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Electronics Waste: Recycling of Mobile Phones

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1. Introduction

As the consumption of electronics products has increased the management of new type of waste, electronics waste (e-waste, WEEE), has become a global concern. Countries in the European Union are creating 17kg e-waste per capita annually and developing markets such as China and India are currently creating 1kg e-waste per capita a year. The amounts are expected to be rising in the future, and the joint disposal of e-waste together with municipal waste cannot continue (Chancerel &Rotter, 2009). E-waste contains many recyclable materials such as ferrous metals and aluminum, copper and precious metals as well as different engineering plastics. These are typically highly integrated into each other. This means that recycling of electronics products is technologically more complicated than for example glass or paper recycling. Most importantly disposal of e-waste causes loss of these valuable, non-renewable resources as electronics products contain wide range of valuable materials, many of them becoming scarce in the nature. Depletion of raw material sources together with increasing need for materials in manufacturing of new products together mean that collection and recycling of obsolete products becomes more and more important. Electronics waste recycling processes may also pose a risk to environment if electronic products are not treated in a proper manner at their end of life stage. Substances of concern may leak to the environment or cause health and safety risk at the treatment phase. Examples of improper treatment of e-waste are widely presented in the literature. The trend has been in the electronics industry to remove the potentially hazardous materials from the products so that there is smaller risk of contamination even if the improper recycling practices take place.

Product end of life process or value chain can be divided into different sub-processes that all aim at recovery of the material and energy content of obsolete products. Optimization of the whole value chain is important in order to get the best value for economy and for environment. This means that a system perspective needs to be taken into account when working to improve the parts of the recycling process as all phases have an impact on the others. For example waste collection logistics should not discredit the environmental or business benefits of recycling. To increase the e-waste recycling it must be noted that not all the recycling challenges are technical. The biggest obstacle in recycling is the lack of consumer awareness on collection and recycling possibilities, leading to low collection amounts. Without returning products for recycling the next phases, technical recycling processes, cannot take place. Leakage outside of the value chain of the products during the end of life process may lead to improper recycling practices. The cooperation and interaction with other players in the value chain becomes essential in closing the material loop. Naturally technical processes for separating and refining the recycled materials need to be in place as well as good data systems supporting the decision making processes (International Council on Mining & Metals [ICMM], 2006).

As the biggest challenge in e-waste recycling is the collection of the waste materials from the consumers, this chapter focuses on to the first step of the end of life process, on how to develop an efficient collection process to collect obsolete products from consumers. Awareness rising is currently the key to successful electronics waste management as the practices are not yet seen as everyday business. Consumer study is presented to show how people in different countries feel about recycling and case studies are presented to demonstrate Nokia's contribution in building a recycling culture. Many similarities can be seen in the results as consumers are appreciative of the information on how and where to recycle their old electronics. The success of consumer collection programs lie not only on the convenience and awareness but also on patience; systems need to be in place for years before recycling becomes a habit.

2. End of life phases

By definition recycling means processing waste (e.g. unwanted or useless materials) into new products to prevent waste of potentially useful materials, reduce the consumption of virgin raw materials, reduce energy usage, reduce air pollution (from incineration) and water pollution (from landfilling) by reducing the need for waste disposal, and lower greenhouse gas emissions as compared to virgin production. Recycling is a key component of today's waste reduction and is a component of the "Reduce, Reuse, Recycle" waste hierarchy. Recycling of products made of one material type, such as newspapers, glass or plastic bottles or metallic structures is already a common practice in many countries. More complicated products, such as cars, batteries and electronic products have entered into the recycling realm as well.

Product end of life treatment is not a single step, but rather a process consisting of process units that aiming at recovering reusable parts and recyclable materials. Every process step consists of one or more unit operations. Process units, or phases, can be classified according to their function in the recycling process (Chancerel & Rotter, 2009). More specifically end of life can be divided into three different phases which require different management methods and focus, and having different impact on recycling economics, as shown in figure 1.

The first phase is the collection and consolidation of waste, so called take back or collection in the case of the consumer recycling initiatives. This is very much a logistics challenge and requires a high awareness level of the consumers who need to return obsolete products for recycling. In the business environment the first phase can be controlled in a much more efficient way than in the post-consumer collection. The second phase is the pre-treatment phase, taken care of by recycling companies who separate the different materials in a product and then sell them further on to the third phase, recycling and recovery of materials and energy or even disposal. Every phase has a minor side flow of disposal of the fractions that cannot be further processed, such as wet cardboard packaging. Product design can make the second and third phase easier or more difficult therefore having an impact on recycling cost and efficiency. The second phase is a bit more complicated in the post-consumer waste collection compared to the business environment, as the collected material typically contain impurities and materials that are not meant to be collected. The second phase can include the usage of different techniques from manual disassembly to mechanical and chemical pre-processing. In the third phase there is not much difference where the waste is originated (Tanskanen, Takala, 2006).

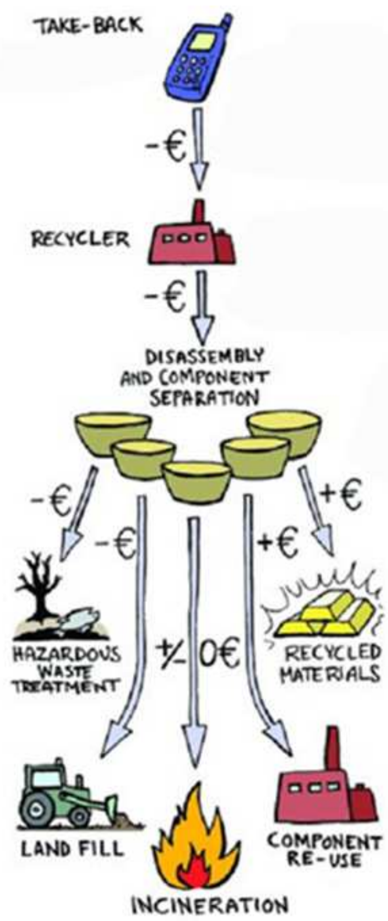

Fig. 1. Process steps of product end of life treatment with economic indicators (Tanskanen &Takala, 2006)

As the biggest challenge in e-waste recycling is the collection of the waste materials from the consumers, this chapter focuses on that phase, on how to develop an efficient take back process. Every step of the recycling process needs optimization, the challenge is not to sub-optimize the value chain but the whole system to support eco-efficient recycling process. Waste collection and management always happens locally, and case studies from different countries are presented here also to demonstrate how a global corporate strategy can be turned into local actions.

3. Challenges in e-waste recycling

Product end of life process needs to be looked as a system and the optimization should be done so that the whole value chain is taken into account rather than focusing on a part of the process. Waste management of post-consumer waste faces different kinds of challenges compared to the waste management of the office or factory waste. Waste management at the corporation's own operations is much easier to control and therefore high recovery rates for waste can be achieved. Post-consumer waste management faces different kind of challenges for post-consumer waste management are in the first phase of the end of life process, the collection.

