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BASEL CONVENTION

MOBILE PHONE PARTNERSHIP INITIATIVE (MPPI) - PROJECT 4.1

GUIDELINE ON THE AWARENESS RAISING-DESIGN CONSIDERATIONS

Revised and Approved Text
March 25, 2009

Foreword

The previously approved Guideline on Awareness Raising-Design Considerations has been reviewed via practical application by selected manufacturing companies to assure the content in relation to best available practice with respect to design and development activities and considerations at the time of issue. The Mobile Phone Working Group would like to express its appreciation to Motorola, Nokia, Sharp, and Sony-Ericson for evaluating the guideline and proposing revisions to the previously approved guideline.

In addition, special thanks is extended to the chair of the Project Group 4.1, Mr. Peter Hine from Sharp, for ensuring that all proposed changes and comments from the Project Group 1.1 participants have been reviewed and incorporated in the revised guideline.

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PROJECT GROUP 4.1 ACTIVE PARTICIPANTS

Betty Fishbein - INFORM, USA
Cindy Thomas - Noranda, Canada
Claudia Fenerol – SBC, Switzerland
Craig Liska - Motorola, USA
Daniel Paska - Sony Ericsson, Sweden
Eric Most - INFORM, USA
Gareth Rice – Panasonic, UK
Gary Straus - ReCellular, USA
Helena Castren – Nokia, Finland
Ingrid Sinclair - Noranda, USA
Jack Rowley - GSMA, UK
John Bullock - IPMI, USA
John Myslicki - Consultant to SBC, Canada
John Onuska - Inmetco, USA
Julie Rosenbach - EPA, USA
Lars Bruckner - NEC Europe, UK
Marco Buletti – FOEN,Switzerland
Mats Pellback-Scharp – Sony Ericsson, Sweden
Milton Catelin – SBC, Switzerland
Patty Whiting - EPA, USA
Paul Didcott – Motorola, UK
Peter Hine – Sharp Telecommunications of Europe, UK
Pontus Alexandersson – Sony Ericsson, Sweden
Robert Tonetti – EPA, USA
Valerie Thomas – Georgia Tech University, USA

1. INTRODUCTION

It is recognized that product design affects every stage of a product's life cycle and can have significant impact in reducing the negative life cycle impacts on human health and the environment, including end-of-life impacts and waste management. In this guideline, end-of-life impacts, and how design changes might reduce them and enhance end-of-life management options, have been examined by a working group of participating experts from mobile phone manufacturers, governments, non-governmental organizations, academia, network service providers and recycling industries.

Section 2 of this guideline, describes the evolution of design changes since the introduction of modern mobile telephony in the 1980s, such as dramatic reductions in weight and changes in battery chemistry, and the end-of-life environmental impacts of those design changes. Section 3 describes current forces driving environmental design changes – substance restrictions and bans such as the European Union's Directives on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Waste from Electrical and Electronic Equipment (WEEE), as well as continuing customer and stakeholder environmental demands – and the mobile phone manufacturers' ongoing responses. Section 4 concludes with an exploration of the possibilities of still further environmental design improvements, and challenges the mobile phone manufacturers to implement them.

2. EVOLUTION OF MOBILE PHONE DESIGN

Attention to the design of a mobile phone for environmental considerations must begin with recognition of the dramatic evolution of the product over the last three decades. It can be said that historically the mobile phone manufacturers have been driven by consumer demand, with initial changes occurring usually for non-environmental reasons, but many of the changes have also had beneficial environmental effects.

The first and strongest demand of consumers was for greater portability. The first mobile phones were so large and heavy that they were usually installed only in motor vehicles, wired into their electrical systems. The first generation of truly portable phones was still large and heavy; they contained lead acid batteries, came with carrying bags with shoulder straps, and weighed upwards of 4 kg. But these devices progressed steadily to smaller, lighter models in the 1980s and today mobile phone handsets typically weigh less than 100g.

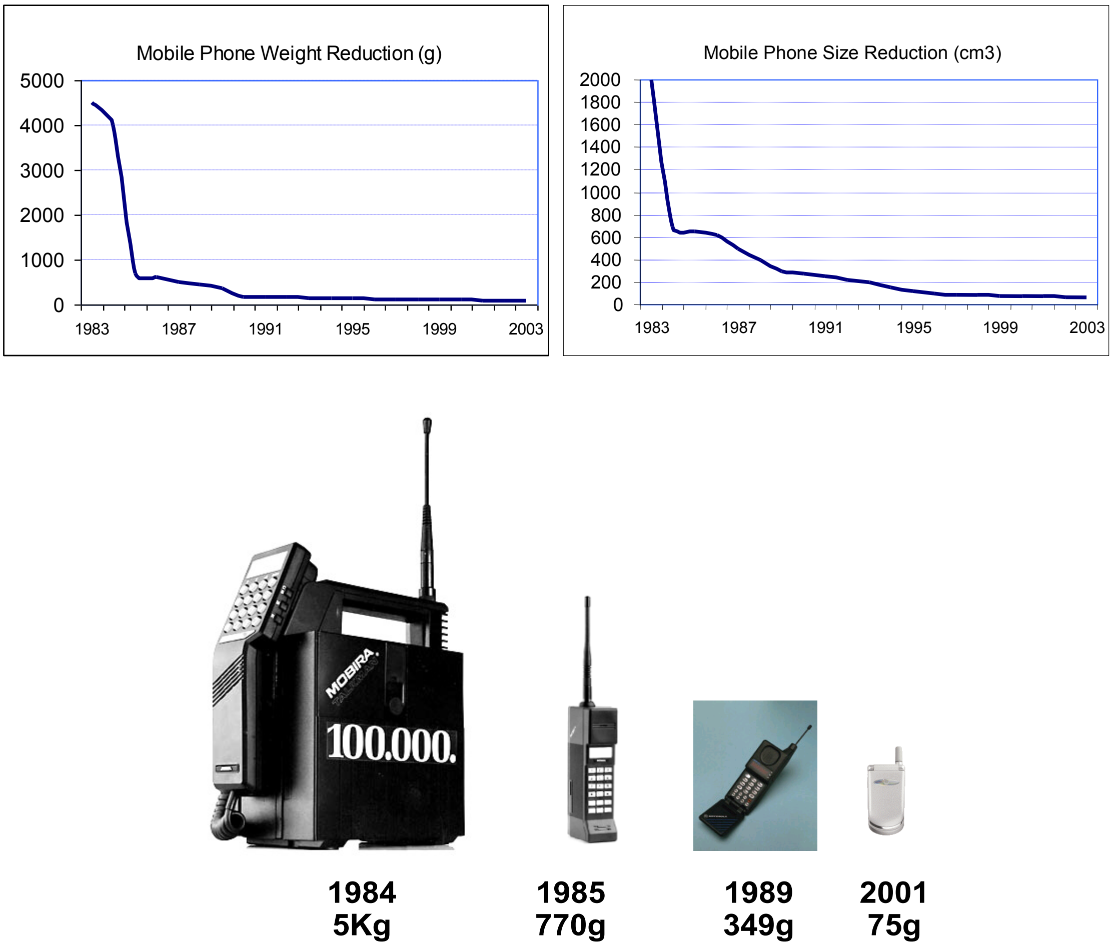

Figure 1: Weight and Size Reductions of Mobile Phones
Source: Nokia Mobile Phones, presentation at IEEE Symposium,
Electronics and the Environment, Boston, 21 May 2003

The environmental benefits of this reduced size and weight, which have encompassed electronics, batteries and cases, are that the manufacture of a modern phone consumes far less natural resources, both in terms of energy and materials in the whole production process.

Consumers have also demanded a longer operating time on a charged battery, and manufacturers have responded with very significant improvements. Since the first mobile phones were introduced, standby operating time of a mobile phone on a single battery charge has increased from around 4 hours to up to 10 days or more, while the size of batteries has been greatly reduced. This has been accomplished with two approaches.

