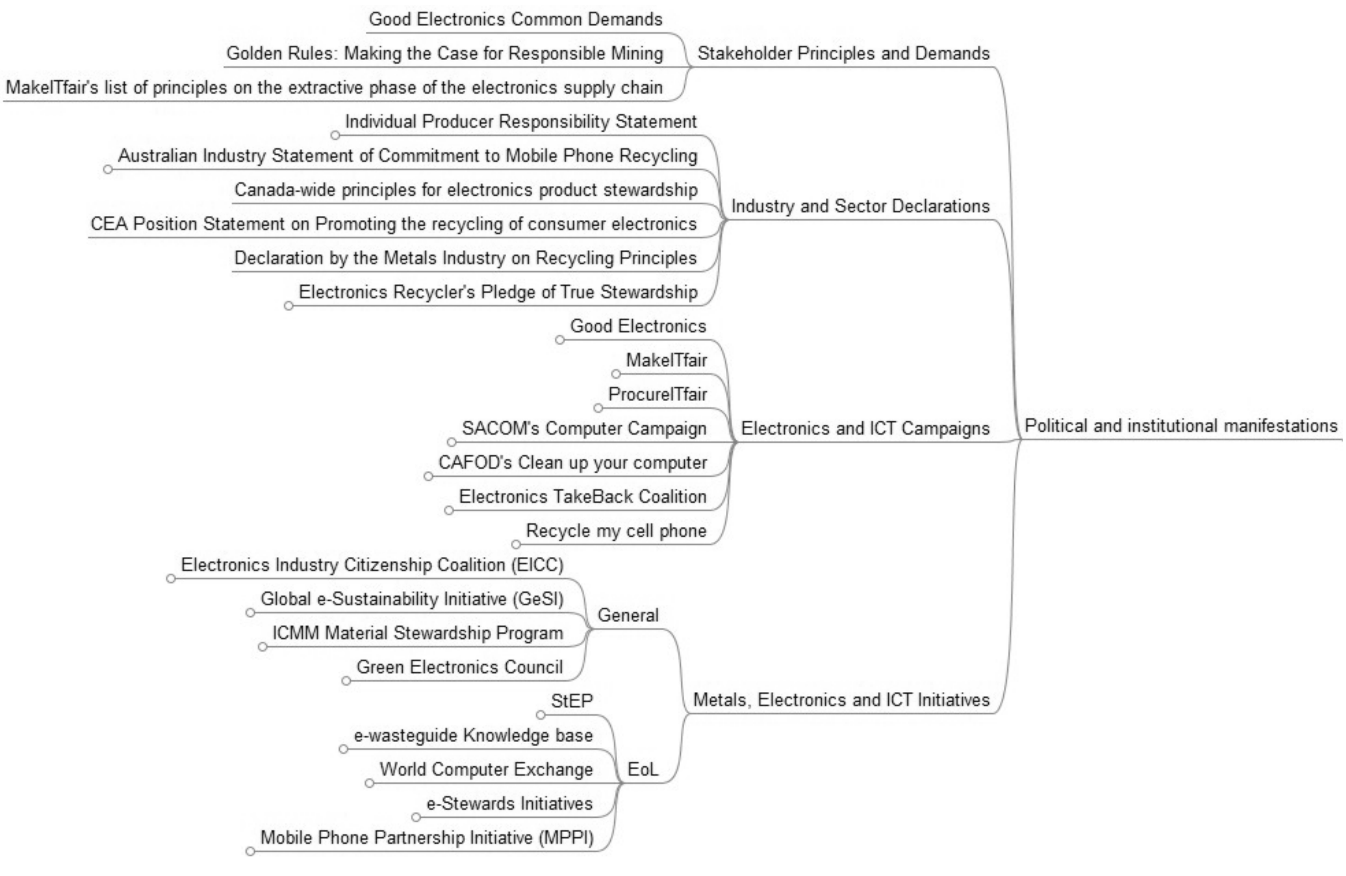
6. Conclusions and Recommended Future Work

98. This brief report has proposed a framework that may help policy-makers identify barriers and opportunities associated with the management of social aspects in the life cycle of metals used in consumer electronics. It has also presented a preliminary literature review related to the social indicators of the framework, and showed its usefulness in the identification of social-related policy tools. The main purpose of this study was to provide a means to explore ways to incorporate social aspects in SMM.

99. The literature review revealed that most of the 26 social indicators of the framework are likely to be relevant in the life cycle of metals used in mobile phones. Given the limitations of this study, future research would be necessary to test the relevance of these and other indicators, as well as of the stakeholder group categories. Specific criteria for the evaluation of each social indicator are also needed.