At company premises processes can be well managed, waste amounts can be predicted and people are easier to train. For example at Nokia production sites Environmental Management Systems (EMS) and the ISO 14001 standards are used to control and manage the environmental aspects. The goal of the Nokia EMS is to improve the environmental performance, where one focus area is waste management. Most of the waste from Nokia factories is packaging waste: cardboard boxes, wood pallets and different types of plastic packaging. Typically the amount of cardboard is about 26 % and the amount of plastic 37 % of the total waste stream. E-waste amounts to only 1 % of the total waste amounts. Waste utilization rates are very high at Nokia plants: average of 92 %, so that 6 out of the 10 factories have utilization rate of over 96 %. Waste utilization rates vary because of the local infrastructure and recycling partner availability and because of the small differences in waste separation at the manufacturing sites. Most importantly all the waste that is created can be sorted and directed to dedicated waste companies for recycling. This is an activity that takes place every day. Most of the challenges that consumer e-waste recycling faces, from awareness to collection are mainly solved in the factory environment.

Consumer plays a big part in the first phase of the value chain, so the recycling behavior of the individual is crucial for the whole process. For the consumer convenience and awareness are the key points that will encourage them to start recycling. All the e-waste that can be collected needs to be directed to proper recycling facilities so that recycling happens in an eco-efficient manner to avoid contamination and ensure the efficient recovery of resources. E-waste recycling today has three main challenges that need to be improved in the way to the full recycling society. These are consumer awareness and collection, best practices in processing such as cost efficiency and value generation, and getting the material to proper recycling.

3.1 Awareness

Consumer study by Nokia shows that less than 10 % of people have recycled their old mobile phones. Most of the unused phones are still at home, making the recycling potential huge. The lack of awareness that recycling is even possible and knowledge on existing recycling programs and locations are the main obstacles for consumers. This means that the first challenge in motivating people to recycle electronics is to get them to understand that it is possible and to show how can be done.

3.1.1 Consumer behavior

There have been many studies on consumer attitudes to recycling. A schema picture is show in the figure 2 to summarize the different features that have an impact to persons recycling behavior. The first layer around the consumer describes the direct impact on the recycling decision, such as accessibility and attitude. The next layer shows the ways how to motivate the recycling behavior, like past experiences or transparency of the system, and the following layer presents the different ways to influence recycling behavior from marketing and social media activities. The outer layer shows the future values and social trends that may have an impact to consumers recycling behavior, communality and downshifting being examples of those trends. As seen from the figure, there are many factors impacting the recycling behavior, from personal attitudes and experiences to the quality of the recycling systems that are in place. Recycling is a global theme that needs local execution. Different ways to communicate, incentivize and motivate consumers are effective in different countries. To better understand what people think about phone recycling, Nokia has conducted two global consumer studies on the topic. The results for the studies are being used in planning and executing phone recycling programs.

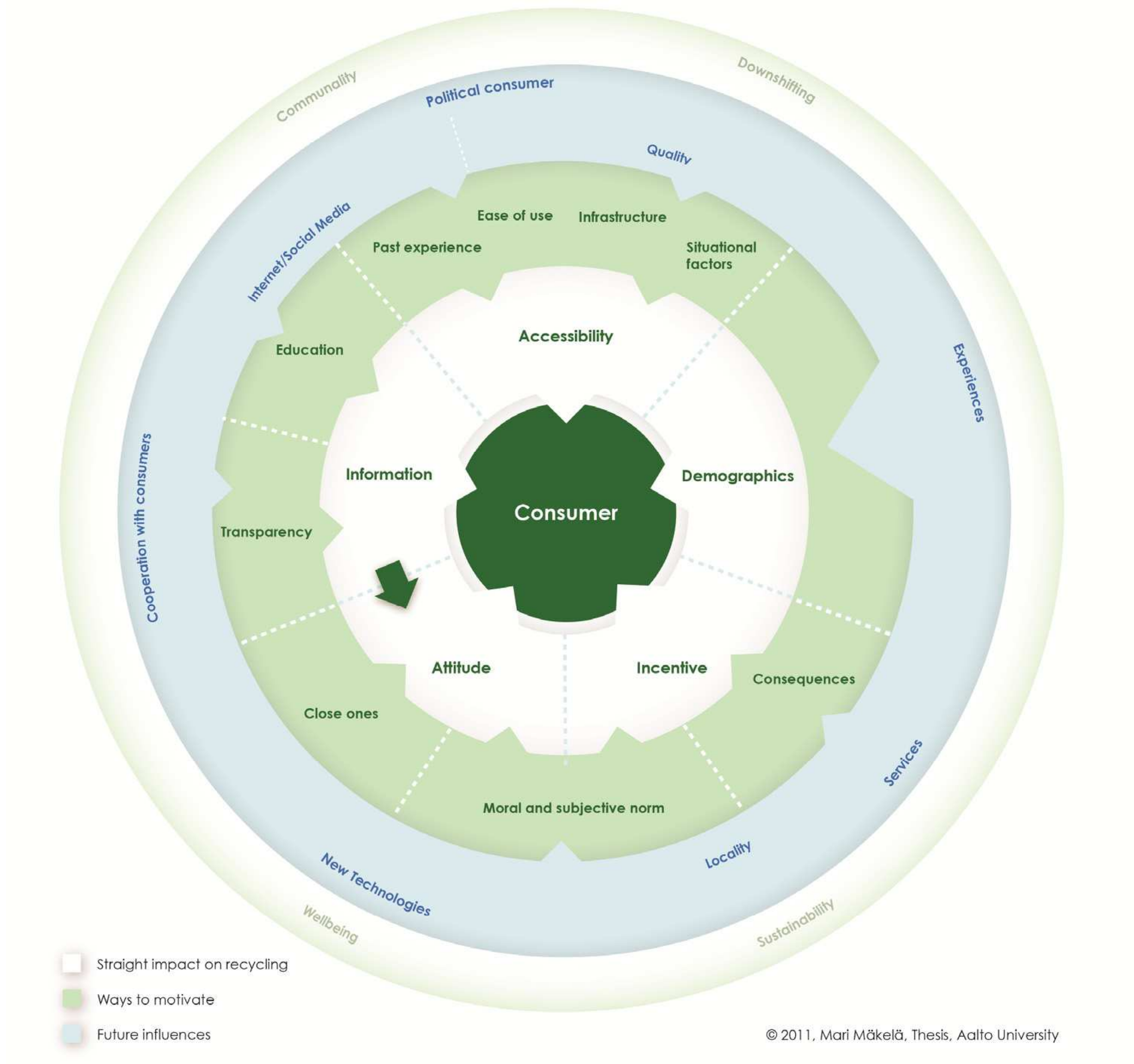

Fig. 2. Features affecting consumer recycling behavior (Mäkelä, 2011)

Based on the first consumer survey on consumer recycling behavior and attitudes at 2007 it was found out that despite the fact that households on average have each owned around five phones, very few of these have been recycled once they are no longer used. Nearly half of the consumers were unaware that it is even possible to recycle a mobile phone. Two thirds said they did not know how to recycle an unwanted device and 71% were unaware of where to do this. Only 3% said they had recycled their old phone. The survey was based on interviews with 6,500 people in 13 countries including Finland, Germany, Italy, Russia, Sweden, UK, United Arab Emirates, USA, Nigeria, India, China, Indonesia and Brazil and in the second study additionally also Argentina, Spain and Nigeria were included, but not Sweden, Brazil, Italy and Russia. Figure 3. shows what people have done with their previous phone according to the consumer study done in 2011. A majority of the old phones is kept at home or given to somebody else for further use. Fortunately the survey in 2008 showed that only 4% of the old phones had ended up into landfill, which is a concern from the environmental efficiency point of view. (Nokia, 2008, 2011).