First, new types of batteries were introduced. The mobile phone industry quickly phased out lead acid batteries, and then phased out their nickel cadmium (NiCd) substitutes. These were replaced by nickel metal hydride (NiMH), and more recently by lithium ion (Li-ion). These newer technologies deliver far superior performance, as illustrated by the comparative energy densities shown in Figure 2. Historically, the batteries most commonly used in mobile phones were lithium ion (45%), nickel-metal hydride (40%), and nickel-cadmium (15%).[2] Since the mid 90's, Nickel cadmium batteries have been completely phased out of the mobile phone market.

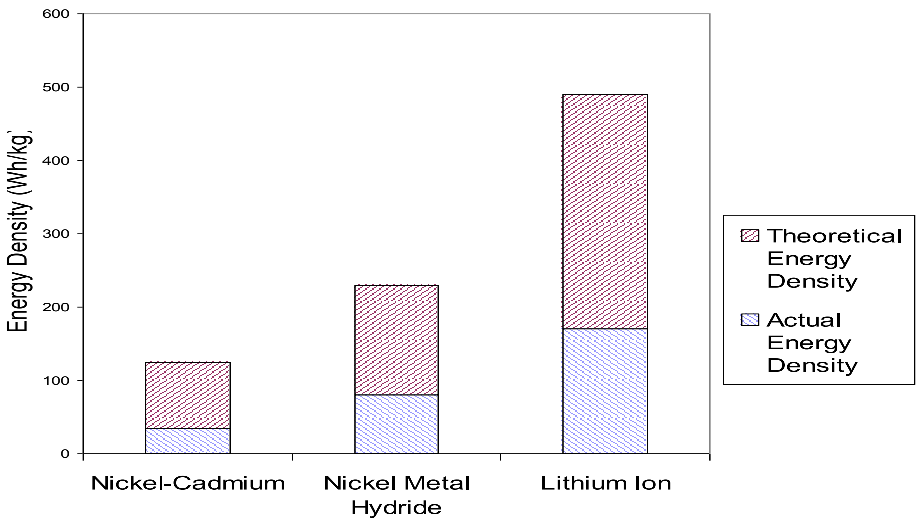

Figure 2: Energy density of batteries used in mobile phones.
Source: D. Linden and T. B. R eddy, Handbook of Batteries,
3rd Ed., McGraw Hill, 2002, Fig. 1.4.

The change in battery types has benefited the environment in two ways. First, it has permitted mobile phone batteries to be smaller, using less material and resources in their manufacture, while delivering equal or better performance. Second, it has greatly reduced the use of the toxic metals lead and cadmium. Nickel-metal-hydride batteries use an alloy based on lanthanum nickel, $LaNi_5$, or, less often, an alloy of vanadium-titanium-zirconium-nickel. Lithium ion batteries contain lithium and manganese, cobalt or nickel. The materials used in both these types of batteries, while not without environmental considerations, are less hazardous than lead or cadmium, and mobile phones now using these batteries are thus much safer at end of life, not only in sound recycling operations for metal recovery, which is preferred, but also in disposal operations such as waste incineration, which still occurs. Current battery technologies also improved charge-discharge cycle characteristics (for example, less memory effect) than NiCd batteries, however, they are still limited in the number of cycles before performance degrades.[33] Future energy technologies, such as fuel cells, may provide greater lifespan but there are regulatory issues that need to be resolved[34].

The second way manufacturers have responded to consumers' demand for longer operating time has been to reduce the energy consumption of mobile phones when they are in use. The Manufacturers have done so by improving the electronic efficiency of components and sub-assemblies, reducing the operating voltage, and reducing the overall energy requirements of the circuitry. At the same time, manufacturers have reduced energy consumption of mobile phones when their batteries are being charged, and also when the battery is fully charged but still connected to their battery chargers (stand-by energy consumption). Since 2003 many, mobile phone manufacturers have been fully compliant with the accepted 2005 reduced limits set by the voluntary European Commission's Code of Conduct on Efficiency of External Power Supplies[4]. These limits are regularly reviewed and manufacturers continue to work towards every greater efficiencies as product technology enables. These reductions in energy consumption have had a beneficial effect on the environment – on a phone-by-phone basis – by reducing the amount of electrical energy drawn from traditional sources such as carbon-based generation, and the many types of air pollution and greenhouse gas carbon dioxide produced by such sources.

A third consumer demand with potential beneficial environmental impact (although it is difficult to measure) is for more functions in a single device, and again manufacturers have responded. A modern mobile phone now communicates with data as well as voice, offers email and internet browsing, and may also serve as multi-function personal digital assistant, digital still and video camera, MP3 music player, pager, alarm clock, global positioning device, and game machine. The use of a mobile phone to pay for purchases in stores, parking, and other goods and services through direct communication of credit information is also being introduced in numerous regions around the world. Such a multipurpose mobile phone can remove the need for some consumers to buy many additional electronic devices, and thus further reduce the use of materials and resources, and particularly of energy, both in the devices themselves and in their peripherals such as batteries and battery chargers. Furthermore, enhanced multi technology mobile communication devices have a positive effect on reducing the need for global travel and thus have a positive effect on an individual's carbon footprint.

It is thus appropriate to appreciate that the mobile phone manufacturers have made substantial design efforts and have succeeded in reducing the environmental impacts of a mobile phone, including but not limited to, reduced material and energy consumption per unit, reductions in hazardous content and a reduced carbon footprint in both manufacture and use. Furthermore, it is clear that such design changes will continue toward additional environmental objectives and benefits, with consumers, governments and environmentally conscious manufacturers alike driving the process. It is accepted that there is more work still to be done to minimize wastes, to design products for longer life and better recycling, and to reduce or eliminate toxic substances. The recently finalised IPP (Integrated Product Policy) pilot on mobile phones, where mobile manufactures, operators and other stakeholders worked together with the European Commission to seek environmental improvements through the whole life cycle of the product, should also be recognised as a substantial effort towards more environmentally relevant design[37]. The learning's and results of this project will also be used in forming the European Commissions Sustainable Consumption and Production Policies[38].

A detailed list of chemicals that are used in a typical mobile phone can be found in Annex I**.**

3. GOVERNMENTAL MANDATES AND INDUSTRY RESPONSES

Beyond consumer demands, many governments have already begun to require specific design changes in electronic products, including mobile phones. The Basel Convention itself has obligated its members to ensure that generation of hazardous wastes is reduced to a minimum (Article 4.2), and product design can play a significant role in achieving this goal, through design for longevity, re-use, and reduced material use and toxic input. The Convention's obligation to take "all practical steps" in achieving environmentally sound management implies upstream design strategies as well as downstream waste management. This is not entirely a new step by governments. Hazardous substances such as lead (in paints and gasoline), asbestos, polychlorinated biphenyls, and ozone depleting substances have long been restricted or banned by national and international law. However, governmental restriction of hazardous substances is increasing; see, for example, EU Directive 2003/34/EC prohibiting the sale to the general public of a specific list of substances determined to be carcinogenic, mutagenic or toxic to reproduction. Furthermore, the Parliament and the Council of the European Union has adopted a very broad regulation that requires registration, evaluation and authorization prior to production, sale or use of chemical substances on the European Internal Market[5], and a directive that would set general principles and criteria for eco-design of select requirements.[6]

The most direct government mandate that presently affects the design of mobile phones is the European Union's Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (the RoHS Directive),[7] which ban's six substances from electrical and electronic devices, including mobile phones, that are placed on the EU market after 1 July 2006: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers.

Of these six substances, lead was by far the most common in electrical and electronic devices. Lead has been used in mobile phones, although in very small quantities, in tin-lead solder, which very efficiently bonded components into integrated electronic devices. Although the amount of tin-lead solder in a mobile phone was typically less than one gram per phone, mobile phones no longer use tin-lead solder in their electronics.

Cadmium has primarily been used in electronics in nickel-cadmium batteries, which have now been phased out of all mobile phones in favor of NiMH and Li-ion batteries. Cadmium is also used in electronics in very small quantities as a surface finish on printed wiring boards, and in electrical contact alloys for relays and switches. Some cadmium may be used in these electronic applications in some mobile phones.

Mercury is used in very small quantities in electronics. It is not known to be used at all in mobile phones.

Hexavalent chromium is used to plate metal, usually steel, to protect it from corrosion and give it a shiny appearance. Almost all mobile phones have plastic cases that do not require corrosion protection.