100. Future studies should consider the framework under lenses other than that of policy tools. One critical requirement for the integration of actions across life cycles is an understanding of political and institutional initiatives. Figure 3 shows some of the most relevant initiatives related to many social issues in the life cycle of metals used in electronics. A more focused evaluation of how these initiatives are related to social problems and life cycle stages may yield insights on how to integrate and find synergies among them. The investigation of how social issues vary for particular metals and geographical regions are also likely to be important for setting priorities and more focused actions.

Figure 3 - Political and Institutional Initiatives Related to Sustainable Metals Management



101. Finally, future studies should consider the expansion of the framework (Figure 1) to encompass not only social indicators, but also environmental and economic indicators in the same structure. Such expansion may facilitate the identification of trade-offs among these three sustainability dimensions and thus better inform decision-makers on the challenges of managing metal flows more sustainably.

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APPENDIX 1: CLASSIFICATION OF SOCIAL INDICATOR REFERENCES ACROSS THE LIFE-CYCLE

Stakeholder / social indicators			Main Life Cycle Stages of Consumer Electronics								
		Design	Raw Material Extraction and processing	Transport (see note below)	Manufacturing	Transport (see note below)	Use	Transport (see note below)	End-of-life		
									Re-use	Recycle	Disposal
Workforce	Child Labor		(Farrell et al, 2004), (Norbrand and Bolme, 2007), (Poyhonen and Simola, 2007), , (Steinweg and Haan, 2007)								
Workforce	Adequate remuneration		(Norbrand and Bolme, 2007)		(Astill et al, 2003), (CEREAL, 2006), (Chan, 2008), (Chan et al, 2008), (Chan and HO, 2008), (Ferus-Comelo, 2006), (Wilde and Haan, 2006), (ILO, 2007), (Kaiming and Xin, 2005), (Manhart, 2007), (SACOM, 2006), (Schipper, 2005, 2007), (Seibert, 2007)					(Jackson et al, 2006)	
Workforce	Corruption				(Wilde and Haan, 2006)						
Workforce	Freedom of Association		(Farrell et al, 2004), (Norbrand and Bolme, 2007)		(Astill et al, 2003), (CEREAL, 2006), (Chan et al, 2008), (Wilde and Haan, 2006), (Manhart, 2007), (Manhart and Grießhammer, 2006), (SACOM, 2006), , (Schipper, 2005, 2007)						

Stakeholder / social indicators			Main Life Cycle Stages of Consumer Electronics								
		Design	Raw Material Extraction and processing	Transport (see note below)	Manufacturing	Transport (see note below)	Use	Transport (see note below)	End-of-life		
									Re-use	Recycle	Disposal
	Adequate working hours		(Norbrand and Bolme, 2007)		(Astill et al, 2003), (CEREAL, 2006), (Chan, 2008), (Chan et al, 2008), (Chan and HO, 2008), (Ferus-Comelo, 2006), (Wilde and Haan, 2006), (Manhart, 2007), (Manhart and Grießhammer, 2006), (SACOM, 2006), , (Schipper, 2005, 2007)					(Manhart, 2007)	
	Forced Labor		(Farrell et al, 2004)		(CEREAL, 2006), (Ferus-Comelo, 2006), (Wilde and Haan, 2006), , (Schipper, 2005, 2007)						
	Equal Opportunities/ Nondiscrimination		(Farrell et al, 2004)		(Astill et al, 2003), (CEREAL, 2006), (Chan et al, 2008), (Wilde and Haan, 2006), (ILO, 2007), (Manhart, 2007), (Manhart and Grießhammer, 2006), (SACOM, 2006, , (Schipper, 2005, 2007), (Seibert, 2007)						

Stakeholder / social indicators			Main Life Cycle Stages of Consumer Electronics							
		Design	Raw Material Extraction and processing	Transport (see note below)	Manufacturing	Transport (see note below)	Use	Transport (see note below)	End-of-life		
									Re-use	Recycle	Disposal
	Health and Safety		(Farrell et al, 2004), (Norbrand and Bolme, 2007), (Poyhonen and Simola, 2007)		(Astill et al, 2003), (Byster et al, 2006), (CEREAL, 2006), (Chan, 2008), (Chan et al, 2008), (Chan and HO, 2008), (Ferus-Comelo, 2006), (Foran and Sonnenfeld, 2006), (Grossman, 2006), (Kaiming and Xin, 2005), (Manhart, 2007), (Manhart and Grießhammer, 2006), (SACOM, 2006), , (Schipper, 2005, 2007), (Seibert, 2007)					(Allsopp et al, 2006), (Brigden et al, 2005), (Davis and Smith, 2003), (Grossman, 2006), (Grossman, 2009), (Jackson et al, 2006), (Manhart, 2007)	
	Social Benefits/Security		(Norbrand and Bolme, 2007)		(Chan, 2008), (Chan and HO, 2008), (Ferus-Comelo, 2006), (ILO, 2007), (Manhart, 2007), , (Schipper, 2005, 2007)					(Manhart, 2007)	
Users	Health and Safety						(Ling, 2004)				
	Improvement of social and economic oportunities						(Ling, 2004), (Scott, 2004)				
	Quality of product or service	(Han and others, 2004)					(Ling, 2004)				
	Protection of users' privacy						(Ling, 2004)				