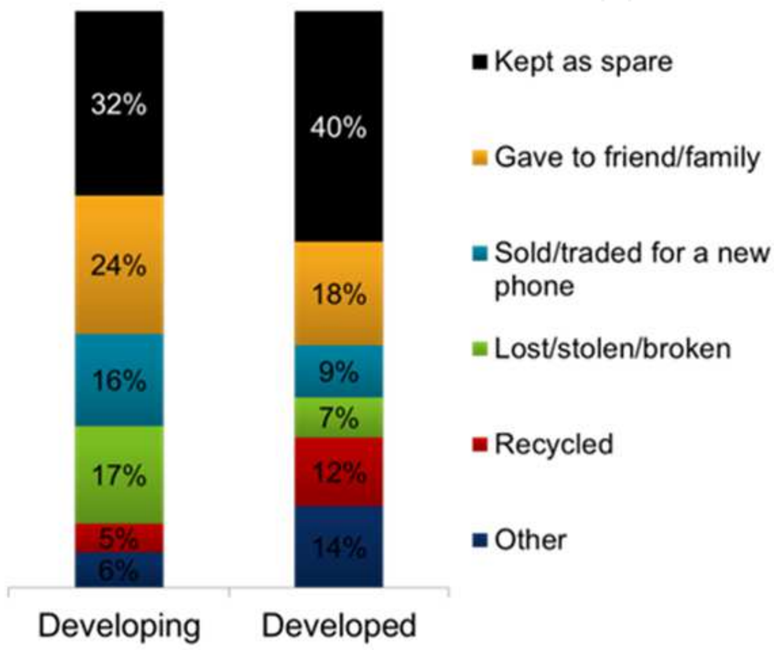

Fig. 3. Global study at developing and developed markets on what people have done to their previous mobile phone (Nokia, 2011b)

It was seen that there is a disparity between awareness of materials and items that may be recycled and reported recycling behavior in all markets that have been studied. Finland, Germany and Spain reported to be the biggest recyclers, in terms of the range of items that people usually recycle. Of the 11 countries in the study, the United Arab Emirates, Nigeria and Indonesia reported to recycle the smallest range of items. Overall, developed countries reported to be more aware of the range of different materials and items that can be recycled than developing nations, and also tend to recycle more. More barriers to recycling were reported to exist in developing countries, where awareness of both recyclable materials and items and recycling channels is lower. Developing nations have fewer recycling channels available to them, and that means that it is not as convenient to recycle as it is in many developed countries. Figure 4. shows the mean number of different items out of 11 possibility people claimed to have recycled when asked. Items that were listed were: paper/cardboard, plastic bottles, cans, glass, metals, clothes/shoes, mobile phones, batteries, televisions, refrigerators and computers. From this list the most commonly recycled materials were paper/cardboard, plastic bottles, glass and cans. More complicated products, like electronics were reported to be recycled less than other materials both in developed and developing markets.

Fig. 4. Mean number of items out of 11 that are being recycled (Nokia, 2011b)

According to the Nokia consumer survey from 2011, overall, 9% of respondents in the survey claimed to have recycled their last mobile phone, an increase of six percentage points from 2007. The developed market is at the forefront of this, although strong growth has been seen in India and China since 2007. Figure 5. shows the results for claimed mobile phone recycling in different countries.

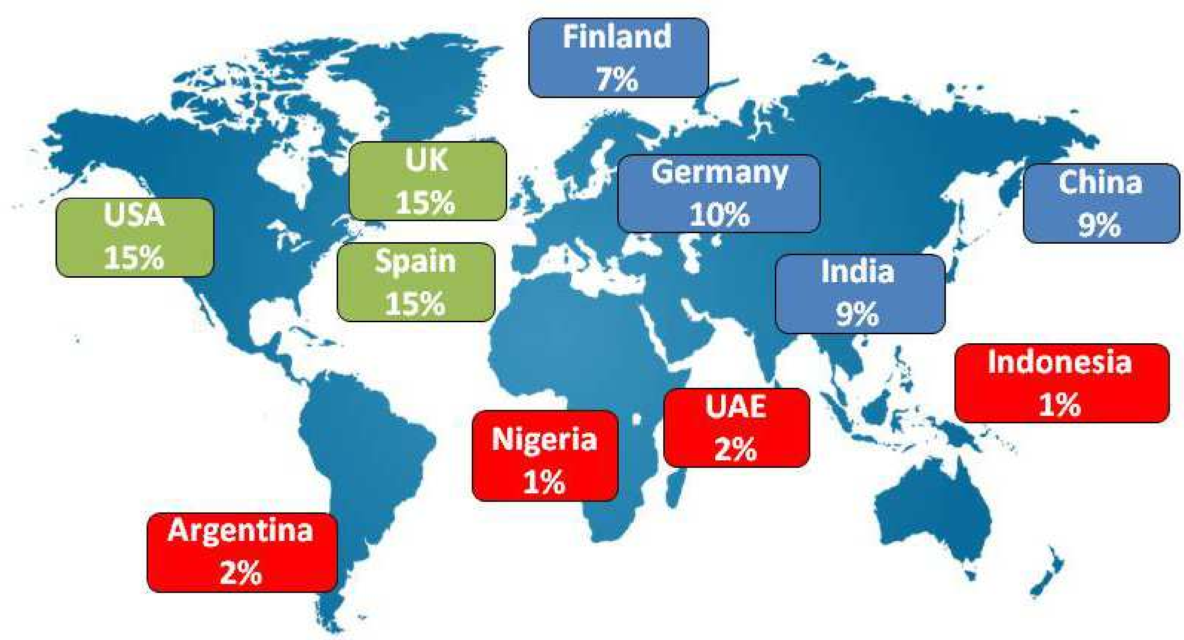

Fig. 5. Reported recycling of last mobile phone (Nokia, 2011b)

For the purpose of the study, recycling a mobile phone was defined as breaking down the phone into its composite parts to reuse in making of new products. According to the study most have an accurate understanding of what recycling a mobile phone traditionally means, although recycling can mean many other things as well, such as trading in old phones for a discount on a new phone, or giving it to someone else. This is an example of the challenges in communicating recycling messages, as the term "recycling" alone can be understood in so many different ways.