Polybrominated biphenyls (PBBs), a family of chemicals, were formerly used as flame retardants in plastics used in electronic equipment, to protect against fire damage, but PBBs have not been used in mobile phones. Polybrominated diphenyl ethers (PBDEs), another family of chemicals, have also been used as flame retardants, as safer substitutes for polybrominated biphenyls. One type of PBDE, decabrominated biphenyl ether (Deca-BDE), is considered to be the safest (or least hazardous) of this family of chemicals, and still has very limited use in plastics utilised in electronics as a flame retardant. It was temporarily excluded from the substance ban of the RoHS Directive, based on risk assessment, and pending continuing research by the EU, and Deca-BDE may be used in a very limited number of mobile components. However, due to the EC RoHS Deca-BDE exemption being withdrawn by the EU which takes effect 1st July 2008, Deca-BDE will shortly be phased out completely in all mobile phones and accessories. However, it should be generally noted that manufacturers have long been seeking to use halogen-free flame retardants, as well as develop designs that do not require any flame retardants.

While the implementation of the RoHS Directive provided a definitive timeline to the mobile phone industry's plans to eliminate banned substances from mobile telephones, some manufacturers have seen the trend of government restriction of substances for many years, and have been proactively responding to it. Of the six substances banned by the RoHS Directive, four of them - cadmium, mercury, hexavalent chromium, and polybrominated biphenyls - have no essential function in mobile phones and are not normally used, or can be easily replaced. Lead, however, has been more difficult to replace. However, the leading mobile phone manufacturers have long sponsored fundamental research and co-operative work with suppliers to identify lead-free alternatives that can maintain the quality and reliability needed in hand-held electronics, which are now in use.

The early work which has been done by the manufacturers during the design phases of products has resulted in mobile phones which use neither lead in electronics nor brominated flame retardants, and all mobile phones on the EU market (and beyond), meet the substance requirements of the RoHS Directive. All the leading mobile phone manufacturers work to significantly reduce the environmental impacts of their products.

These examples demonstrate the feasibility of removing lead and other substances from mobile phones, and the intent of major manufacturers. A challenge remains to ensure that the entire worldwide supply chain does not use any of the six substances banned by the RoHS Directive. All leading manufacturers of mobile phones are already managing their supply chains, requiring that all their component products comply with the RoHS Directive. Some have required that all of their suppliers identify a wide range of substances in their component parts and materials, and have established lists of controlled and restricted substances that go beyond the RoHS Directive.[8]

Through industry groups such as the Electronics Industries Alliance (EIA), the European Information and Communication Technology Association (EICTA), and the Japan Green Procurement Survey Standardization Initiative (JGPSSI), mobile phone manufacturers are also active in promoting a framework for the whole range of electronics industries to report the material content of products within many supply chains.[9] This common framework will allow manufacturers to ensure that a wide variety of electronic products are free from hazardous substances at the outset, as well as facilitating the supply of data to recyclers and waste handlers for the environmentally sound treatment of products at end-of-life.

These efforts to control and restrict hazardous substances are not limited to Europe. Although the EU RoHS Directive encompasses the market of its member countries, its effect upon mobile phone design is worldwide. Because the European market is very large, and because it is in the economic interests of major manufacturers to have a global design for all of their mobile phones, the provisions of the RoHS Directive are changing design and manufacturing processes throughout the world. As other countries around the world implement their own form of RoHS legislation, design for global product compliance becomes obligatory for all mobile phone manufacturers.

In addition to the product design changes mandated by the RoHS Directive, the EU's companion Directive on Waste Electrical and Electronic Equipment[10] (WEEE) is influencing design of mobile phones. The WEEE Directive mandates that manufacturers of electronic equipment, including mobile phones, take responsibility for the recycling of their products sold within the European Community. This application of Extended Producer Responsibility gives an incentive to manufacturers to design their products to minimize costs involved with a wide range of end-of-life management, including collection and recycling. Manufacturers should have to design mobile phones to promote the efficient separation and recycling of at least some of their plastics, such as the handset cases. This mandate, like the RoHS Directive, will also influence the design and manufacturing processes of mobile phone manufacturers throughout the world, as they examine the options for management of their products: reuse, recycling and recovery of contained materials, such as plastics and metals.

4. CHALLENGES AND RECOMMENDATIONS

As the foregoing sections show, technologies and markets for mobile phones continue to develop, responding to consumer and government requirements. The only certainty is that there will be more change. Some changes seem predictable; there will be new screen and battery technologies in the not distant future. Other changes are harder to guess. Mobile phones might become larger; incorporating still more functions such that a full keyboard will be needed. They might become still smaller, with control by voice recognition overcoming the current practical limit of the size of human hands and fingers. However, where the design of mobile phones might take us, the MPWG cannot predict. And we do not presume to advise mobile phone designers what features and characteristics the world's consumers might demand, or to force the design of mobile phones that people will not buy.

The MPWG also recognizes the environmental achievements that mobile phone manufacturers have already made, and we have described some of those achievements in Section II above. It is clear that some manufacturers have been particularly proactive in their environmental thinking. But we can nevertheless advise, and do advise, that all manufacturers follow certain environmental principles in their current practices, and that they adopt certain environmental features and characteristics, within the complex task of mobile phone design. As the unpredictable future of mobile phone design evolves, we can and do ask that protection of the environment always be an important consideration.

Recommendation 1: Eliminate Waste Caused by Unnecessary Transmission Technology and Hardware Incompatibility.

Some technical differences among mobile phones are legitimately based upon valuable proprietary innovations, special expertise of individual manufacturers, and differing needs of consumers. Manufacturers strive for creative improvements that appeal to consumers and often provide environmental benefits, such as lower energy use, and thus increase sales. We recommend that this competition not be hindered or stifled by mandatory adherence to old technologies, unnecessary uniformity or standardization. However, some technical incompatibilities among manufacturers appear to be unnecessary, and give rise to excess waste. For example, consumers must sometimes discard mobile phones when changing service providers, even if the phones are in good working order. The United States has several competing transmission technologies, including CDMA (code division multiple access); TDMA (time division multiple access); and GSM (Global System for Mobile Communications). Mobile phones sold in the U.S. are typically designed to operate on only one of these competing technologies, and U.S. consumers often must purchase a new phone when they change service provider, even when the old phone is still functional.[11] Almost one third of mobile phone users in the U.S. change service providers each year, so a very large number of new phones must be acquired and old phones are taken out of use.[12]

This unnecessary generation of waste can be reduced or eliminated through design changes in mobile phones, either by making them compatible, through hardware or software, with all technical transmission technologies, or by incorporating a modular component that can be easily changed in order to make the mobile phone adapt to different transmission technologies.

Alternatively, of course, such incompatibility and unnecessary waste can be reduced or eliminated solely through adoption of a single transmission technology protocol throughout the world, and design of all new mobile phones in accord with such a universal standard. The MPWG recognizes that this is not an issue that mobile phone manufacturers can decide, because it is political in nature, but it nevertheless deserves consideration as an environmental issue. An example of an already widespread transmission technology is the GSM system, used by seventy percent of the world's mobile phone subscribers in 197 countries[13], who can operate their phones in all of these countries.[14] (GSM services are also available in the US but operated in a different frequency band, 1900 MHz, than the 900 MHz or 1800 MHz typically used in other countries. Many GSM phones sold in the US now operate at two (900 and 1900 MHz) or three (900, 1800 and 1900 MHz) frequencies, but others may not be compatible with the worldwide GSM system, and vice versa.). Emerging markets such a China must also be considered with its adoption of the TD-SCDMA technology. The MPWG also notes that the 3G (third generation) mobile phone standards intend to achieve the goal of worldwide compatibility, but different options exist and compatibility may not be complete. Furthermore the desire for new mobile phone services will continue to drive the evolution of transmission technologies beyond 3G, perhaps perpetuating some differences. However, initiatives such as software defined radio may reduce hardware incompatabilities[35].

