Environmental Innovations in the Nordic Mobile Phone Industry

Green Markets and Greener Technologies (GMCT)

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Nordic co-operation

Nordic cooperation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and three autonomous areas: the Faroe Islands, Greenland, and Åland.

Nordic cooperation has firm traditions in politics, the economy, and culture. It plays an important role in European and international collaboration, and aims at creating a strong Nordic community in a strong Europe.

Nordic cooperation seeks to safeguard Nordic and regional interests and principles in the global community. Common Nordic values help the region solidify its position as one of the world's most innovative and competitive.

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Preface

Environmental technologies and eco-innovations are promoted both in European Union and Nordic countries to achieve the dual goals of maintaining competitiveness in a dynamic and knowledge-based economy while integrating environmental consideration in this process. The European Environmental Technologies Action Plan (ETAP) points to the fact that despite the significant technological potentials for environmental technologies, they are still underutilized. Therefore, policy measures are considered to enhance the commercialization and diffusion of environmental innovations.

In this context, a 2-year research project (2006–07), Green Market and Clean Technologies – Leading Nordic Innovation and Technological Potential for Future Markets (GMCT) has been carried out funded by the Integrated Product Policy Group of the Nordic Council of Ministers. The overall aim of the GMCT project has been to provide analyses of the ways in which the development and diffusion of environmental technologies can be enhanced, by exploring existing research in the Nordic countries and through in-depth analysis of specific cases of environmental innovations. The purpose has been to identify policy interventions that could also be applied to sectors other than those analysed and, thus, provide input for the discussions on the feasibility of a Nordic-wide action plan on the promotion of environmental technologies.

The project is a collaboration of four Nordic research institutions: International Institute for Industrial Environmental Economics (IIIEE) at Lund University (project coordinator), Finnish Environment Institute (SYKE), Department of Development and Planning at Aalborg University and Risø National Laboratory at the Technical University of Denmark.

The project consists of the following four main components: 1) literature review and development of a common analytical framework, 2) review of national innovation systems, 3) case studies of three industrial sectors: buildings, pulp and paper and mobile phones, and 4) synthesis of the case findings relevant to policy development (the content of this report). A “systems of innovation” approach has been the basis for an overall analytical framework, and three activities crucial for fostering innovation has been in focus: the creation, transfer and pooling of *knowledge*, the access to *resources* and the formation of *markets*. The sectors are selected based on the relevance to the Nordic countries, availability of existing information, possibility of cross sector comparison and coverage of various types of environmental technologies and environmental innovations.

This case study report is dealing with environmental innovations related to mobile phones and with the effect of the environmental policies related to electronics. The authors want to thank for all the useful information provided by the persons, who have been interviewed as well as the participants in the workshop in Copenhagen in June 2007.

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Summary

The environmental impacts of mobile phones are related to the use of resources, process chemicals and energy consumption in all production stages, and especially during production of chips, LCD and PCB. Energy consumption during use phase is another impact area due to the chargers standby consumption as well as the energy use of the whole communication system. Furthermore, the mobiles phones are complex devices with huge amounts of components with potential hazardous substances, which also can cause problems in the waste treatment and recovery of materials. The production of one mobile phone causes 75 kg of waste.

The mobile phone industry is globalised with six major brands. Nokia has more than 1/3 of the market share, and Sony Ericsson is one of the other six brands. Ericsson is the leading supplier of network equipment. Nokia and Ericsson have become global players due to an early involvement of the Nordic countries in the creation of a mobile communication system with the first international standard in 1982.

The global character of the market and the leading brands is corresponding to a globalised and fragmented supply chain. A mobile is made all over the globe with specialised components produced in USA, Japan, Taiwan, Korea and EU, and assembled by contract manufactures in China, Thailand and increasingly India.

The dilemma between mass production and customisation has been reduced by making basic platforms and modularisation of the phones – in this way, it is possible to keep the prices down, make phones to specific consumer segments and reduce the time to the market for new designs. Recent innovation dynamics are characterised by: convergence with other consumer electronics and introduction of new features (radio, MP3 player, camera, GPS, etc.) as well as increased data transmission.

These innovation dynamics and the market trends, where consumers change their mobile phone in average every 18 months, are some basic characteristics that environmental policy has to consider, when making a mix of different policy instruments.

So far, consumers do not take environmental impacts into account, when buying new mobile phones. Therefore, the companies do not believe that they can gain competitive advantages by adopting environmental labels – and for this reason the labels have not influenced development of ‘cleaner phones’ in the front-runner companies.

The effect of voluntary agreements such as the EU Code of Conduct (CoC) on external power supplies can be difficult to measure. Energy efficiency of chargers has been put on the agenda, and main brands such as Nokia apply chargers with a standby consumption less than 0,3W as required in the CoC and the US Energy star label.

The EU directive on Energy-using Product (EuP) is setting minimum requirements to the environmental performance of products. However, the current drafts to implementing measures have requirements to energy efficiency in focus, and the ambition level is rather low (1W) compared to the voluntary agreements and best available technology.

In contrast, the RoHS directive, which restricts the use of six hazardous substances, has influenced the mobile phone industry not only in the EU but globally. Specific requirements with clear goals and time frames have an effect even in global and fragmented supply chains.

The WEEE directive is improving the waste handling of electronics, but has not so far had any influence on the product development of phones towards eco-design – even though this was the ambition in EU. Waste minimisation, increased recycling and use of recycled materials are still a challenge to the mobile phone industry and governments.

The first case study shows that standby consumption of chargers can be improved with a factor 10 compared to the best performing chargers on the market today. However, neither consumer interests nor the EU directive on Energy-using Products (EuP) give incentives to such radical improvements. Competitive advantages can not be gained by providing new phones with more efficient chargers as this is not an issue for the consumers, and the draft for implementing measures for chargers in EuP is not that ambitious and can be achieved with existing technologies.