3.2 Collection

Electronics waste needs to be collected separately in order to the recycle and reuse the material content. E-waste can be collected on a voluntary basis or to fulfill legislative regulations. The motivations for collecting electronics for recycling range from economic to environmental protection and to brand enhancement motivations. The main objective for the majority of the legislations for e-waste is to prevent it to be disposed together with household waste.

Collection methods can be classified by the used models and by the persons or organizations responsible for organizing and/or financing the operations. The following models are available for collection (Chancerel, 2010, Hai-Young, 2005):

1. Drop-off program, with permanent collection centers or retailers, containers on the streets, or temporary collection events;
2. Pick-up program, where the e-waste is collected at the homes or offices
3. Distance collection, where the user sends the e-waste by post to the collector.

Collection methods each have they pro's and con's. Pick-up and mail-back programs generate higher logistics cost than drop-off programs. Collection places need space and they need to be supervised, which can be a challenge e.g. with retail and home. Event type of drop-offs can help in raising the awareness of the recycling and are simpler to operate than the permanent systems. Convenience is highest in the pick-up collection, but drop-off points are helpful in the case when the waste material is difficult to store at house because it takes lot of space or is dirty. For valuable waste materials there are typically many programs for recycling them, e.g. for charity, so the competing scheme must be even more convenient than the existing ones. A study shows the distribution of the different types of e-waste collection programs as follows: permanent collection (47%), special drop-off events (45%), and curbside collection (8%) (Hai-Youg, 2006, Jenkins, 2003).

The responsibility to finance and/or to organize the collection can be done by one of the following: (Chancerel, 2010)

1. Public authorities like municipalities and governments;
2. Private commercial organizations like manufacturers, retailers or recyclers, informal sector
3. Private non-commercial organizations like non-governmental organizations or citizen initiatives.

Generally the optimal level for collecting and recycling waste materials is difficult to determine as the recyclable material, local conditions, technical and operational issues have an impact on it. When households recycling behavior has been studied the results show that the most important factor to enhance recycling is convenience. Improvements on collection service and design are the most important factors on enhancing the recycling behavior; together with information and promotion. Other factors, such as financial incentives and socio-economical features show more mixed results. Financial incentives may play a role when non-recyclers are being activated to change their behavior, and they are the most effective when they are directed in improving the community or influencing tax rebates. (Shaw, 2008). It has been proven that the familiarity with recycling other household waste fractions, such as glass, paper, metal and plastics boosts the willingness to recycle e-waste as well. (Saphores, 2006) Improvements should focus on improving the program and information about it.

The largest environmental impact of small electronic devices recycling can easily come from the logistics related to consumer activity in recycling. This is the part where consumer takes recyclable material to a collection point, in the worst case driving to the collection location without any other reason. An example from household glass collection shows that the collection amount would triple if the collection box is placed close to the household, but at the same time environmental impact is increased because of the increased logistics. (Teerioja, 2010). These suggest that optimizing the convenience with logistics, costs and environmental benefits is important in recycling programs to keep them attractive and still eco-efficient.

3.3 Best practices in processing

Even though metal recycling as such is an ancient technology, there is room for the development. Electronics products are first of all complex, containing materials from all different material types. Materials are highly integrated into each other, they are present in low quantities are therefore not always easily separated in recycling processes. On the other hand each product group, from refrigerators to hair dryers and mobile phones are different in structure and composition. Not even all mobile phones are the same, so the variety of the product types and structures in the recycling process is huge. When a closer look is taken to the product composition, it can be seen that they vary not only on the structure, but also on recycling economics. Some of the products contain relatively large amounts of valuable materials, and recycling of these products generates value and profit. These are typically products with precious metal containing printed wiring board or large metal pars. Some products contain hazardous parts that need to be disassembled and treated in specialized waste treatment facilities, like cooling agent removal from old refrigerators. Products may also be constructed of materials with no reselling value, which means that in these latter cases recycling becomes a cost. Product design can either help or hinder the efficient pre-treatment of waste electronics products and has therefore an impact to recycling cost. There has been lot of development in removing potentially hazardous substances from the electronics products. For example materials such as lead, brominated flame retardants and PVC are no longer used in Nokia mobile phones. Typical material content of a mobile phone is presented in the figure 6.

Because electronics products are so diverse in composition and structure, it is quite challenging to develop advanced recycling technologies that would be suitable to all product types. Another important factor hindering the development is the low collection amounts of e-waste, influencing revenues of the recycling operators. These things together mean that there is not yet many facilities that could focus on specific type of e-waste recycling, but most of the processors need to take different products into their facilities. As volumes for each of the different products are low, automatization levels remain low and waste treatment remain on a relatively general level.

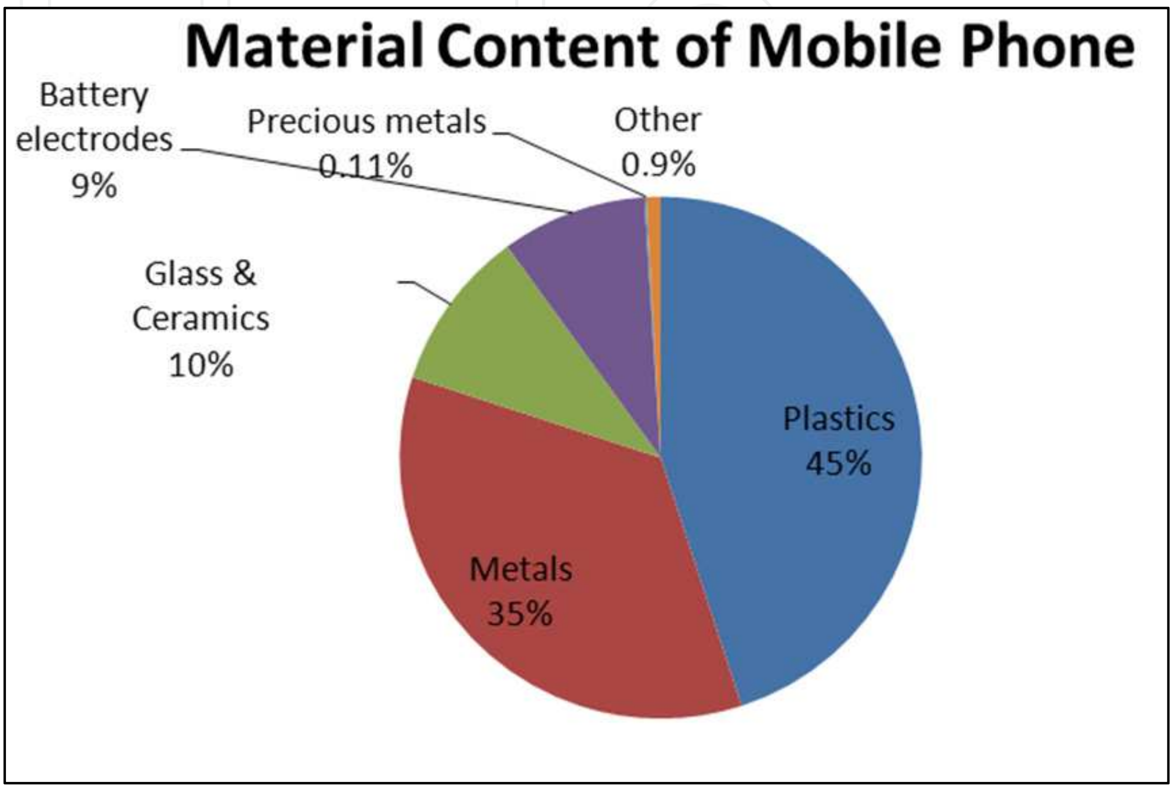

Fig. 6. Material content of a mobile phone (Nokia, 2011a)