There are additional opportunities to reduce waste through elimination of hardware incompatibilities. When a mobile phone is discarded and replaced, peripherals must often also be discarded and new ones must be acquired for the new phone. Some manufacturers have already reduced this area of incompatibility by introduction of wireless accessories, which use a world standard radio frequency communication protocol, and are therefore interchangeable among many makes and models. We recommend that these efforts be continued and expanded. The problem of hardware incompatibility is especially evident with battery chargers. A battery charger may weigh more than the handset, so this incompatibility can result in more than double the amount of waste generated at a mobile phone's end of life.[15] Again we note that some manufacturers have addressed this area of incompatibility by making a small number of chargers applicable to a broader range of their mobile phones. The Open Mobile Terminal Platform has also local connectivity recommendations based on a single, universal cross manufacturer USB (Universal Serial Bus) cable connector that enables mobile consumers to connect and charge their mobile devices. The Chinese Ministry of Information Industry announced similar plans in 2006[36]. We recommend that these efforts continue to be investigated by all mobile phone manufacturers. Furthermore, where an environmental benefit is shown to exist, based on whole life cycle analysis of charger and phone, and is technologically justifiable, these efforts can be expanded to a wider range of suitable devices within each manufacturer's product line, and also among the different manufacturers and where appropriate network operators. An example of this type of activity is the collaborative study being undertaken in Japan between manufacturers and network operators to standardize a common AC charger from 3.5G models onwards, including the option not to pack a charger with each new mobile phone sold. The MPWG recognizes that the charging of a battery, particularly a lithium-ion battery, requires care and special electronic circuitry to avoid damage, and that each manufacturer's concerns about brand quality and warranties are involved in possible cross-brand utilization of battery chargers and peripherals. We nevertheless recommend that this area of potentially beneficial compatibility be investigated, both within brands and among brands whilst careful consideration is given to avoid having standardization stifle technological innovation, ongoing energy efficiency improvements or compromising product safety and EMC system level requirements. Manufacturers continue to increase charger compatibility across a wide range of phones, driven by consumer demand and technological capability. However, any requirement for a standardized charger and possible separate sale, must be justified based on a comprehensive, holistic (whole life cycle) study, in order to determine that a significant environmental benefit exists. If a significant environmental benefit is demonstrated to exist, viable solutions must also be defined to overcome the technological, safety, EMC, energy efficiency, liability, quality, and warranty issues which must also be addressed.

Recommendation 2: Life Cycle Energy Use should be further reduced.

An improvement in energy use can reduce the adverse environmental impacts of carbon fuel electricity generation. Notwithstanding the successes to date in reducing the energy demand of a mobile phone, further efforts should be made to design still more energy efficiency into its life cycle, especially as mobile phones support more functions, through both hardware and software innovation. Energy consumption of mobile phones in actual use should continue to be reduced, through increasingly efficient electronic components and software power management. In addition to a reduced energy use, a very energy-efficient handset will facilitate a wider choice of battery technologies, as well as renewable energy battery charging sources such as solar cells and micro fuel cells. A very low energy mobile phone could also reduce or eliminate the need for flame retardants.

As set forth above in Section 2, energy consumption of battery chargers has been reduced by most manufacturers due to the ongoing drive to achieve the most cost effective and efficient technologies available. Further energy reductions are underway due to the ENERGY STAR program[40] and also the European Commission's Code of Conduct on Efficiency of External Power Supplies[39]developed in conjunction with mobile phone manufacturers. Both of these voluntary programs are currently undergoing revision to further reduced standby power and increased energy efficiency of external power supplies. Early reports indicated that most battery chargers were inefficient, and energy used to charge mobile phone batteries (even when they are fully charged but still connected to chargers [stand-by mode]), greatly exceeded the energy used by those batteries in actual use.[16)] Due to wide deployment of the EC CoC on Efficiency of External PSU's, and the ENERGY STAR program by mobile phone manufacturers, this situation has significantly improved over recent years, and continues to do so. The increasing use of microelectronics and software controls to monitor use, electrical charges and heat in batteries and chargers, in place of simple transformers and rectifiers, deliver precise calculated charges that also help accomplish the goal of reduced energy consumption. The Mobile Phone Working Group (MPWG) specifically recommends that all mobile phone manufacturers join the European Commission's Code of Conduct on Efficiency of External Power Supplies, and advocate that the energy limits and implementation dates set for mobile phone chargers by the EC Code of Conduct and ENERGY STAR program are fully aligned to ensure globally consistent requirements. In addition, mobile phone manufacturers are working together to help educate users to disconnect chargers from the mains supply when their phones are unplugged or fully charged. This consumer awareness would significantly reduce energy use where conventional chargers are usually left connected to the mains supply after the phone has finished charger and has been disconnected from the charger.

We recognize that energy efficiency is a complex issue, and do not want to promote one-sided advice. Some steps that might reduce the operating energy consumed by a mobile phone might also increase energy use in other ways, and thus may be counterproductive. For example, while it would be preferred to have longer-lived, more durable mobile phones that will be used for a longer period of time, an older mobile phone may be less energy efficient, and thus may use more energy in actual continued use than a new phone. On another level, the energy required by a mobile phone to send a signal could be reduced by installation of more (and thus nearer) base stations, but this could be counter-productive if more base stations then use more total energy, but operate at less than full capacity. Therefore the overall environmental effect of each energy efficiency step needs to be carefully considered. The overall goal of increased energy efficiency, with reduced environmental impacts of energy generation through air pollution and generation of greenhouse gasses, is strongly recommended.

The Energy Using Products (EuP) Directive (Lot 7) sets a mandate to regulate the energy efficiency and maximum permitted standby power for a broad range of external power supply (EPS) devices. Once implemented within EU member state legislation, these limits and requirements will apply to mobile phone chargers, as well as other types of EPS. It should be noted that the existing energy efficiency and standby power limits within the Version 2 (Issued: 24.11.2004 - valid until 31.12.2008) of the voluntary EC CoC (Code of Conduct) on Energy Efficiency of External Power Supplies are more restrictive (providing better energy efficiency) than the EuP Lot 7 requirements. The new limits within Version 3 (Issued: 28.11.2007 - valid from 1.01.2009) of the EC CoC on Energy Efficiency of EPS's, are more restrictive than Version 2 limits. As most of the leading European mobile phone manufacturers are signed up to version 2 of the CoC, and planning to sign up to version 3, mobile phone chargers within Europe, and wider markets, provide some of the lowest energy use levels for ICT product power supplies on the global market. This ongoing energy reduction is expected to continue as the EC CoC on Energy Efficiency of EPS partnership reviews technological developments and undertakes further revisions of the CoC.

Ref: EC CoC on Energy Efficiency of External PSU's: http://re.jrc.cec.eu.int/energyefficiency/

The new EuP Directive is expected to define and implement other energy efficiency requirements in the future, and these may also apply to mobile phones and/or their accessories.

Recommendation 3: Mobile Phones should be better Designed for Reuse and Recycling.

The current rates of reuse and recycling of mobile phones vary considerably by region. Where the reuse and recycling rates are low, the major barriers include the lack of convenient, environmentally sound options and the lack of consumer awareness of the options that do exist, followed by the perception that a mobile phone is too valuable to give up for recycling.[17] There are thus opportunities for educational and marketing initiatives that will improve collection and recycling, utilizing, where appropriate, the knowledge and expertise taken from regions with established effective schemes. However, there are also design changes that can enhance recycling options. Policies such as Extended Producer Responsibility (EPR) and/or product stewardship-type programs may be used to provide incentives to companies to design products that generate less waste and are easier to recycle.

Reuse of mobile phones, including refurbishment, is described in the Guideline on Refurbishment of Used Mobile Phones, as developed by the project group 1.1., and we refer the reader to that guideline. We note that mobile phones that are collected can be reused, and repaired and refurbished if needed, at quite high rates. Current design of mobile phones produces a durable product that can already be used for an extended period of years, by multiple users in multiple locations.