The case study on 4th generation mobile networks (4G) illustrate the ‘energy trap’ that increased data transmission and new features put high pressure on energy consumption both in the network and the handsets. In other words, the relation between energy consumption and data rates has to be detached in order to create a successful 4G system. However, the transmission capacity can be expanded by organising the system so users “share” common data from the base station via more energy efficient short-range wideband connections (e.g. Bluetooth and Wlan). This is called cooperation and requires only limited new technologies, but mainly new ways of structuring the network systems

1. Environmental Impacts

In this sector report the innovation dynamics of the mobile phone industry is analysed in order to evaluate how different policy tools can influence the future innovation of more environmental friendly mobile phones. Before this, a short presentation of the environmental issues related to the lifecycle of mobile phones is given. This is at the same time an overview of the challenges that policy tools should deal with.

1.1 Hot spots – environmental impacts of mobile phones

Contrary to what seems to be the general impression, the small size of a mobile phone does not mean few impacts on the environment. The continuous reduction of the weight and size of the phones means that material consumption has been minimised. However, the phones are complex devices, which contain several hundred components, many of which are complex products themselves. Even though, materials in the phone are minimised, the character of these materials often causes high consumption of energy, resources and process chemicals for their production. Furthermore, several materials contain a number of known and unknown potential hazardous substances. Especially chips (integrated circuits), Printed Wiring Boards (PWB) and LCD have high impacts.

As the phones are small, they are easily disposed along with household waste in contrast to larger appliances that are treated in separate waste handling systems. Therefore, valuable and often scarce materials in the phones are not recycled and that hazardous substances are released to the environment uncontrolled. The production of one mobile phone is said to cause 75 kg of waste (www.elektronikpanelet.dk)

The mobile phones are powered by batteries. An important parameter for the customers is that the phones do function in long periods in between charges, and therefore the phones are optimised in respect to having low-energy consumption during use. However, the chargers receive little attention as these are attached to the wall outlet and energy resources are seen as abundant. As most consumers are unaware of the energy consumption of the charger in standby this has low priority to the consumers, and therefore also to the brand holders. For this reason the energy efficiency of the chargers can be improved.

Mobile phones are part of a greater system consisting of various network equipments. The network also demands energy, and accounts according to most life cycle assessments to some of the largest impacts in the whole lifecycle of mobile phones.

These environmental impacts are of special interest as mobile phones are sold in huge amount all over the globe (1.1 billion expected in 2007), since the replacement takes place at a fast speed (1.8 year in average in the western world) and due to the huge penetration of mobile telephony (2.4 billion subscribers in 2006).

Summary 1: Environmental Impacts of Mobile Phones

High resource and energy consumption during manufacturing

- Especially some components: Chips, LCD and PCB

Use of chemicals

- Process chemicals in production and additives in the products
- Several suspected to be hazardous

Energy consumption during use

- Standby of charger (left in the socket)
- Energy consumption in the network (strongest effect in the LCA that include these aspects)

Limited knowledge about waste treatment

- Production of one mobile phone causes 75 kg waste
- Mobile phones are small and might go into household waste
- Difficult to recycle other than precious metal

Structure of the report

The report is structured in three general parts:

- An overall description of the mobile phone industry globally and in the Nordic countries;
- A discussion of the innovation dynamics of the industry;
- The influence of environmental policy initiatives on the innovation dynamics in the industry.

Two case studies are presented that analyses ways of reducing energy consumption: energy use of chargers and energy consumption in future wireless communications systems. Finally, an overall conclusion and policy recommendations are given on how to influence the innovation process in order to promote environmental improvements of mobile phones.

This report is based on a background report that is more detailed regarding the general descriptions of the innovation dynamics of the mobile phone industry and of different policy instruments applied (the background report can be downloaded at www.plan.aau.dk). For that reason most references are in the background report – except for the specific case studies, that are fully described here.

2. The Mobile Phone Industry

2.1 From professional products to consumer electronics

Mobile phone systems have developed from using national and regional standards for their communication interfaces to use world wide recognized standards with only minor variations. This has affected the markets, which today are highly globalised. At present, brand holding companies can supply the same phone to several markets around the world, whereas earlier different phones were developed to national and regional markets due to different standards.

This development has resulted in fierce competition among a few global brands with five brand-holding companies controlling 80% of the world market. Nokia is the absolute leader with more than 1/3 of the sales and together with Motorola, they have more than half of the sales. The rest (Samsung, Sony Ericsson and LG) have between 6,3% to 11,6% of the market share.

Figure 1: Proportion of world sales of handsets distributed on brands.

Source: Strategy Analytics

As the market has evolved, so have the phones. During the nineties the phones changed from being expensive devices for professional use to become a product for the mass market; an integrated part of consumers' everyday life. As technology evolved and the market matured, prices for purchasing a phone as well as using the network services dropped dramatically leading to the diffusion of mobile communication, first in the

industrialised countries and hereafter to developing economies in e.g. China, India and South America.

This development means that the world sales of mobiles in 2006 reached the landmark of 1 billion handsets, making mobile phones the world fastest growing piece of consumer electronics. There were about 2.6 billion subscribers world wide in 2006 (between 1/3 and 1/2 of which brought a phone), with a market diffusion of up to 100 subscribers per 100 inhabitants in many industrialized countries.

According to Nokia, mobile phones have a use phase of less than two years on average, and phones are often replaced long time before technical failure due to fashion and technological oscillation. This development is expected to continue with the use phase becoming even shorter as prices keep falling, new features are introduced at an even faster rate and as fashion has become important, and where the phones are perceived as part of the user's identity and image. Furthermore, operators subsidize handsets in order to attract new customers and sell more network services, which make the price for purchasing a new phone low and reduce the length of the use phase even more.

2.2 The Nordic mobile phone industry

The Nordic countries have a leading position in the global mobile phone industry with Nokia as the largest provider of handsets and Sony Ericsson among the top five brands. At the same time Ericsson is the largest producer of network equipment followed by the newly established joint venture between the network divisions of Nokia and Siemens.

The presence of these huge players is not a coincidence, but the result of the Nordic Countries early involvement in the development of the first European cellular phone systems, the Nordic Mobile Telephone (NMT) in 1981. The NMT standard was superior to other first generation systems (1G) as it was international and included automatically handover from cell to cell and roaming across national borders. The NMT standard was open, which enabled all companies to freely develop devices for the system and meant that Nordic companies from the beginning were involved in a trans-border competition. This forced them to adopt more international oriented strategies, whereas Motorola in the US had an almost exclusive home market due to an incompatible system. The small size of the Nordic countries facilitated cooperation among states in order to create a larger market, which later on turned out to be a great advantage as it promoted positive features such as trans-border mobility and compatibility, and the supply of a broader handset portfolio with competition between different brands.