It has been shown that products containing relatively high amounts of precious metals, such as mobile phones, separate collection and treatment, even including higher costs for logistics, will bring higher environmental and economic value. For the products containing about 250 ppm gold and 150 ppm palladium separate collection is always more eco-efficient that mixing these products with the ones containing smaller amounts of precious metals. An assumption for the calculation is that collection amounts are big enough, few tonnes rather than few hundred kilograms. (Huisman, 2003). With the use of proper recycling technologies, 100 % of the materials in mobile phone can be recycled and recovered as material or energy, and nothing is wasted. (Nokia, 2011a).

3.4 Getting material to proper recycling

One of the risks in e-waste handling is that the materials end up to be treated in improper recycling facilities, often in developing countries. These practices, like recovering copper or precious metals by uncontrolled burning and leaching processes, have been reported to not only contaminate the surrounding environment but also causing health risk to the people operating the process.

E-waste can leave the formal management system to enter the informal sector and be even exported to developing countries. This show how important it is to look at the whole recycling process and how it needs to be controlled in order to direct e-waste to proper recycling facilities. E-waste can leave the system at any point of the end of life process, creating value at that point of the process but causing harm and lost resources at some other point.

4. Mobile phone take back cases – Creating a recycling culture

The first take back pilot program for mobile phones took place in Europe in 1997. It was run in Sweden and the UK and it was executed by member companies of ECTEL (European Telecommunications and Professional Electronics Industry association) group consisting of six mobile phone manufactures (Tanskanen & Butler, 2007). Since the first program there have been many Nokia led collection initiatives globally aiming at raising the consumer awareness on mobile phone recycling. For Nokia the target for running recycling campaigns for mobile phones is to raise the consumer awareness on the recycling options. Campaigns are always supporting the existing infrastructure that is in place, so that there is continuity for recycling behavior. Nokia has for example in 2010 run co-operation programs with telecom operators and retail companies in seven countries, university events in 11 countries, direct consumer campaigns and events in 19 countries and special campaigns in Nokia repair network in eight countries. National recycling programs with Nokia's participation was done in 29 countries and four countries had a mail-back system in place in 2010. Altogether Nokia was offering permanent take back for obsolete phones in almost 100 countries in more than 5000 locations. (Nokia, 2010)

The build-up of the working recycling process for consumers can be divided into four subsequent steps. Introducing the recycling agenda and building up the infrastructure are the first steps leading to wider collection network together with partnerships. When the program has been tested and expanded through cooperation with others the next phase is the improvement and development of the program through data collection and analysis and through better understanding of the local consumer behavior. Case examples are shown here on how to raise the awareness on recycling in traditional media and in social media.

Four steps in building up a recycling program:

- Introducing recycling agenda at new markets
- Building up an infrastructure
- Expanding the program and building partnerships
- Data collection and understanding consumer recycling behavior

4.1 Introducing recycling agenda

When Nokia started to plan the first mobile phone recycling campaign in Uganda in 2010, many people were sceptical about the success of the campaign. Comments stated that "Recycling may work in Western countries, but not in Africa" "People expect money in return for their old phones, and if you do not give money you will not get any phones back." Even with the skeptical comments there was a belief that with more than 11 million mobile subscribers in Uganda, there is great potential to influence and make a difference to the environment and find a solution to increasing the problem of electronic waste.

The first recycling campaign was arranged in the Uchumi supermarket in Kampala, Uganda for two days. During those two days 459 old phones, 254 chargers and 239 batteries, in total of almost thousand items, were collected and good feedback was received: "Recycling makes a lot of sense". Consumers in Uganda see every day the problems created by the illegal dumping of electronic waste in their country, and they are ready to take action. One of the success factors of the campaign were the radio ads which Nokia ran on several radio stations to encourage people to recycle. Radio is a powerful medium in Uganda, and many people heard the message and took action. Another success factor was the fact that Nokia gave small gifts (for example, a bag made out of recycled material) to people who brought handsets back for recycling. And everyone also got the chance to enter a raffle, with the chance to win a Nokia N8 mobile phone. The short campaign in Kampala was a small, but successful step, as it is noted that creating awareness and changing people's behavior towards the environment takes time. In addition, permanent collection points have been set up at the Nokia repair centers in Kampala, with recycling bins for people to drop of their unwanted phones and accessories.

In 2010 Nokia introduced new recycling programs in Kingdom of Saudi Arabia, Lebanon, Uganda, Sri Lanka, Uruguay, Pakistan, Panama, Belarus, Bosnia, Malta and Ukraine in order to take the first steps in of creating the recycling culture. (Nokia, 2010)

4.2 Building up an infrastructure

Recycling starts with setting up a collection infrastructure. Although take back vehicles are in place for all consumers the lack of awareness of these possibilities can offer some real challenges in making the take back program successful one. Making the consumer aware of the opportunities to recycle and changing the mindset and habits of the disposal patterns in society are the true keys to any successful program. Communication together with easy take back options are seen as means to increase awareness which further leads to increased recycling of electronics waste.

Commonly used methods to collect mobile phones, batteries and accessories are special collection bins for phones, mail back envelopes and general e-waste collection locations.

A visible collection method is the take back kiosk or bin, an example of the collection bin is shown in figure 7. In this approach, challenges are many; location of the bins must be easily accessible and secure, bins need to be emptied often and finding an effective logistics solution that is economically viable is difficult in rural environments. People also tend to put all kinds of rubbish from empty cans and paper cups to apples to the recycling bins. However, bin collection can be an effective means on company premises –Nokia has implemented collection bins in all its locations globally. Bins are also effective in communicating the recycling message.

For a consumer, one of the easiest ways to recycle is to use postal services. This is especially suitable for small devices such as mobile phones. With a pre-paid postage envelope one can drop off the phone to the nearest mailbox and it will be sent to recycling. An example of a recycling envelope is shown in the figure 8. There are several ways to distribute the envelopes. Prepaid postage and addresses can be downloaded and printed from the internet, envelopes can be mailed directly to the consumers, distributed in retail shops, or can be included in the sales package of a new product. Envelopes provide an easy return process, but are costly in terms of reverse logistics and are neither efficient nor safe when larger volumes or unknown waste is in question. Results from envelope programs have shown an average of 1.2 handsets per package. This cannot be classified as low environmental impact in terms of logistics compared to programs where hundreds or even thousands of handsets can be collected in a single drop off location. However, mail back programs do offer the consumer the easiest method possible.