As a matter of design, however, reuse may be enhanced by better marking or labeling,[18] or by internal software that permits current information to appear on the LCD screen, such as advice to a consumer about collection locations in proximity to the current network cell[19] or technical information that would be useful to a refurbisher or recycler. As set forth in Recommendation 1, a mobile phone, including its peripherals, can be designed and manufactured with fewer incompatibilities, and therefore may be more suitable for continued use by more consumers, in more places, for a substantially longer time. Reusable parts such as fuel cell cartridges, soon to be used in mobile phones, can be designed and made for very long, widespread use, and systems need to be put in place for their recovery and reuse. Design that facilitates cleaning, or dismantling and replacement of cases with surface blemishes, or dismantling for simple repair, would increase the opportunities for reuse. In summary, we recommend that manufacturers continue to consider reuse and (if necessary) repair and refurbishment in their design processes to facilitate repeated use by multiple consumers, and a much longer life before disposal.

Recycling for material recovery can also be enhanced by design considerations. Material recovery and recycling processes for mobile phones are described in the Guideline on Material Recovery and Recycling of End-of-Life Mobile Phones, as developed by the project group 3.1, and we refer the reader to that guideline. In this chapter we note that the design of a mobile phone can have a significant impact upon recycling at the end of a mobile phone's useful life. There are two categories of materials that are recoverable: plastics and metals. Plastics are the largest single category of constituent, by weight and volume, of mobile phones[20].

Recycling of mobile phone plastics for production of new plastics presently faces several barriers. An engineered plastic such as acrylonitrile butadiene styrene - polycarbonate (ABS-PC), which is used in mobile phone cases, should have positive economic value as a recyclable material, but only if it is collected in a reasonably large volume, and is free of other substances that would make it unsuitable for recovery processes. Plastic mobile phone cases are not often collected in large volumes, and they often contain paints and metal coatings, such as radio frequency interference shielding, which are difficult to remove. Automated processing of mobile phones, such as shredding followed by separation techniques (*e.g.*, eddy current, gravity), will not achieve the necessary degree of separation, and the resulting plastic mix can only be used for crude plastic applications. Even careful manual separation of mobile phone plastic cases, which is expensive, does not result in a clean plastic feedstock for a new product. In addition, the presence of a brominated flame retardant may reduce the resale market for recovered ABS-PC, because many potential buyers do not want a flame retardant to be present, or will only pay a reduced price.

The total volume of available end-of-life ABS-PC from mobile phones, even when suitable for high-end use, will always be relatively small, and thus the economics of reclaimed ABS-PC may continue to be an obstacle.[21] We nevertheless recommend that mobile phone designers and manufacturers work specifically toward the goal of recycling plastic mobile phone cases. Some manufacturers are currently investigating a number of designs, such as elimination of metal fasteners and use of active disassembly materials, that will facilitate mobile phone dismantling, and which may then provide cleaner and larger stream of ABS-PC plastic cases. Elimination of paints for coloring, and substitution of pigments within plastic, will further improve recovery economics for the separated plastic cases, because plastic with different pigments (but not paints) can be mixed and recovered as black plastic, which has a large market share. (While limiting available colors would also enhance recovery, we recognize the market appeal and demand of color.) A high volume of recovered ABS-PC cases might have a strong potential for economically sound recovery and production of new ABS-PC.[22] And it may also be that clean plastics from mobile phone cases will be completely compatible with ABS-PC plastics from other sources, such as personal digital assistants, MP3 players, etc., so that even greater quantities will be available for cost-efficient recycling to produce new plastics. The MPWG recommends that these possibilities, including collaboration with other electronics manufacturers and associations, continue to be explored. Research into the use of alternative materials i.e. plant plastics (PLE) and plant / organic non-oil based paints is also recommended.

Recycling of mobile phones for metal recovery, particularly copper and precious metals will have a very positive environmental impact in a mobile phone's life cycle analysis.[23] Currently, metal recovery is conducted by a growing number of preliminary processors, which shred the phones and may do some separation, and then by a limited number of secondary non-ferrous metal smelters and refiners. The shredding process begins with whole phone handsets and peripheral devices, and reduces them to pieces with a maximum size of about 2 cm. Plastic pieces may then be separated from metal-bearing materials, but the process is crude and, as set forth above, results in only a mix of plastics that has little or no value as recovered plastic. The plastic content can instead be (and usually is) left with all other constituents. This reduces the energy that would be required in separation processing at this stage (e.g., eddy current), and further reduces the energy required in the subsequent smelting process, by substituting for other hydrocarbon fuel.

The shredded metal-bearing pieces (with or without plastic) are put into an appropriate copper smelter, in which the mass of material is melted at high temperature and selectively oxidized to separate copper, gold, palladium, and silver. These metals are further separated through electrolytic and chemical processes to produce market-grade commodities, typically at 99.9 to 99.95% purity and completely equivalent to the same metals produced from ores.

Two substances in mobile phones require particular attention in metal reclamation processes - beryllium and brominated flame retardants. Beryllium is contained in a copper-beryllium alloy with an elastic property that is useful in connectors. A modern mobile phone will contain approximately 3 mg of beryllium per handset, or about 40 parts per million. In the copper smelting process, this beryllium may be released from the molten mass as a fine particulate, and the prevention of worker inhalation of this particulate requires considerable attention and care, with engineered ventilation to remove and collect it from ambient air. The most proficient copper smelters have established an internal control of ambient beryllium at $0.01\mu g/m^3$, which is 200 times lower than the current permitted exposure level allowed by the U.S. Occupational Safety and Health Administration. To achieve this level, these smelters have not only implemented engineered emission control systems, but have also established an incoming feedstock beryllium limit of 200 ppm. A current design mobile phone meets this standard, so beryllium is not an absolute barrier to environmentally sound material recovery, but it is a consideration in selection of appropriate recovery processes and facilities.

Two brominated flame retardants are used in current mobile phones: tetrabromobisphenol-A (TBBP-A or TBBA) and decabrominated biphenyl ether (Deca-BDE). TBBP-A is reacted into the resins used to make printed wiring board substrates, and either TBBP-A or Deca-BDE may be added to a mobile phone's plastic case. A flame retardant is used in a mobile phone case because of the possibility of an electrical malfunction, especially at the battery, if the phone is misused, with a larger than normal release of electrical current, and consequent fire. A flame retardant will not necessarily prevent such a fire, but will slow its initiation, and thus it adds a safety factor to mobile phone use. A current design mobile phone may contain up to approximately 2 g of flame retardant.

The toxicity of some brominated flame retardants is widely acknowledged, but the toxicity of others is debated, and continues to be researched. TBBP-A has not been banned by the EU RoHS Directive, and is considered to have significantly different toxicity characteristics than many other brominated flame retardants.[24] There is no significant movement to prohibit its use. Deca-BDE is one of the polybrominated biphenyl ether family of chemicals, and it is believed by some persons to have potential adverse health effects similar to other PBBEs. Research indicates, however, that it is different in some characteristics from other PBBEs,[25] and the European Commission initially excluded it from the RoHS ban pending a continuing investigation into its toxicity.[26] That exemption of Deca-BDE from the RoHS ban is currently set to expire on 1st July, 2008.

A brominated flame retardant is unlikely to be released into the environment in recycling operations, including during the shredding of mobile phone plastic cases.[27] When it is used as a reactant in a circuit board, TBBP-A combines chemically with the plastic of the board itself, and no longer exists in its original form.

However, for both types of brominated flame retardant, when mobile phones are oxidized during smelting, the bromine will be released. The released bromine may then recombine with unoxidized carbon under certain conditions in smelter emissions in the form of brominated dioxins and furans. Copper smelters that use mobile phones as feedstock therefore need to be particularly attentive to combustion conditions and emission control, and to install systems that prevent the formation of dioxins and furans. The potential for such formation in copper smelters is well known, as are the preventive process and emission controls,[28] and such smelters are regulated by their competent authorities specifically for emissions of dioxins and furans.

Notwithstanding that beryllium and currently used brominated flame retardants (TPPB-A and Deca-BDE) are not absolute barriers to environmentally sound recovery of metals, Deca-BDE is scheduled for elimination under the EU RoHS Directive, as of 1 July, 2008, and the MPWG recommends that substitutes for these substances of concern always be considered in ongoing design developments for mobile phones.