NMT was over time adopted in other countries and gave inspiration for the development of the now world leading GSM standard created at

EU level with a dominant involvement of Nordic companies. In line with this Finland became the first country in the world to offer a commercial GSM service in 1992.

Facts about the ICT sector in Nordic countries

The mobile phone subscribers in the Nordic countries were around the 100 per 100 inhabitants in 2004. Norway and Sweden being above (having more subscribers than people), while Finland and Denmark lacks a little behind with less subscribers than inhabitants

The Nordic ICT sector had a turnover of 121,642 million Euro in 2003 where only the 34,729 million is in ICT manufacturing. There were 60,973 enterprises of which 3,252 were production companies. Sweden has by far the highest number of ICT manufacturing firms with over 1,770 enterprises. There are respectively 660 and 600 in Finland and Denmark, 200 in Norway and 20 in Island.

The sector employ equivalent to 460,000 fulltime jobs making the Nordic countries one of the regions with the highest percentage of people employed in the ICT sector. Finland takes the lead with over 10% of the workforce in the private sector employed within the ICT sector and ranks first among all OECD 25 countries.

The biggest subsector within ICT manufacturing is telecommunication equipment, which accounts for 20,585 million Euro of a total production of almost 30,000 million Euro. [Nordic Council of Ministers 2005: Nordic Information Society Statistics 2005]

2.2.1 Ericsson

Ericsson was established in 1876 and began focusing on cellular infrastructure in the 1980's. Between 1994–2002, Ericsson had 37–40% of the world sales on cellular equipment. This dominating position was achieved through a close cooperation with the Swedish state and the state owned Telia. Telia had an offensive strategy regarding mobile telephony that motivated the development of important technologies through this cooperation, which later on were sold worldwide. The close cooperation ended with the liberalization of the operator market in the mid 90's, as Telia became a private enterprise with its own strategy and profit requirements.

By the end of the 90's Ericsson experienced a massive crisis as a consequence of changing market dynamics. On the market for handsets Ericsson experienced a 30% price decrease in 1998 on the entire product portfolio. The low-end market segment gained importance, which was problematic, as Ericsson had focused on the high-end segment with technologically advanced phones. The price competition became fierce and low costs were extremely important in the industry. Everything had to be optimized and Ericsson had difficulties as it was used to larger profit margins. The solution was to outsource most of the production of hand-

sets to contract manufactures (among other Flextronics) and further on to take out the handset division as a separate company, which became partner with Sony (Sony Ericsson). Ericsson instead focused on providing the basic technology to the phone for both Sony Ericsson and other makers of mobile phones as well as focus on their network infrastructure competences. However, the market for such was also saturated during the same period as operators were holding back investments in GSM network infrastructure due to expectations of a rapid introduction of the 3rd generation of mobile phones and because there was overcapacity in the backbone of the GSM net.

These changing dynamics meant that the amount of employees at Ericsson fell from 107,000 to less than 56,000 in 2005. A drop far from the 5000 employees Sony Ericsson employ in 2005.

2.2.2 NOKIA

In the beginning of the 1990's Finland experienced one of the most severe recessions of any OECD counties after World War Two with an unemployment rate of 17%. However, with adoption of the Regional Development Act with focus on knowledge and building up knowledge infrastructure and providing specific subsidies to boost the economy, and as a consequence of the entrance in the EU (where trade relations shifted away from the USSR towards trade with the European countries), Finland had one of the largest growth rates among the OECD countries in the second half of the 90's.

One of the factors of the fast recovery was the tremendous success of Nokia, which in 1991 had a turnover of 15,457 million FIN marks (3,7 billion USD), a figure that was already doubled by 1994. In 2006 NOKIA had a turnover of more than 41 billion Euro and employed 68 483 people, 23 894 of which worked in Finland. China was the second largest country when it comes to the amount of employees with 7191.

In contrast to Ericsson, which had a strong focus on developing technologically advanced handsets for the professional use, Nokia benefited from the driving the shift to mass market, as they included low- and mid-end segments in the product portfolio and were capable to attract especially young customers with user friendly phones that could be individualised in their expression.

2.2.4 Other Nordic players in the industry

Nokia and Ericsson play important roles in the industry as well as in Finland and Sweden, but also companies in Denmark and Norway are present in the industry. Denmark began under the NMT net with actually having two companies Dancall and Storno competing with Nokia and Ericsson. However, Storno failed to move to GSM while still focussing

on NMT, while Dancall simply lacked sufficient financial capabilities to support a promising development of a prototype [Pedersen, 2001]. Foreign players brought both companies. Storno was sold directly to Motorola, and they also brought in 2006 the former Dancall of BenQ (had formerly been owned by Siemens and Bosh).

This early involvement means that two clusters in Denmark has emerged; one in Northern Jutland and the other in Copenhagen; each in close proximity to research environments, respectively Aalborg University and Danish Technical University. In this way Nokia employs around 1400 employees Denmark and has the one of the largest R&D department outside Finland in Copenhagen. At the same time, Motorola has several R&D activities in both clusters in Denmark, while also several design-houses are present incl. TI (Texas Instruments).

Summary 2: Nordic Mobile Phone Industry

- First international mobile communication standard: NMT
- Nordic dominance with Nokia as leader in handset and Ericsson in network equipment.
- Provide a “community” with several suppliers, sub-suppliers, design houses, etc. for global brand holders
- Presence of several foreign “big players” such as Motorola and Texas Instrument
- Strong competences e.g. electrical design, communication standards, communication protocols, modularization

3. Innovation dynamics

Mobile phones are complex devices based on several hundred components among which many are very advanced. The production and development of these components are in the hands of specialized producers placed in industrial clusters all over the industrialized world; and increasingly in East Asian growth economies such as China, Taiwan, Korea and India.