Fig. 7. Recycling Bins for mobile phones

Communal waste collection points can be used as take back locations for a wider spectrum of waste having special containers for mixed e-waste. In these locations there can be collection for not only different types of e-waste but also other materials such as wood, metal and glass. This is a cost efficient way of collecting waste materials, and also easy for people dropping of a different kinds of waste materials at one location.

Fig. 8. Recycling envelope for mobile phone

4.2.1 Case India

Nokia started its take-back and recycling program in India in 2008 with the key objective of raising consumer awareness on recycling of mobile devices and making it easy for consumers to recycle. Before the project could be started there was a need to build up a collection infrastructure, after that the following steps were awareness rising by using a variety of media and incentivizing consumers for recycling. The main challenge in starting the recycling program in India was a low level of environmental awareness amongst the consumers and among trade partners and retailers. This meant in practice that there was no existing recycling infrastructure (collection places and recycling companies) in place and information on e-waste recycling was also not available. In addition there was no regulatory framework or policies on e-waste management and roles of different stakeholders were not defined.

Recycling program was initiated by laying out recycling infrastructure across India. Building up an infrastructure for phone collection included the following:

- Recycling bins and information material for consumers were put in place. More than 1400 specially designed secure bins where placed at Nokia Care Centers and Branded Retail Stores.
- Reverse Logistics and IT system were developed for collection of phones from drop-off points, consolidation and shipment to recycling company. IT system was also used for capturing the number of phones and accessories dropped for recycling along with some details of the person who had dropped it.
- Local recycling companies needed to be assessed to ensure that they fulfilled the requirements from business, environmental and security point of view. Cooperation model and contract was set up with the selected company.
- Training of over 8000 employees of the Nokia Care Centers and Branded Retail Stores was done so that they could engage consumers on mobile phone recycling.
- A SMS based solution was developed to make it easier for consumers to identify the nearest location of recycling points.

After setting up the infrastructure, the recycling program was launched as a pilot in four cities - Bangalore, Delhi, Gurgaon and Ludhiana for a period of 40 days in 2009. The aim of the program was to make recycling easy and to raise consumer awareness. A key challenge during the launch was overcoming the skepticism of the trade partners and retailers. The trade partners believed that Indian consumers were not yet ready for recycling. In the second phase the program was expanded to cover an additional 28 cities. Different marketing methods were used to get more publicity. Roadshows were run at shopping malls and in the main markets. Billboards, radio and print media were also used in advertising together with Bollywood celebrities.

An incentive was added to the recycling program to get people more involved. Nokia committed to plant a tree for every phone dropped for recycling during the specified campaign period. By using plantation of trees as a declared incentive, Nokia aimed to build the right consumer attitude towards recycling wherein recycling is done for benefits to the environment and society at large rather than for personal gains.

The recycling programs have received positive feedback and results. More than 50 tons of old phones and accessories have been collected in India during the first 2.5 years of the recycling program. The collection amount has been increasing every year showing the importance of the long term planning of the recycling programs. The recycling message has reached more than 100 million people across India via various marketing media. Until the summer of 2011 Nokia has in return planted over 90.000 trees and planting continues. Collection and recycling is now put into the agenda and will continue after the active marketing campaigns.

The pilot campaign in India brought some insights on recycling behavior. An important conclusion is that people will start recycling if they are provided the right information, and it is easy for them to recycle. Cooperation in the collection efforts is also crucial as it was noticed that trade partners are important in convincing the consumers and encouraging them to recycle.

It was noticed in India that old mobile phones are used until no further value can be extracted out of them. They are then kept as back-ups, handed over to others or sold or exchanged for a discount on a new phone. Many consumers hang on to their old phones for the sake of emotional attachment.

For the majority of the consumers the concept of recycling is not clear. For most people recycling means getting some value out of something that has become useless. The findings implied that any communication around recycling needs to be very short and simple and emotional and social rather than rational. Rational messages are more likely to put consumers in a skeptical frame. Taking care of the environment should be linked to doing one's duty for society: either the future of children or healthy environment for the family. In India the results indicated that engaging women & youth should be the main focus for communication efforts. The last important learning is that the take-back initiative should make consumers understand that this initiative is a 'process', 'a way of thinking' rather than a 'scheme' to ensure the continuity of the action. (Singhal, 2010)

4.3 Expanding the program and building partnerships

After setting up a basic infrastructure for recycling and starting to raise the consumer awareness on recycling possibilities the program can be expanded in cooperation with different partners. Nokia aims to learn from each of the recycling program and develop the programs to be more attractive, convenient and efficient. Recycling programs are being done in cooperation with telecom operators, retail chains, environmental NGOs and with schools and universities. These are the partners that can help in getting the programs closer to the people so that they are convenient to use and also help to raise the awareness of recycling by education.

Nokia started a recycling program in China already at the end of the 2005. The program was launched together with the teleoperator China Mobile and with Motorola. The next year six other mobile phone manufactures joined the program. The program has been growing every year, it started with 40 big cities and 1500 recycling location and after six years it covers already 300 cities. Program has collected more than 160 tons of e-waste by the end of 2010. Different activation methods have been used over the years, from prepaid phone cards, eco-friendly shopping bags and tree planting. Experience van has also been used to spread the message to smaller cities that were not included in the program. In Latin American countries recycling programs started in 2006 in Mexico in cooperation with telecom operator Telefonica. Cooperation has expanded to other countries Peru, Brazil, Chile, Columbia, Ecuador and to Argentina (in cooperation with Claro). Latin American countries have collected 375 tons of e-waste in these programs in the first four years. These programs are good examples of how long term one must think when starting to communicate and operate recycling program for consumers and how the working concept can be duplicated from one country to another.

Nokia has also raised recycling awareness in cooperation with environmental NGO's in many countries. In Lebanon Nokia has been working in cooperation with The Association for Forests, Development and Conservation (AFDC) to conduct recycling events in universities. In United Arab Emirates there is collaboration with Emirates Environmental Group (EEG) working with schools and corporations to raise the awareness level about recycling. Posters created by a well-known film maker in UAE help to change children into "recycling heroes". Nokia India also made two educational books for children in cooperation with TERI- The Energy and Resource Institute to support awareness raising at schools. In Singapore as part of Nokia's Environmental Conservation initiative - Recycle A Phone, Adopt A Tree Program- students from Temasek Polytechnic got a change to participate in a field trip to WWF re-forestration site Rinjani Forest in Lombok Island, Indonesia that Nokia is sponsoring. Wild Ocean is a nature film that in the USA has helped Nokia to spread the sustainability message for school groups. A Wild Ocean education campaign was launched utilizing Nokia-branded educator guides and activity posters available for schools.