Stakeholder / social indicators			**Main Life Cycle Stages of Consumer Electronics**								
		Design	**Raw Material Extraction and processing**	**Transport** (see note below)	**Manufacturing**	**Transport** (see note below)	**Use**	**Transport** (see note below)	**End-of-life**		
									Re-use	**Recycle**	**Disposal**
Local community	Health and Safety		(CorpWatch, 2007), (Farrell et al, 2004), (FOE, 2003), (Grossman, 2006), (Norbrand and Bolme, 2007), (Poyhonen and Simola, 2007), (Poyhonen and Simola, 2007)		(Brigden et al, 2007), (Byster et al, 2006), (Wilde and Haan, 2006), (Manhart, 2007)					(Allsopp et al, 2006), (Brigden et al, 2005), (Jackson et al, 2006), (Manhart, 2007)	(Allsopp et al, 2006), (Byster et al, 2006), (Cox, 2009)
	Human Rights		(CorpWatch, 2007), (Farrell et al, 2004), (FOE, 2003), (GW, 2006), (Hayes and Burge, 2003), , (Steinweg and Haan, 2007)		(Chan and HO, 2008)						
	Indigenous rights		(CorpWatch, 2007), (FOE, 2003)								
	Corruption		(Farrell et al, 2004), (GW, 2005)								
	Conflicts and violance		(Cox, 2009), (Farrell et al, 2004), (FOE, 2003), (GW, 2005), (Hayes and Burge, 2003), (Norbrand and Bolme, 2007), (Poyhonen and Simola, 2007)								
	Mantaining and improving social and economic opportunities		(FOE, 2003)		(Manhart, 2007)		(Scott, 2004)				

Stakeholder / social indicators		Main Life Cycle Stages of Consumer Electronics									
		Design	Raw Material Extraction and processing	Transport (see note below)	Manufacturing	Transport (see note below)	Use	Transport (see note below)	End-of-life		
									Re-use	Recycle	Disposal
Society	Public commitment to sustainability										
	Prevention of unjustifiable risks	(Brigden et al, 2008), (Byster et al, 2006), (Rifer et al, 2009), (Boswell, 1999)	(GW, 2006), (Norbrand and Bolme, 2007)	(Young et al, 2008), (Steinweg and Haan, 2007), (SOMO, 2008)				(BAN, 2002), (Cobbing, 2008), (Grossman, 2006), (Johnson and Graedel, 2008), (Johnston, 1998), (Puckett, 2006), (Puckett et al, 2002), (Weston, 2009)			
	Employment creation		(FOE, 2003)		(ILO, 2007), (Manhart, 2007), (Manhart and Grießhammer, 2006)					(Williams, 2008)	
	Contribution to the national economy and stable economic development		(GW, 2006)		(Manhart, 2007)		(Ling, 2004), (Scott, 2004)		(James, 2001), (Williams, 2008)	(James, 2001)	
	Prevention & mitigation of armed conflicts		(FOE, 2003)								

Stakeholder / social indicators		Design	Raw Material Extraction and processing	Transport (see note below)	Manufacturing	Transport (see note below)	Use	Transport (see note below)	End-of-life: Re-use	End-of-life: Recycle	End-of-life: Disposal
			Main Life Cycle Stages of Consumer Electronics								
	Transparent business information		(GW, 2005), (GW, 2006)	(Young et al, 2008), (Steinweg and Haan, 2007), (SOMO, 2008)	(Poyhonen and Simola, 2007)			(BAN, 2002), (Cobbing, 2008), (Grossman, 2006), , (Johnson and Graedel, 2008), (Johnston, 1998), (Puckett, 2006), (Puckett et al, 2002), (Weston, 2009)			
	Protection of intellectual property rights				(Manhart, 2007)						

Table notes:

This table attempts to classify all of the literature referenced in Section 7 of Annex 12 according to the life cycle that begins with design and goes to end-of-life. In this context, materials and products move from one life cycle stage to the next: this movement is referred to as “transport” in this table, which in LCA work should be accounted for. In Figures 1 and 2 in Annex 12 the word “trade” is used to represent the same activity (and see discussion in Section 4 in Annex 12). In either case, there is a social dimension for those players involved in these activities.