Therefore, the brand holding companies are dependent on R&D and production activities of their suppliers. During the past decade, the structure and characteristics of the supply chains has changed dramatically. Two of the main drivers have been falling prices on one side and increasing need for flexibility and customisation on the other.

Continuous price reductions permeate the whole electronic industry putting pressure on all parties to optimize expenditures and reduce costs. However, at the same time there is demand for new designs, continuous innovations, and customisation of the products.

In order to overcome this contradiction the product concept and supply chain has been reorganised. On the product side increased modularity and technology platforms enables the combination of mass production with customisation. This means that brand holders can keep a broad product portfolio targeting a diversified market, where consumers are segmented according to various technological and design preferences. Today, the top brands have a broad product portfolio to maintain as they release several new phones each month – in contrast to previously, where new phones only were released a few times a year.

In spite of this customisation, the use of outsourcing through contract manufacturers has increased fivefold during the last couple of years. Furthermore, the industry has experienced a high specialisation in respect to the production of the different components in the phone.

In the coming years more integrated units is likely in the mobile phones, which supports optimisations of energy and space. Furthermore, energy consumption will rise as a consequence of the upcoming 4G mobile communication system supporting higher data transmission and the tendency to converge mobile phones with other consumer electronics.

3.1 Increased modularity and technology platforms

A mobile phone can be illustrated as a combination of different building blocs similar to building a toy with Lego. The basic chips, which control the overall performance, create a platform on top of which various modules are added in order to provide certain functionality. Furthermore, a software module makes it possible to operate the device, see figure 2.

Previously, large brand holders developed and produced most of the core components themselves. Today, this is to a high degree outsourced to specialised producers. Current mobile phones become more complex with increasing demands to the single component. At the same time, the increased modularity of components allows a larger flexibility throughout the supply chain, as components are compatible with each other.

The modularized component can thus be used in different phone models and often also in products from competing brand holders, whereby innovation costs can be spread on more products. Modularity combines economy of scales with the need for a broad product portfolio. Many components are today developed as modules for the general market rather than dedicated for a single phone or brand. The brand holders can therefore use a standard component without need for a close cooperation with the supplier.

In line with these changes, the supply chain has restructured towards more specialized companies rather than a few spanning across the product chain. Even those that span over the whole chain split their divisions into independent units with their own profit requirements and strategic interests. These independent units often originate from Asian conglomerates such as Sony, Samsung and LG; and they are not bound to the interest of other business groups in the conglomerate. Thus the supply chain transforms towards smaller units and higher specialization.

Figure 2: Basic components of a mobile phone.

In line with the increased modularity, big brand holders such as Ericsson and Nokia have begun to develop technological platforms, which consist of all the basic chips, the software, and a reference design specifying the electrical circuits. Preferably, these chips should be designed together and be integrated with each other in terms of software. Since the development process is costly and time consuming (often around two years) the plat-

form can be used for developing several phones models by adding different modularized components.

In a similar way, major chipmakers such as Texas Instruments develop platforms as a mean to increase the sales of their chips. These platforms are sold on the general market making it easy for firms to develop a complete phone on top of a platform by just adding modules such as a camera or a display. Especially, in low- and mid-end phones these platforms are widely used.

3.2 Application of contract manufacturing

The brand holders have outsourced production of final products and not just the assembling of components as a result of price competition, increased marketing and R&D expenditures, fluctuations on the demand side as well as difficulties to raise capital for investments due to the crack of the dot.com bubble around the millennium. These tasks are outsourced to contract manufacturers in order to reduce the fixed capital in production facilities and in order to give priority to R&D, portfolio management, and marketing.

In the electronic industry these contract manufacturers are referred to as Electronics Manufacturing Services (EMS). The competition among EMS's is even harder than among the brand holders. Hence, the profit margins are correspondingly lower. High volumes and efficient production methods are central parameters in the EMS sector. The EMS businesses are characterized by large global providers that match or even exceed the size of the brand holders in terms of employees and turnover.

Recently, the big EMS has begun offering services like supply chain management and own production of components, logistics and after-sales services as well as product design. In this way they allow the brand holders to cut expenses and to deposit capital for investments in downstream activities such as marketing and market surveillance.

Today, most of the big EMS's provide turn-key services so brand holders only need to deal with one supplier instead of managing various relations. The EMS's are the ones selecting and purchasing components.

Especially the low-end handsets are designed and produced by contract manufactures with own development capabilities, so called Original Design Manufacturers (ODM). These ODM's actually design and produce the phones based on their own property right with only an overall specification such as brand name, brand recognition theme along with overall concepts from the brand holder. In contrast, EMS provides produced base on the property rights of the brand holders.

As the basic platform is sold on the market, contract manufacturers can rather easily become Original Design Manufacturer by just buying

such a platform and modifying it for mass production according to the different preferences of the brand holder.

Northstream (2004) has estimated that by 2005 approximately one third of all handset would be produced by ODM providers. This is a significant increase from 2004, where the number was below one tenth. At the same time, ODM services only account for a part of the contract manufacturing industry, and the total share of phones produced on contract manufacturing terms is probably over 50%. In general, the industry is rather reluctant to inform about their use of contract manufacturers, as they want to preserve the impression that they still make the phones themselves due to branding considerations (Northstream, 2004).

[www.economist.com/background/displaystory.cfm?story_id=2628495]

In addition to the use of contract manufacturers in respect to final phones, they are also widely used for the production of central components such as chips and displays (LCD's). These components are extremely capital intensive to produce and have short payback times due to short innovation cycles. Chipmakers and producers of LCD's are therefore generally large companies.

The outsourcing tendency has influenced the chip-packing industry resulting in so-called foundries, which are established to provide full chip production on contract manufacturer terms. Most big chipmakers still maintain their own production facilities for up-front products and uses foundries as buffers and to production of older less advanced models. The present of foundries has however given rise to so-called fabless chipmakers, which are chipmakers without own production facilities.