The EU Batteries and Accumulator Directive (2006/66/EC) comes into effect within the EU and EEA markets on the 26th Sept 2008. Batteries are defined as primary batteries, and accumulators are defined as rechargeable (also known as secondary) batteries This Directive places the obligation on member states, and subsequently producers through national legislation, to achieve minimum levels of collection rates for used/end of life batteries. Within the scope of the Directive, mobile phone batteries classify as ‘portable batteries’. Whilst most mobile phones are returned for recycling and reuse together with their batteries, this Directive should help facilitate collection and recycling of used mobile phone batteries when they are replaced.
Article 11 of the Directive requires that products are design to ensure that batteries are readily removable from the device in order to facilitate both battery replacement during product life, and also recycling at the end of battery or product life. The majority of mobile phones on the global

market are already designed to facilitate ready removal of the batteries incorporated within them, either by the user or by an approved service facility. This Directive should ensure that such effective design practices are maintained for the long term.

Recommendation 4: Reduce or Eliminate Toxic Substances.

As set forth above, some substances i.e. brominated flame retardants and beryllium, are of concern in recycling for metal recovery because they may be released into the environment and expose workers, especially in very primitive recycling operations. It is also likely that some mobile phones will not be collected for recycling but instead disposed of in landfills or via municipal waste incineration. Disposal in a landfill may release *some* toxic substances to ground and surface waters in acidic leachate. Incineration of mobile phones, even in state of the art facilities may not eliminate all toxic substances in flue gases and ashes. Accordingly we recommend that manufacturers always take into account the likelihood of environmental and human risk in the management and mismanagement of their mobile phones at end-of-life. Furthermore, we recommend that manufacturers investigate the feasibility of replacing all toxic substances with benign substitutes.

It is important that manufacturers understand the life cycle circumstances in which their products may create exposures to hazardous substances. Manufacturers should communicate with users, recyclers and others to determine such circumstances and exposures, and then set priorities among such hazardous substances for replacement, where possible, with alternatives that are more benign and fulfill the same functions. We further recommend that all manufacturers require, by explicit contract terms and conditions, that all suppliers disclose the substances used in component parts and sub-assemblies, and comply with specifications set by the manufacturers for substances banned or restricted from use. Some manufacturers and industry associations are currently doing this,[29] and we recommend that it be a universal practice.

Recommendation 5: Adopt Life Cycle Thinking.

All of the recommendations contained in this guideline document reside as part of a much more important concept for product design, product management, and product stewardship. Mobile phone technology changes constantly and rapidly, and it is critical to include end-of-life management concerns in a culture of decision-making about the design of products of the future. Life Cycle Thinking (sometimes called Life Cycle Approach, incorporating Life Cycle Analysis) brings environmental considerations into the multitude of decisions that are made for any product and any activity, by manufacturers, by consumers, and by civil society. It is not just a design concept. Applied to marketing of mobile phones, for example, it will take into account the end-of-life fate, with possibly changing likelihood of casual discard. It will consider the environmental consequences of advertising phones as “disposable.” Management systems will integrate environmental considerations at every point.

The MPWG particularly recommends Life Cycle Thinking at the design phase of a mobile phone, which has arguably the greatest contribution to make to reduce environmental impacts during its lifetime. Figure 3 shows the steps that are taken when Life Cycle Thinking is applied to product design.

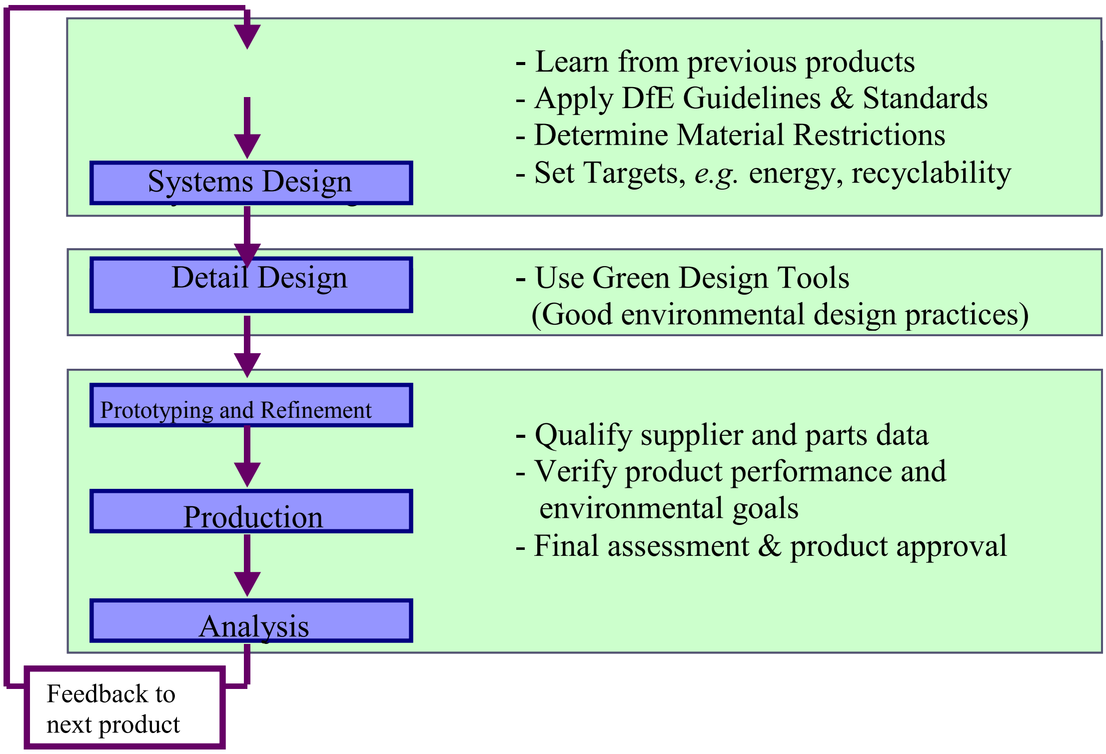

Figure 3
Steps in Life Cycle Thinking - Design

Beginning with experience from previous products, knowledge of current material restrictions (such as the RoHS Directive), and general Design for Environment guidelines, a designer can set targets for improved environmental performance. Then, using software tools, the designer can quickly see how a product will affect energy consumption, resource depletion, greenhouse gas production, air pollution, toxicity, carbon footprint etc. By trying different design solutions and inputting data to the software models, designers can visualize and assess how different material choices and manufacturing techniques change the environmental profile of their products. Qualified suppliers for selected materials and manufacturing processes can be selected, and the final product can be approved. And with a goal of continuous improvement, that experience will be applied to a Life Cycle Thinking design of the next product.

Leading mobile phone manufacturers, such as those that participate in the Mobile Phone Partnership Initiative (MPPI) with the Basel Convention, have applied Life Cycle Thinking in product design, and have identified opportunities for improvement such as:

To facilitate disassembly and separation of handsets:

- Minimise the steps necessary for disassembly.
- Minimise use of welds and adhesives.
- Reduce the variety and number of connections (*e.g.* fastener and screws).
- Minimise the tools required for disassembly.
- Use re-openable snap fits for joining of plastic parts.
- Use designs that facilitate removal of modules for reuse.
- Use advanced materials for active disassembly

To facilitate production of new plastics through recycling:

- Limit the plastic types used throughout a mobile phone.
- When different plastics must be used, use combinations that are compatible with respect to recycling.
- Mark plastics with plastic type.
- Avoid non-recyclable composites and coatings.
- Avoid incompatible coatings.
- Use moulded-in colours and finishes on plastics, rather than paints.
- Avoid adhesive -backed labels, stickers or foams.
- Use labels and marks made from the same or compatible material used elsewhere in the product.
- Avoid metal inserts in plastic parts.
- Eliminate use of brominated flame retardants.

To facilitate reclamation of metals

- Eliminate or reduce use of toxic substances.

This type of research may improve opportunities for recycling of end-of-life mobile phones, facilitate compliance with targets such as the WEEE Directive, and improve environmental performance through a longer lifetime.

Although some manufacturers may be less familiar than others with such research, and with the concept of Life Cycle Thinking and its application, we believe that even small, new manufacturers can use “off the shelf” software packages and processes to emulate the efforts and achievements of the larger manufacturers. Accordingly, the MPWG strongly recommends that all manufacturers undertake such research, as part of their adoption of Life Cycle Thinking.