Cooperation with universities and researchers can also be wide ranging. In Mexico Eco Rally 2010 was a two day recycling event at the Technical University of Monterrey. During the two days not only thousand items were collected for recycling but also a workshop with students was arranged to raise environmental awareness. Nokia is also a member of United Nation University SteP (Solving the E-waste Problem) initiative. One of the SteP activities is an annual E-waste Summer School with post graduate participants from all over the world looking to find solutions on how to manage e-waste in their countries. To take a totally new perspective for recycling, Nokia together with an environmental design office S.E.O.S have organized two "Phone Liberation" workshops. These workshops have collected engineering, industrial design and economics students in Espoo Finland and in Shanghai China to brainstorm improvements for phone recycling. The second workshop was done in cooperation with Aalto University and Tongii University who hold a summer school program on public transportation. The purpose of this workshop was to innovate how recycling can be done in public transportation environment. An example of the ideas on how to communicate recycling in public media is shown in the figure 9. In the idea an old mobile phone is exchanged with the access ticket to public transport, e.g underground or train.

Fig. 9. Mobile phone used as an access ticket to public transportation

4.4 Data collection

Data collection and analysis is one of the cornerstones for measuring and improving of any activity. For recycling this is important for example for planning the logistics or collection methods, calculating the business cases for marketing campaigns and for setting targets for programs. Good and transparent data systems are also important in supporting the decision making for closing the loop in recycling society and for building partnerships. These include sharing the best practices in public forums and public reporting of performance. (ICMM, 2006). Transparent information systems are also important in preventing the illegal waste transportation from developing to developed countries leading to improper recycling practices.

4.4.1 Case Finland

In Finland, the EU WEEE directive was implemented in national legislation in 2004. As a member of producer association Elker (www.elker.fi), Nokia is taking part in maintaining take back points for the public to return old devices and the reporting of imported product and recycled waste flows to authorities. In addition to these collection points, end users may return old devices to the retailer when buying a new device. Nokia also offers a service where an old device may be returned to an authorized service point or through pre-paid mail service for proper end of life treatment. Existing channels for unused mobile phones in Finland are many, but the awareness of consumers regarding these options can be increased.

Three different recycling campaigns have been carried out in Finland in 2006, 2008 and 2009 to raise awareness of various take back options. The idea of the campaigns was to bring answers for two main obstacles in recycling consumer electronic products: awareness and incentives. On top of that the idea was to make recycling as easy and convenient as possible in order to activate typical non-recyclers. Campaigns utilized prepaid postage envelopes for collecting obsolete devices for recycling. Different distribution methods for envelopes were studied. Envelopes were distributed in the sales box for online sales, direct mailing to households, as magazine insertions, at Finnish Post offices, Nokia service points and retail and it was downloadable from Nokia internet page. Marketing efforts included campaign web pages, banners on partner web pages, posters and also newspaper ads.

Different incentives for consumers were used to get the consumers to mail back their used phones utilizing postage paid envelopes. In the two first projects Nokia donated 2 Euros for each returned Nokia phone or accessory for WWF campaigns, first to a climate program and later to protect the Baltic Sea. The third campaign promoted the use of immaterial services for mobile devices, such as games, music and navigation. When a phone was returned, the consumer received a code for free download of the selected service.

These campaigns have offered a unique opportunity to analyze consumer behavior regarding recycling The combination of advertising and incentives can be attributed to increasing consumer awareness and participation. As seen in many other recycling initiatives as well, not only private consumers were activated but also companies started asking how to return used phones, batteries and accessories for recycling.

These three campaigns together managed to collect 53.000 phones. Not all the consumers were interested in the incentives; it was interesting to see that there was a group of consumers, 16 % from total, who only wanted to recycle without any incentive at all. This supports other studies showing that financial incentives do not need to be in place for recycling activities to start- convenience is the main driver. After the campaign the mail-back system is still in use and one can download pre-paid envelope anytime at the Nokia.fi internet page.

Recycling campaigns are activating people to recycle and the large amounts of envelopes that have been distributed and downloaded are coming back to recycling. In the first campaign all the envelopes were distributed directly to people by using different channels from direct mail to magazine inserts, and 11 % of the envelopes were returned to recycling. Previous experiences showed that 2 % of the envelopes put into the sales package were returned back, so the result was really good. In the next campaigns people were directed to pick-up an envelope themselves, or even go to the internet page to seek for more information. 19 % of the people who visited the campaign internet page also downloaded the recycling envelope. From the ones who had downloaded the envelope 64 % returned it to recycling, while the envelopes that were distributed elsewhere (street, retail) 29 % were returned. These very high return rates were achieved when envelopes were given to those who showed some interest in recycling. Envelopes are being stored at home and they are being used later, when there is something to return. It has been seen that envelopes are returned even five years after the campaign has finished. When different distribution methods have been compared it can be concluded that the most efficient return rate can be achieved when people download or pick up the envelope themselves, rather that when it is provided to them.

The phone models which have been returned in recycling campaigns are rather old, typically from the 1990's. In addition to mobile phones, return envelopes have included batteries, chargers and plastic covers. This indicates consumers have been saving handsets, old parts and even plastics waiting for a proper and easy disposal option. An average of 14 % of the envelope includes more than one phone. 12 % of envelopes have not had a phone but they contained accessories and batteries and 60 % included one phone with a battery. People typically have more than one item for recycling, in 2009 envelopes contained an average 1.43 items and 1.05 phones, showing small decrease from the first campaign in 2006 with 1.52 items and 1.1 mobile phones.

4.5 Utilizing consumer insight

The main barrier for phone recycling is that people like to keep the phones as spare or back-up. Figure 10. shows the ten main reasons for not recycling a mobile phone. According to Nokia consumer survey, globally over a third of the respondents claimed to have kept their last mobile phones, see also figure 3. People in developed countries are particularly likely to keep their old mobile phone, whereas in developing nations people are more likely to seek further value from their old phone by giving it to someone else, or selling or trading it for a new phone. Following the desire to keep old mobile phones as spares, awareness is also a major barrier to recycling, with a fifth of respondents citing this as the reason for not recycling their previous phone. This is particularly relevant in the developing countries where there is the lowest awareness that mobile phones can be recycled and where they can be recycled. The study also showed that there is an opportunity to encourage more recycling through education, by building awareness that old mobile phones can be recycled, and highlighting both the environmental and personal gains associated with this. It must also be noted, that recycling amounts of e-waste are still quite low because recycling infrastructure for e-waste is not yet mature or easily available in most countries. Legislative frameworks are also important to foster this development.