Summary 3: Global Supply Chains and Innovation Dynamics

Global supply chains

- R&D and production is carried out by many companies in the supply chain around the world
- Specialised suppliers supplying several of the brand holders
- High use of Contract Manufacturers also design and supply chain management

Innovation process split

- R&D on new features
- Integration of new features to existing concepts

Use of technology platforms and modular product architecture

Platform:

- Broad product portfolio but on few basic platforms
- Combine differentiation (segmentation of customers) with cost reductions and mass production

Modularisation:

- Optimising each component on standard criteria instead of designing components together (still necessary in the basic chipset)
- Possible with multi-sourcing instead of dependence on supplier

Easier to produce phones: take platform and add different modules

New players

- Design-houses (Texas Instrument moved from chipmaker to platform design)
- Contract Manufacturers (CM) creates brands (BenQ),
- Operator branded phones on CM (Vodafone on phones produced by Flextronic)

3.3 The innovations paths

Standards play a central role in the innovation dynamics of the mobile phone industry. Standards largely determine the single companies innovation possibilities of the products, since components, final products or accessories, always need to be compatible with the standard in order to function with the rest of the system. Thus, each shift in standards has affected the innovation dynamics in the industry. The NMT standard created e.g. several Nordic players, while the GSM standard was part of developing a global market with a strong competition that has shut down many companies. Finally, the 3G standard has opened the door for new enterprises such as LG.

As mentioned new communication standards has had an important influence on the innovation dynamics, but otherwise the overall innovation path in the mobile phone industry is incremental. In other words, the in-

novation process concentrates on redesigns of existing concepts along the whole product chain from semiconductor and component industries to circuit design in both platforms and final products.

The pace of the innovations cycles is resulting in continual introduction and adoption of new features and technological ideas into the existing product concepts. Parallel to these incremental innovations, especially many large chip producers and brand holders have dedicated research to possible future aspects of the mobile phones, where the research is a more open process and not necessarily tied to existing concepts. However, the adaptation of future research will rely on how the research findings fit into future de facto standards.

The immense amount of development resources already laid down in the existing concepts including production facilities is a substantial incentive for the industry to keep an incremental innovation strategy. The innovations process is split into different processes; i.e. one with focus on finding new possibilities and another with focus on adapting such findings to the existing concepts. The use of platforms and modularisation can also be seen in this light: the application of different innovations throughout the supply chain can easily be adjusted via the standardised platforms and modularisation.

3.4 Ongoing innovation trends

The innovations trends of the mobile phone industry are manifold. Below, some dominant trends for the next couple of years are described, i.e. the reduction of energy and space consumption, increased functionality in terms of data management, as well as new features.

3.4.1 Space and energy optimisations

Handsets are transportable and battery driven. Therefore, the occupation of space and power use is critical. Thus, e.g. battery-time is an important sales parameter as consumers dislike charging the phone too often.

A general applied way to optimise space and energy consumption is to integrate the passive components into chips (Integrated Circuit). The energy “budget” for the IC is often better than for designs based on passive components, and the IC design can be made significantly smaller. Furthermore, it is generally cheaper to integrate components if produced in high volumes, and the quality is better, as only one component is to be mounted on the Printed Wiring Board. This ongoing development has together with increased use of software solutions and multi purpose chips meant a significant reduction of the number of components in the phone from around 1.000 few years ago to less than 500 today.

Additional, optimisations of the energy consumption of the individual modulated components has lead to further reductions of the power use allowing longer battery time and the continual increase of data transmission capacity, as well as the inclusion of new features plus bigger and better displays and loudspeakers. These trends can be expected to continue, since power as well as space remains important for the innovation process.

3.4.2 Increased data transmission in the 4th generation

The mobile communication systems (phone and network) of today are the third generation (3G), and each generation has increased data transmitting capacity, and thereby also the energy consumption. Along these lines, a central discussion in the industry today relates to the next generation of communication networks – the fourth generation (4G).

The second and third generations of networks have been developed through different international collaborations, where the EU played a central role in establishing GSM, which today is by far the leading standard. In the development of 3G, efforts were made to make the system compatible between the EU, US, and Japan.

The importance of standards is also the case in development of the mobile communication system, thus different stakeholders do agree for various specification of 4G. The Americans advocate for a technological scheme in prolongation of WLAN and Wi-max, as they have a dominating position within in the PC industry but lack behind within mobile phones technologies. Opposite Asia players advocate for 4G as a linear extension of the cellular systems of 2G and 3G, as they have a strong position within data providing services over 2.5G and 3G. The EU commission suggests that 4G relates to a combination of the various existing networks such as GSM (2G), UMTS (3G), WLAN (computers), Bluetooth (short range wideband) making it a converging platform that enables seamless shift among these.

All scenarios include higher data rates making it possible to offer more data demanding services such as video streaming and music downloading. Regardless of chosen approach for 4G, it is likely that the terminals will need multi access technologies, as well as additional hardware that enable them to receive and process such high data rates. The 3G phones already apply two antennas in the phone, whereas more might be needed in future scenarios. The past shift from 2G to 3G caused increased amounts of energy consumption and the shift from 3G to 4G can similarly be expected to increase the energy use further.

3.4.3 Convergence with other consumer electronics

During recent years, mobile phones have integrated additional features such as cameras, radio and later on video players, gaming, e-mailing, and Internet browsing. Thus modern mobile phones have similar functionality as PDA's and various consumer electronics. This product integration has become possible due to continuous improvements in areas like processing power, space- and energy savings, increased modularity, as well as reduced costs. This product integration process will most likely continue and new features from e.g. computers and consumer electronics will be adopted. Already today, high-end models include broadcasting of digital TV to handsets (DVB-H), access to WLAN and gaming.

This development raises the discussion of whether multifunction devices that are able to handle all kinds of different features will substitute several dedicated products. So far the dedicated products have superior performance e.g. in the case of digital cameras. However, the quality has improved significantly making substitution an option in many cases. For instance Sony Ericsson has had great success with reintroduction the Walkman in a phone version. In 2006, 300 million music phones were shipped and many of these most likely will supersede many dedicated MP3 players. Apple has as a response recently announced that they will launch an iPod with integrated phone (iPhone). Still, dedicated music players are sold showing that the market is very diversified in its preferences.

Summary 4: Current Innovation Dynamics

Constant introduction of new features and improvement of existing

- Messages (SMS), e-mail, Camera (pixel improvement), mp3 (sound improvements), Video-, TV streaming and gaming (still bad quality), text processing programs (Word, PDF reader etc.)