5. CONCLUSIONS

The MPWG has examined typical mobile phone(s) from the perspective of its original design, with a view to how the end-of-life fate and management of a mobile phone might be enhanced through design changes. We have found, in fact, that much progress has already been made. Mobile phone design has changed dramatically since its beginning. Its overall environmental impact is much less than before, in its use of material resources, its use of energy, its end-of-life impact. But while those changes were being made, so that each mobile phone is better from an end-of-life perspective, the use of mobile phones has expanded to all parts of the world. There are now more than a billion phones to consider, and a much larger cumulative end-of-life impact that requires another look. The future promises even greater and widespread use, with multiple new hardware and software technologies, all of which require Life Cycle Thinking to prepare for their manufacture, lifetime use, and end of life. End-of-life design must now take a view toward easing the collection of hundreds of millions of phones each year (e.g., by incorporation of reuse and recycling information in product marking, labeling or internal software), as well as toward further reduction of toxic substances, greater steps to make reuse, refurbishment and recycling easier and extending the life of products and reusable components which are then recovered.

There are practicable steps for managing end-of-life mobile phones that will meet the Basel Convention’s definition of environmentally sound management. Systems and infrastructures can be created, and environmental impacts can be controlled, and reduced. All of these steps should be taken into account at the design phase, such that substantive improvements in end-of-life management will be facilitated and enhanced. This should be part of Life Cycle Thinking, a concept to be applied by all manufacturers, so that the promise of mobile telephony, bringing personal communications to all, will be environmentally sustainable for the future.

Annex I

Typical substance list for a circa 2005 mobile phone [1] (not including battery or accessories)

Used Base Materials	Mass in [g]	Relative Weight
ABS (Acrylonitrile butadiene styrene)	0.796	0.989%
Acrylic	1.269	1.571%
Acrylic based paint	0.149	0.184%
Ag (Silver)	0.150	0.186%
Al (Aluminium)	8.166	10.106%
Au (Gold)	0.018	0.022%
Ba Compounds	0.503	0.623%
Be (Beryllium)	0.002	0.003%
Bi (Bismuth)	0.0005	0.001%
Br (Bromine)	0.427	0.528%
Butadiene	0.270	0.334%
Ca (Calcium)	0.166	0.205%
Co (Cobalt)	0.035	0.043%
Cr (Chromium]	1.046	1.294%
Cu (Copper)	9.996	12.371%
EP (Epoxy)	1.089	1.348%
Fe (Iron)	8.399	10.395%
Glass fibre	2.464	3.050%
Glass	7.501	9.283%
Mg (Magnesium)	11.645	14.413%
Mn (Manganese)	0.263	0.325%
Mo (Molybdenum)	0.002	0.002%
Ni (Nickel)	3.276	4.054%
P (Phosphorous) compounds, organic	0.001	0.001%
PA (Polyamide)	0.155	0.192%
PAI (Polyamideimide)	2.810	3.477%
Paper	0.063	0.078%
Pb (Lead)	0.010	0.013%
PC (Polycarbonate)	12.500	15.470%
Pd (Palladium)	0.001	0.001%
PE (Polyethylene)	0.038	0.047%
PEI (Polyether imide)	0.010	0.012%
PEN (Polyethylene naphthalate)	0.442	0.547%
PET (Polyethylene terephthalate)	1.223	1.514%
PMMA (Polymethyl methacrylate)	0.060	0.074%
polyesters	0.371	0.459%
POM (Polyoxymethylene / Polyacetal)	0.370	0.458%
PP (Polypropylene)	0.006	0.008%
PP/EPDM	0.520	0.643%
PUR (Polyurethane)	0.001	0.001%
PVA (Polyvinylacetate)	0.013	0.016%
PVC (Polyvinylcloride)	0.012	0.015%
S (Sulphur) compounds, organic	0.004	0.005%
Sb (Antimony)	0.003	0.004%
Sb Compounds	0.053	0.065%
Si (Silicon)	0.076	0.094%
SI (Silicone polymer)	1.841	2.278%
Sn (Tin)	0.911	1.127%
Sr (Strontium)	0.050	0.062%
Ti (Titanium)	0.267	0.330%
TPU (Thermoplastic Urethane)	0.381	0.472%
W (Wolfram)	0.319	0.395%
Zn (Zinc)	0.655	0.811%
	Note: All figures above corrected to 3 decimal places	

Annex II

Glossary of Terms

Note: *These terms were developed for the purpose of the overall Guidance Document and individual project guidelines, and should not be considered as being legally binding, or that these terms have been agreed to internationally. Their purpose is to assist readers to better understand this Guideline and the overall Guidance Document. The processes of dismantling, refurbishment or reconditioning and repairing may entail the removal of batteries, electronic components, printed wiring boards or other items which should be managed in an environmentally sound manner and in accordance with the Basel Convention when destined for transboundary movement.*

Basel Convention: UNEP's Convention of March 22, 1989 on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, which came into force in 1992.

Components: parts or items removed from used mobile phones which may include batteries, electronic components, circuit boards, keyboards, displays, housing or other parts or items

DfE: Design for Environment; meaning a product has been designed to reduce environmental impact throughout its whole life cycle.

Dismantling: (manual) separation of components/constituents in a way, that recycling, refurbishment or reuse is possible.

Disposal: means any operations specified in Annex IV of the Basel Convention.

EMC: Electromagnetic compatibility (EMC) means the ability of equipment to function satisfactorily in its electromagnetic environment without either introducing intolerable electromagnetic disturbances to other equipment in that environment, or being adversely affected by the emission of other electrical equipment.

EMF : Electromagnetic Fields (EMF) are a combination of both electric and magnetic fields. EMF occurs naturally (light is a natural form of EMF) as well as a result of human invention. Nearly all electrical and electronic devices emit some type of EMF. Safety standards are applicable, but these may vary from country to country.

Eco-efficiency: producing economically valuable goods and services with less energy and fewer resources while reducing the environmental impact (less waste and less pollution) of their production. In other words eco-efficiency means producing more with less. It may include, for example, producing goods through recycling when that is more efficient, and more environmentally friendly, than production of the same goods with primary resources and methods.

End-of-life mobile phone: a mobile phone that is no longer suitable for use, and which is intended for disassembly and recovery of spare parts or is destined for material recovery and recycling or final disposal. It also includes off-specification mobile phones which have been sent for material recovery and recycling or final disposal

Environmentally Sound management: taking all practicable steps to ensure that used and/or end-of-life products, or wastes are managed in a manner which will protect human health and the environment.

Evaluation: the process by which collected used mobile phones are assessed to determine whether or not they are likely to be suitable for re-use. This assessment may include:
a) A visual check
b) A 'power-on' check
c) A check that the model is included / not included on a list of handsets provided by the refurbishment company.

Hydrometallurgical processing: processing of metals in cyanide, and/or strong acids such as aqua regia, nitric acid, sulphuric acid, and hydrochloric acid.

Incineration: a thermal treatment technology by which municipal wastes, industrial wastes, sludges or residues are burned or destroyed at temperatures ranging from 1000*C to more than 1200*C (high temperature incineration used mainly to incinerate hazardous wastes) in the presence of oxygen resulting from the rapid oxidation of substances. Most of them have an air pollution control equipment to ensure the emission levels meet the requirements prescribed by the regulatory authorities.

Integrated copper smelter: a facility, or related facilities in the same country under the same ownership and control, that melts metal concentrates and complex secondary materials that contain - among others - copper and precious metals, using controlled, multi-step processes to recycle and refine copper, precious metals and multiple other metals from managed product streams.

Labelling: the process by which individual or batches of mobile phones are marked to designate their status according to the guideline developed under the project 2.1.

Landfilling: the placement of waste in, or on top of ground containments, which is then generally covered with soil. Engineered landfills are disposal sites which are selected and designed to minimize the chance of release of hazardous substances into the environment.

Leachate: contaminated water or liquids resulting from the contact of rain, surface and ground waters with waste in a landfill.