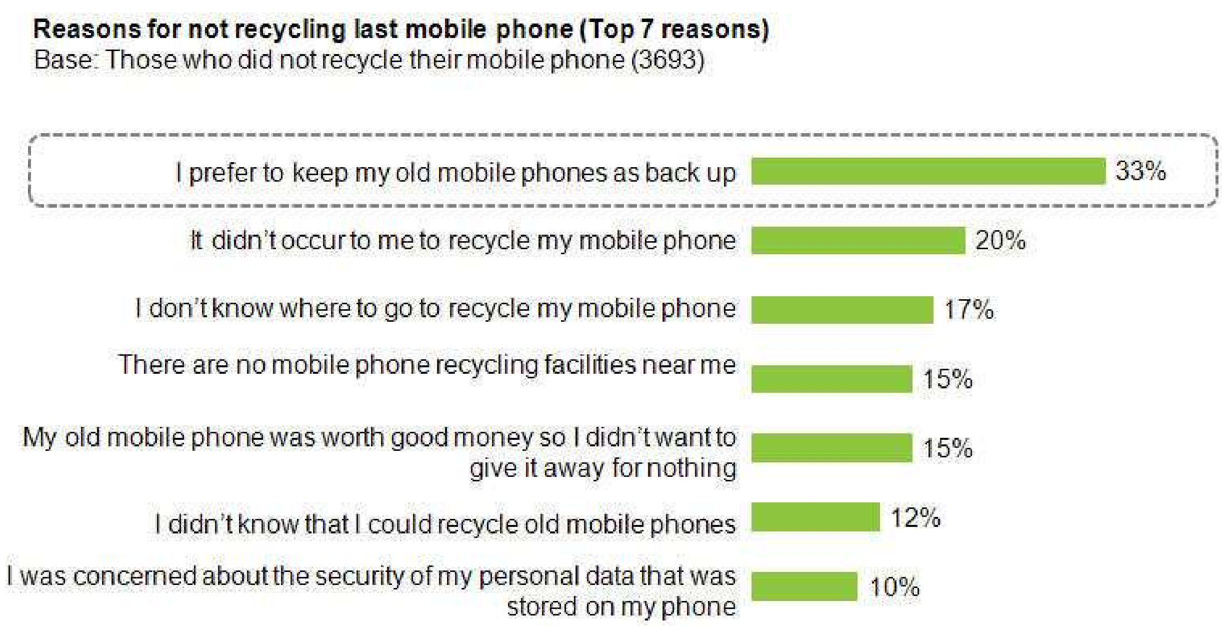

Fig. 10. Reasons for not recycling last mobile phone (Nokia, 2011b)

The more opportunities people are presented with, and the more convenient it is, the more likely people are to recycle their mobile phone. Even though people feel positive towards recycling campaigns, the underlying questions "how much effort do I have to make?" and "what's in it for me?" are typically noted. More mobile phone recycling may be encouraged by seeing this as a transaction in which consumer's effort (and the value of the phone) is traded for a benefit, an incentive, that can be a soft (emotional) or hard (financial) one. This especially encourages first time recyclers into action. Through all markets the biggest interest is expressed in exchanging an old phone for discount for new handsets, and this is being followed by more altruistic initiatives such as making a donation to an environmental charity.

The results of the consumer survey showing that awareness and phone hoarding are the main barriers for not recycling has lead into the development of the Nokia recycling program "3 steps to recycle". In this digital program simple answers are given to people on how and where to recycle. These include a 3 step program with the relevant information that phone can be recycled and how the data can be saved followed by map showing the locations of the recycling points. As noted previously one of the main reasons not to recycle is an emotional attachment to an old mobile. It is quite common that people like to store the old devices as there are so many precious memories attached to them. To tackle this recycling obstacle Nokia started a recycling campaign in Twitter, called "I#recycling". The campaign utilized old iconic Nokia phones such as Cityman, Nokia 3310, Nokia 8810, Nokia 5110 and Nokia 2760 and gave them different personalities. Phones were tweeting about recycling in order to make it fun and interesting and they also gave practical hints on where and how to recycle. During the 3 weeks of the campaign time it reached 170 000 people online in 44 countries and created 2800 Facebook likes. The campaign was translated also into Chinese and run in Chinese social media channels. These digital marketing campaigns are changing recycling attitudes and help to move towards a recycling society.

5. Conclusion

Electronics waste is globally an increasing waste stream that needs to be directed to proper recycling systems in order to save precious natural resources and to avoid contamination caused by landfilling or waste incineration practices. Product end of life is a process with three main steps from consumer collection to pretreatment and material refinery. First step of the process, collection, is a prerequisite for the rest of the process. The main challenge there is to get people to return their old products for recycling when they no longer need them. Consumer attitudes and recycling behavior has been studied in many countries to improve the success of the recycling programs. The most important factors enhancing the recycling behavior are convenience and awareness on where and how to recycle. The inhibiting factors for recycling are the emotional attachment to the old phone and willingness to keep a spare product. The following steps of the recycling process, pre-treatment and refinery are the ones where possible environmental risks may take place in the cases where e-waste is not handled properly. With proper technologies 100% of the materials in a mobile phone can be recovered and nothing needs to be wasted.

First mobile phone recycling programs started in the late 90's in Europe. Today Nokia is offering recycling programs for mobile phones in almost 100 countries. At the company's own premises waste sorting can be very efficient leading to true closed loop material circles. When take back of obsolete phones from consumers is discussed, the challenge is more in the awareness raising and in building up the eco efficient collection infrastructure at different parts of the world. Financial incentives can be used in initiating the recycling behavior, but the importance of them is getting lower when recycling becomes a daily habit. The different phases for starting a recycling program have been presented from building up a recycling infrastructure to partnerships and to different marketing campaigns. One of the main learning has been the usage of right language and tonality to communicate the benefits for recycling and finding the right partners, and most importantly long-term commitment to programs. Consumers who have recycled their old mobile phone have been reported to increase from 3 % to 9 % between 2007 and 2011. There are differences between developed and developing markets in the access to recycling points and information, but the importance of the topic is becoming globally understood.

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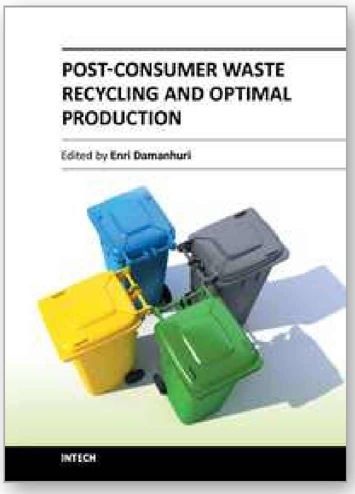

Post-Consumer Waste Recycling and Optimal Production

Edited by Prof. Enri Damanhuri

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This book deals with several aspects of waste material recycling. It is divided into three sections. The first section explains the roles of stakeholders, both informal and formal sectors, in post-consumer waste activities. It also discusses waste collection programs for recycling. The second section discusses the analysis tools for recycling system. The third section focuses on the recycling process and optimal production. I hope that this book will convey both the need and means for recycling and resource conservation activities to a wide readership, at both academician and professional level, and contribute to the creation of a sound material-cycle society.

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