Converging of phones with other ICT and consumer electronics

- PDA Phone (HP), Music Phones (iPhone and Walkmann phone), Camera Phones, gaming and picture streaming phones (Nokia N91)
- New players (HP, Apple)
- One gadget covering all features is unlikely at the moment

Increased data transmission

- From below 50 kb/s in GSM to over 300 kb/s in WCDMA and improving
- 3G beyond / 4G expected to go to MBit/s (Wlan e.g. 108 Mbit/s)

The energy trap:

- Increased data transmission and addition of new and improved features put high pressure on energy consumption
- Need to focus on energy and space efficiency in the mobile phones because of all the new features / product integration

4. Environmental Policy and the Mobile Phone Industry

This chapter describes the environmental legislative framework affecting the mobile industry. The emphasis is on the EU framework as these initiatives structure the work in the member states and influence the globalised mobile industry in general. The purpose is to analyse to which degree and in which way the environmental legislative framework support the development of environmental innovations in electronics.

The section is divided in three parts. In the first section, important EU environmental regulations of electronic products are analysed. The second section deals with voluntary approaches, i.e. environmental labelling, energy savings schemes, and the stakeholder involvement related to the EU Integrated product Policy (IPP). The last section examines the relatively new directive on Energy using Products (EuP). The background report establishes a broader evaluation of the influence of different policy approaches on environmental innovations.

4.1 EU Regulation on Electronics

During the last decade two EU directives on respectively Restricted use of certain Hazardous Substances (RoHS) and Waste from Electrical and Electronic Equipments (WEEE) have to a large extent been on the agenda throughout the industry. Both RoHS and WEEE are designed so legislative requirements refers to the product rather than the production sites. Still, in terms of impact on the industry, the two approaches differ significantly. RoHS has supported a technological shift away from specific substances, while WEEE has had little or no influence on the characteristics of the products.

4.1.1 Restricted use of certain Hazardous Substances (RoHS)

RoHS (EC Directive 2002/95/EC) has caused the electronic industry to phase out (or minimise substantially) the use of lead, mercury, cadmium, Chrom VI and two brominated flame-retardant (polybrominated biphenyl and polybrominated biphenyl ethers).

In 1996, when the debate on lead was intense and the work on RoHS and WEEE began, Nokia and other big players in the electronic industry began assessing alternatives to lead in the solder paste in order to find alternatives that actually made it possible for the brand holders to get

components in compliance with the expected regulation. In spite of the early involvement, Nokia's first RoHS compliant product was launched in 2001. In 2006 the Nokia product portfolio globally was fully EU RoHS compliant. In other words, it has been a process of five to ten years to implement a full compliance scheme to RoHS.

As a response to EU plans regarding RoHS and other similar regulations several brand holders began operating with a corporate list of substances, which are banned, restricted or has to be monitored. These lists do often provide a global benchmark of the regulation in different countries, where the strictest regulation set the norm. This trend is a consequence of the brands need for flexibility, because it is expensive to have double or triple stocks in terms of which components and products that can be applied in which countries.

The big brand holders' substance lists are similar and refer to the same regulations. These substances are getting huge attention throughout the supply chains. If a producer uses any of substances on the corporate lists, they risk being excluded, not only from a smaller regional market, but from the entire global market. Banning substances appears thus to be an effective tool to impact the whole supply chain worldwide, and not only the country or region that implements the ban. However, there might be a limitation, as companies most likely will begin having several stocks if the requirements in a single market will lead to radically higher costs.

4.1.2 Waste from Electrical and Electronic Equipment (WEEE)

The intention of WEEE (Directive 2002/96/EC) is to set up separate waste handling systems for electric and electronics waste in the member states and to minimise waste as well as improve recycling by means of improved product designs. While the first has been implemented throughout the EU, the latter seems not to be an outcome so far.

The preparation of WEEE did actually put waste on the agenda in design work around the millennium, where e.g. Nokia and Motorola developed prototype models such as a self-dismantling phone. However, after the adoption of the final directive the actual implementation of the projects as well as the execution of further research on these issues was downplayed revealing that neither the established collective schemes nor the possibilities for creating an individual scheme did create incentives for implementing design for End-of-Life or for waste minimisation. Focus is instead on having an efficient waste handling system.

More recently, Nokia has experimented with a prototype "Re-made" and introduced Nokia 3110 Evolve that has bio-covers made from more than 50% renewable materials (<http://europe.nokia.com/A4739007>).

4.2 Voluntary Policy Tools

In addition to these normative regulations different voluntary policy tools have also been applied to motivate the industry to include environmental concern in their business strategies. In the background report, the use of general environmental labels, energy savings schemes and a stakeholder involvement project is analysed in more details.

4.2.1 Environmental Labels

In EU, no Flower labelling scheme exists for mobile phones. However, both the Swedish TCO and the German Blaue Engel have established criteria for mobile phones focussing on strict SAR values (Specific Absorption Rate/SAR is an indication of the amount of radiation absorbed into a head while using a mobile phone) banning of several chemicals and requirements to environmental management schemes incl. statement on waste management.

At present no phones exist with either of these labels. One argument from brand holders for not adopting is that the extra costs and time needed to obtain third party verification is a barrier in an industry, where time to markets is critical.

In respect to this argument it seems possible to increase the effectiveness of the validation process by e.g. validate the core building blocs such as platform and the different modules (same approach has the industry applied in respect to CE validation). The final validation of the phone will thus be much easier and faster as the validation of the platform and modules can be used as basis for validation of several products.

The actors involved in the stakeholder initiative (see below) propose instead to adopt a Product Environmental Fact Scheme as something in between the different ISO types of labelling (Third party verified marks; self declaration of specific aspects; and full product declaration), where the consumers are provided information on several parameters and the information is verified through market surveillance.

However, the cost and time constraint to achieve a label on every single product is only one side of the story. Another reason for not joining a labelling scheme is, that environment is – so far – not seen as a potential competition parameter. In general, the brand holders do not believe that environmental concerns will be a parameter consumers do consider important, when buying a new phone.