Life cycle management: holistic way to consider the environmental issues associated with a substance, product or process from resource utilization, through manufacture, transportation, distribution, use, to waste management and disposal of residues from treatment or recycling operations.

Material Recovery: means relevant operations specified in Annex IVB of the Basel Convention.

Mechanical Separation: mechanical means to separate a mobile phone into various components or materials.

Mobile phone (sometimes called a cellular phone or cell phone): portable terminal equipment used for communication and connecting to a fixed telecommunications network via a radio interface (taken from International Telecommunication Union K.49 (00), 3.1). Modern mobile phones can receive, transmit and store: voice, data, and video.

Printed wiring board: also called a printed circuit board, consisting of integrated chips, resistors, capacitors and wires.

Pyrometallurgical processing: thermal processing of metals and ores, including roasting and smelting, remelting and refining.

RoHS: Directive of the European Parliament and the Council on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment.

RF: describes electromagnetic energy transmitted through radio and microwaves.

Recycling: means relevant operations specified in Annex IVB of the Basel Convention.

Refurbishment or Reconditioning: the process for creating a refurbished or reconditioned mobile phone.

Refurbished or reconditioned mobile phone: a mobile phone that has undergone refurbishment or reconditioning, returning it to a satisfactory working condition fully functional for its intended reuse and meeting applicable technical performance standards and regulatory requirements including the original product's rated operational characteristics. The intended reuse must include full telephony capability.

Repairing: a process of only fixing a specified fault or series of faults in a mobile phone.

Reuse: a process of using again a used mobile phone or a functional component from a used mobile phone, possibly after repair, refurbishment or upgrading.

SAR: stands for Specific Absorption Rate, which is the amount of Radio Frequency (RF) absorbed by the body. The unit of measurement is in Watts per Kilogram (W/Kg). SAR is determined, in laboratory conditions, at the highest certified power level of the mobile phone. When in use, the actual SAR can be well below this value due to automatic power control by the mobile phone. The SAR of each model of mobile phone is measured as part of the safety standard compliance process.

Segregation: sorting out mobile phones from other (electronic) wastes for possible reuse or for treatment in specific recycling processes.

Separation: removing certain components/constituents (e.g. batteries) or materials from a mobile phone by manual or mechanical means.

Transport of Dangerous Goods: UN Recommendations on the transport of dangerous goods which deals with classification, placarding, labeling, record keeping, etc. to protect public safety during transportation.

Treatment: means any activity after the end-of-life mobile phone has been handed over to a facility for disassembly, shredding, recovery, recycling or preparation for disposal.

Upgrading: the process by which used mobile phones are modified by the addition of the latest software or hardware.

Used Mobile Phone: a mobile phone, which its owner does not intend to use it any longer.

WEEE Directive: Directive of the European Parliament and the Council on Waste Electrical and Electronic Equipment.

Wastes: substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

Annex III

Endnotes

[1] Data provided by the UNEP 4.1 project manufacturing partners
[2] Fishbein, B., *Waste in the Wireless World*. INFORM Inc. 2002
[3] No reference
[4] EC Directorate-General Energy And Transport, 15 June 2000
[5] Proposal for a Regulation of the European Parliament and of the Council Concerning the Registration, Evaluation, Authorisation and Restrictions of Chemicals (REACH), 2003/zzz (COD)
[6] Proposal for a Directive of the European Parliament and of the Council on Establishing a Framework for the Setting of Eco-design Requirements for Energy-Using Products and Amending Council Directive 92/42/EEC, COM(2003) 453 final, 2003/0172 (COD)
[7] Directive 2002/95/EC
[8] See, for example, Nokia's Substance List, which identifies substances that Nokia has banned, restricted or targeted for reduction, http://www.nokia.com/nokia/0%2C%2C27566%2C00.html, and Motorola Eco-design Substances List, http://www.motorola.com/EHS/environment/supplier/eco.pdf.
[9] See the Material Composition Declaration, Joint Industry Guide, Draft of 19 September 2003, issued by the Electronics Industries Alliance (EIA), the European Information and Communication Technology Association (EICTA), and the Japan Green Procurement Survey Standardization Initiative (JGPSSI), http://www.eia.org/resources/2003-09-10.pdf.
[10] Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003, OJ L 37, 13.2.2003, p. 24.
[11] This can arise because of a technology incompatibility or because the handset has been 'locked' on a certain network as part of the handset cost subsidy often associated with provision of a new mobile service.
[12] Changing service providers is expected to increase when, by U.S. Federal Communication Commission ruling, subscribers can retain their telephone numbers when doing so. The waste generated because of technical incompatibility may therefore increase as well.
[13] May 2003, http://www.gsmworld.com/news/statistics/index.shtml
[14] For services to be available, a subscription with a local GSM network operator is necessary, of course, or a commercial roaming agreement must exist between the home and roaming network operators.
[15] The Mobile TakeBack scheme in the UK reported collecting 9 tonnes of mobile phones from 1999-2001, and 16 tonnes of accessories over the same time. http://www.mobiletakeback.co.uk/
[16] Nicolaescu, Ion V. and Hoffman, William F., *Energy Consumption of Cellular Phones*, IEEE Symposium on Electronics and the Environment, 2001, pp. 134-138
[17] Survey conducted by Surrey University, UK, on behalf of UK Takeback Ltd (now Mobile Takeback Forum – MTF), evaluating reasons for consumers returning or not returning mobile phones at end-of-life.
[18] Care should be taken, however, that a label does not interfere with plastic recycling. Any label may be difficult to remove, and also may (especially if it contains metal) contaminate batches of otherwise clean plastic.
[19] Provision of information related to mobile phone location may be limited by privacy regulations in some jurisdictions.
[20] See Introduction, Part 2, what is a Mobile Phone, substances described there and references.
[21] But not necessarily a barrier. NTT DoCoMo announced that it is incorporating recycled ABS resin, from mobile phones, in mobile phone accessories. Press Release, 23 May 2003
[22] Cases from one million mobile phones would provide about 25 tonnes of plastic. That amount of plastic, if it were a single blend and clean, would have positive economic value and a ready market. Source: personal conversation with Michael Biddle, PhD., MBA Polymers
[23] Stevels, A., *Is the WEEE Directive EcoEfficient*, IEEE Symposium on Electronics and the Environment, 2003, pp. 7-12: "[T]he environmental impact of the gold and palladium makes that it is top priority to have it all recycled."
[24] World Health Organisation, International Programme on Chemical Safety (IPCS): *Environmental Health Criteria 172: Tetrabromobisphenol A and Derivatives*; U.S. National Toxicology Progam, *Toxicological Summary for Tetrabromobisphenol A* [79-94-7] 06/2002
[25] U.S. Agency for Toxic Substances and Disease Registry, *Toxicological Profile on PBBs and PBDEs*, September 2002; U.S. National Academies of Science, *Toxicological Risks of Selected Flame-Retardant Chemicals*, Chapter 5, Decabromodiphenyl Oxide.
[26] See note 6
[27] TBBP-A, and other brominated flame retardants, have been found in the working environment at a Swedish shredding facility at only extremely minute concentrations. See Sjödin, A., Carlsson, H., Thuresson, K., Sjölin, S.,

Bergman, A., Ostman, C., *Flame Retardants in Indoor Air at an Electronics Recycling Plant and at Other Work Environments*, Environmental Science and Technology, 35, 448-454 (2001)

[28] OECD ENV/EPOC/WMP(97)4/REV2, *Report on Incineration of Products Containing Brominated Flame Retardants*, 1998. See also, *e.g.*, Lehner, Theo, *E&HS Aspects on Metal Recovery from Electronic Scrap*, IEEE Symposium on Electronics and the Environment, 2003, pp. 318-322

[29] See notes 10 and 11

[33]http://www.motorola.com/testservices/article1.htm

[34]2http://www.fuelcellsworks.com/Supppage2196.html

[35] See http://www.sdrforum.org/

[37]See http://ec.europa.eu/environment/ipp/home.htm

[38]See http://ec.europa.eu/environment/eussd/escp_en.htm

[39]EC CoC… http://re.jrc.ec.europa.eu/energyefficiency/index.htm

[40]Energy Star http://www.energystar.gov/