Where this table contains blank cells, the authors were unable to find published reports: this then provides for the identification of potential knowledge gaps where social life cycle assessment is concerned.

ANNEX 13: COMPOSITION OF MOBILE PHONES OVER TIME

102. Handsets without batteries – all data are in percentages.

Material/Element	1995-6 (a)	2002 (b)	2005 (c)	2008 (d)	2008 (e)	2008 (f)
organic	29	45.3	30.2	43.0	43.0	44.0
glass	nd	15.0	12.3	13.7	11.6	15.4
Ag (Silver)	0.48	0.140	0.1858	0.3512	0.2792	0.5441
Al (Aluminum)	1.76	0.165	10.1	2.3	1.4	3.1
Au (Gold)	0.025	0.030	0.0219	0.0341	0.0276	0.0446
Ba (Barium)		0.0	0.6	0.8	0.5	1.1
Be (Beryllium)	nd	0.004	0.0031	0.0084	0.0006	0.0154
Bi (Bismuth)		0.015	0.0006	nd	nd	nd
Co (Cobalt)		0.008	0.0429	nd	nd	nd
Cr (Chromium]	0.15	0.84	1.29	nd	nd	nd
Cu (Copper)	15.6	19	12.4	12.6	11.7	15.0
Fe (Iron)	3.7	8	10.4	6.6	4.9	8.0
Nd (Neodynium)		0.36	0.00			
Mg (Magnesium)		0.1	14.4	1.9	0.4	3.2
Mn (Manganese)		0.12	0.33	0.2	0.10	0.30
Mo (Molybdenum)			0.0024			
Ni (Nickel)	2.07	0.9	4.1	1.4	1.1	2.0
Pb (Lead)	0.61	0.6	0.01	0.6	0.4	0.7
Pd (Palladium)	0	0.111	0.0012	0.0144	0.0091	0.0349
Ru (Ruthenium)		0.005				
Sb (Antimony)		0.030	0.069	0.1	0.1	0.1

Sn (Tin)	0.53	0.94	1.13	1	0.80	1.10
Sr (Strontium)		0.004	0.06			
Ta (Tantalum)		0.24		nd	nd	nd
Ti (Titanium)		0.14	0.33	1.6	1.1	2.2
W (Tungsten)		0.2	0.4			
Y (Yttrium)		0.001	0.00			
Zr (Zirconium)		0.005	0.0	0.1	0.1	0.3
Zn (Zinc)	0.7	0.6	0.8	1.1	0.7	1.6

(a) Geyer and Blass, 2008 (cited Wright, L. Product Life Cycle Management. Eng.D. Thesis, Centre for Environmental Strategy, University of Surrey, UK. 1999)

(b) Nokia 2002 average

(c) MPPI 2005 average

(d) Hagelüken, C. Mobile Phone Partnership Initiative (MPPI)-Study to test the recycling guideline, 2008-02. (also MPPI) (average)

(e) Hagelüken 2008 (minimum)

(f) Hagelüken 2008 (maximum)

Note: The Hagelüken report was released in 2008 but the actual sampling/testing may have been conducted in 2007.

"nd" refers to "not determined" or in effect, not measured. As a result, columns do not add up to 100%.

ANNEX 14: NEW MOBILE PHONES

Nanotechnologies and future changes in the composition of mobile phones

103. The future composition of mobile phones will be determined by new advanced materials provided by nanotechnologies. In this regard, Nokia and Motorola have been expanding their in-house research groups to increase their expertise in nanotechnology. Nokia has also introduced its mobile phone of the future to illustrate new characteristics provided by new advanced materials. The concept phone demonstrates some of the newest functions that nanotechnology can deliver, such as flexibility, transparent electronics, and surfaces that are self-cleaning.

104. The integrated electronics contained in the Morph concept (see graphic) may help reduce future mobile phone costs. However, the impact of these new mobile phones on reuse and recycling activities is uncertain. Several questions arise: First, how will the waste stream be affected by these new materials and, second, what are the economic implications for recycling operations? Further research is required to better understand the repercussions of introducing new, advanced materials into the economy.

Source: http://www.nokia.com/about-nokia/research/demos/the-morph-concept (accessed August 2009)

105. At a 2009 conference in Las Vegas, Motorola unveiled a mobile phone that has recycled plastic water bottle content and is in turn 100 percent recyclable. This device is marketed under the name “Renew.” Its packaging size was reduced by 22 percent and is made from post-consumer recycled paper feedstock.

Source: http://www.mediacenter.motorola.com (e-article published Jan-2009)