Experiences from other product groups reveals that consumers mainly act on environmental labels if they are connected to either their own safety or economic gains, such as energy savings.

TCO has for a long time monitored different phones in respect to compliance of the strict SAR value of their own standard and has found that only few phones comply. However, consumers seem to pay no atten-

tion to these assessments. Furthermore, the potential energy savings are minor from a private economic perspective.

A scheme, where consumers need to make an evaluation between the different parameters, is most likely not going to promote environmentally conscious choices by consumers. However, such scheme could facilitate different consumer organisations and NGO's to benchmark the performance of the different brands. Such benchmarks can have an effect on the industry e.g. Greenpeace has launched a global ranking of producers of PC and mobile phones that received a lot of publicity and attention from the industry.

4.2.2 Energy schemes

The energy consumption of products has during the last decade received attention with the establishment of obligatory energy labelling of white goods and light bulbs as well as energy stars for energy consumption of office equipment and some consumer electronics.

In contrast to these products, mobile phones are optimised to have low energy consumption due to general market considerations, as they are battery driven. A little attention is however given to the chargers.

In this regard, EU has established a Code of Conduct (CoC) on energy consumption of external power suppliers (including chargers) and the US has established Energy Star, and both are requiring chargers to have standby consumption less than 0,3W.

Most actors in the industry have adopted either the EU CoC or Energy Star, and an average charger use around 0,2W in standby. The energy consumption of the charger is in contrast to white goods, office equipment and some consumer electronics limited, and from a consumer perspective not contributing significant to costs. There is thus no consumer drive for minimising the energy use of mobiles, whereas CoC and Energy Star have set levels that are rather easy to achieve.

The case on chargers (see later) reveals, it is technological feasible to get a factor 10–15 improvement with limited extra cost.

4.2.3 Stakeholder involvement initiative – IPP

As part of EU's Integrated Product Policy (IPP) strategy, some stakeholder initiatives in different product sectors have been initiated – called IPP pilots. One of these is on mobile phones with Nokia appointed to lead a consortium with other brand holders and component suppliers within chips and LCD, as well as network operators, recyclers, government agencies as well as NGO's.

The objectives have been to identify environmental areas of concern from a lifecycle perspective and find solutions to minimise those. The project is carried out through five steps: identifying the main areas of

environmental concern; brainstorm on different options for improving the performance in these areas; discuss the improvement options according to their business and environmental feasibility, selecting the initiatives that shall be implemented; and implementing the initiatives. The last step was carried out during 2007.

An quick look at the comprehensive materials produced gives the impression that the five initiatives seems proper and can provide environmental improvements throughout the lifecycle of mobile phones. However, a closer look (see the background report) at the five initiatives reveals that only one initiative implies changes in the hardware in the phone in opposite to almost 15 of such hardware changes proposed in the brainstorm part. The majority of the initiatives are related to alter the consumers' behaviour through mainly information.

The arguments for why to focus on the chosen initiatives – instead of other identified options – are mostly missing. Some areas that are perceived as being important such as the short use stage are rather unlikely to be changed by the industry itself. In general, the IPP pilot project has focused on voluntary actions and it seems rather unlikely that these will promote significant technological innovations (see background report for details).

Finally, the IPP pilot project can be seen as a governance initiative with all the actors around the same table, and as a way to create a mutual understanding of environmental problems and improvements potentials both in a short and long perspective. On the other side, NGOs and governmental agencies might come to justify an agenda of the industry, in case there is not consensus on ambitious objectives and if they do not have the knowledge about technological potentials in order to ask for more ambitious improvements.

4.3 The Directive on Energy using Products (EuP)

As an IPP initiative, EU has adopted a framework for setting minimum standards for energy using products sold in the EU – the Directive on Energy using Products (EuP).

Several policy instruments such as eco-labelling, green public procurement, etc. are targeting front-runner companies to give incentives for introducing cleaner products on the market. In contrast, the EuP directive will set minimum performance standards for products in order to receive the CE-label and be sold on the internal market of the EU.

At present, preparatory studies have or are being made of 20 product groups, which have significant energy consumption such as boilers, pumps, refrigerators, etc. and including two horizontal groups for stand-by consumption and external power supplies (see the case on chargers). So far, mobile phones have not been chosen as a product group.

All preparatory studies are made in a generic way under a common structure with the following issues covered: definition of product category; economic and market analysis; consumer behaviour and local infrastructure; technical analysis of existing products in the different phases of the product life cycle; definition of base-cases; technical analysis of BAT (Best Available Technology); improvements options; and policy, impact and sensitivity analyses.

As indicated, the studies are covering a comprehensive set of aspects and present a detailed knowledge on the energy and environmental impacts of products. Different experts and interested stakeholders from industry, governmental agencies and NGOs are consulted in the process.

Based on the study, 'implementing measures' are formulated with requirements to e.g. energy consumption of the products. So far, only the energy efficiency has been included in the requirements, even though the ambition with EuP was to improve the environmental performance of products throughout the product life-cycle by integration of environmental aspects at an early stage in the product design.

The first drafts for implementing measures do also indicate a rather narrow definition of the product group. For example the focus is on air-conditioners and not on the function – cooling of a room. In several cases, a broad understanding of the technological system is necessary in order to achieve significant environmental improvements.

Summary 5: POLICY INSTRUMENTS

- RoHS has affected electronic industry to phase out six chemicals
- WEEE has put waste treatment on the agenda, but fails to foster design improvements of the products (eco-design)
- NO use of energy or eco-labels for mobile phones – no market pull at the moment
- Voluntary agreements have an effect, but limited to what rather easily can be achieved
- IPP pilot on mobile phones with Nokia as project leader. The outcome related to environmental improvements is unclear
- EuP will push for improvements of energy consumption in external power supplies and reduction of stand-by consumption, while other environmental impacts are not included.

5. Chargers standby consumption

This case study describes the technological shift from linear-mode to switch-mode chargers for mobile phones, with emphasis on the energy efficiency improvements on the charges' standby load. The purpose is to illustrate how especially policy have influenced the industry's work on the technological shift from linear-mode to switch-mode chargers.

5.1 Energy Awareness regarding Mobile Phones

Energy has increasingly become an issue of concern, which is illustrated by the raising concern on global warming and the need to find several ways to reduce energy consumption such as development of energy technologies, increased energy efficiency, energy labels on products and new energy regulations. In the life cycle perspective of mobile phones, the chargers contribute to a significant part of the energy consumption, especially if the mobile network is not included in the lifecycle assessment. This makes chargers an interesting area for environmental improvements; especially the standby consumption is of interest, as the chargers are often left plugged in, even if the phones are fully loaded.

Around the world, politicians are aware of the issue of energy consumption for appliances. As a result different labelling systems has appeared, e.g. a Code of Conduct (CoC) in the EU, the Energy Star in US, and similar initiatives are developed in China and Australia.

The voluntary CoC stipulates that charging units with an output of the size needed for a mobile phone should have a standby power load on 0.3 Watt or less.

5.2 Energy Efficiency of Chargers

Linear mode chargers convert less than half the energy to the mobile phone while charging. Furthermore, they have a poor performance in standby mode, i.e. when the phone battery is full while the charger is still plugged in. The in-efficiency among the linear mode chargers is significant: the worst chargers have a standby consumption, which is equal to the consumption when charging. In contrast, the best switch-mode chargers convert above 80 % of the energy during load mode and a standby consumption below 0,1W. The average standby load is around 0,3W to 0,2 W. According to Professor Michael Andersen the average performance level during load is roughly 75%.

Switch-mode chargers are generally smaller than linear mode as well as more powerful, faster and flexible in respect to power input. In 1988 Finish Salcomp launched the first mass produced switch-mode chargers for mobile phones. The first mover advantage was beneficial and still today Salcomp is a market leader. [www.salcomp.com, [www.steve-dircon.co.uk/fleadh/mphil/history.htm#sec2](http://www.steve-dircon.co.uk/fleadh/mphil/history.htm#sec2;);]

5.3 From Linear to Switch-mode Chargers

During the 90es and in the first years of 2000 linear chargers were still dominating on the market. Switch mode chargers were sold with high-end phones and as accessories if consumers wanted faster charge of their phone and a charger, which could be used worldwide with different power inputs. Before mobile phones were able to use several frequency bands, they could often only be applied in one region; hence there were no need for flexibility regarding input-power. Linear chargers are today sold with low-end phones due to the low cost.

Today, the power demand in mid- and high-end phones has increased, the consumers expectations for short charge times has raised and the phones are expected to work all over the world, including the charger. At the same time the cobber and plastic prices have increased, and energy efficiency is in focus due to CoC and a general political interest in a reduction of energy use. These factors are all in favour of switch mode based chargers; hence most mid- and high-end phones come with switch mode chargers. According to Salcomp the average price on chargers has increased in 2005, which could be explained by an increased change towards switch mode chargers as well as increased energy focus [Interview Salcomp; http://en.wikipedia.org/wiki/Switched-mode_power_supply; Salcomp, 2005].

The main driver for the technological change has not been environmental or energy reasons but technical and commercial arguments. The primary reason for choosing switch-mode chargers is the smaller size, the flexible input, and the lower weight, which allows more powerful chargers and still keeping the weight and seize down. This provides shorter charge time compared to linear chargers. In addition the stand-by consumption is lower, which enables the producer fairly easy to fulfil and meet the CoC and other regulations.

Switch mode technology is however more complex and expensive, as it requires more components and production processes, compared to linear chargers that are cheap and more simple to produce. The increased cobber prices (factor 3 from 2004 to 2006 [LOT7 S2-8x]) is influencing the economical break-even point between switch mode and linear charges, which today is in the range of the chargers that comes with low end phones (4-5W). [EU LOT7, Salcomp newsletter, nr. 2, 2006]

5.4 Reducing standby energy consumption

Even though the switch mode technology has triggered energy efficient improvements already, the potential improvements are still in the range of a factor 20–30.

5.4.1 A DTU developed power supply

In 2000 a PhD thesis was finalised at Denmark Technical University with the objective to develop a high efficient switch mode power supply with low energy consumption. The power supplier was developed for a TV, but the technology is basically the same as in chargers for mobile phones, except that phone chargers usually have a slightly higher output.

The project was financed by a fund under the Danish Energy authority, which supports research focused on energy savings. B&O the Danish producer of high-end audio and video equipment played a central role in the project as a partner, as the charger was developed for one of their TV. In addition, Dantrafo A/S, Electrolux Hot-Tech Center and Aalborg University were involved. This innovation came about by interactions between the state, technical universities and industrial actors.

Figure 3: Efficiency of various power suppliers. Inspired by Nielsen (A).

A key issue in PhD relates to the fact that small power supplies have a greater standby/low load energy loss, as the basic electronics circuit constitutes a higher proportion of the total energy consumption. Hence, a challenge was to develop an electrical design that consumes as little energy as possible by itself. [N. Nielsen]

In the project an alternative technique to twist the coil was developed, which increased the efficiency of the power supply. The final result was a

power supply designed to provide 1W but it can easily deliver 3W. The efficiency is 83 %, when supplying 1W and <0,006 W in stand-by. As seen in figure 3 this is a radical improvement compared to a linear power supply (left column) and a good performance improvement compared a traditional switch mode supplier (middle column).

As a charger to a mobile phone is slightly more powerful it is likely to have a little higher energy pull in stand by mode. A conservative estimate of the energy pull is that it is possible to develop a charger for mobile phones, based on the design concept of the PhD that provides 5–6W with stand-by energy consumption below 0,01W. This would be a factor 20 improvement compared to an average switch mode power supplier today. [N. Nielsen 2000; M. Andersen]

5.4.2 A charger optimised for standby

As part of the preoperational work for the implementing measures under EuP on external power suppliers Salcomp has developed a charger for mobile phones dedicated to reduce standby energy consumption. With standby consumption on 0,01W, the Salcomp charger has a similar standby performance as the older DTU charger. But the Salcomp chargers efficiency in use is only 63% compared to the 83% efficiency in the DTU charger. This shows that Salcomp has experienced a trade-off between the load efficiency and stand-by consumption. However, as the stand-by consumption is a major problem, the Salcomp charger is environmentally much better than traditional switch mode chargers.

[<http://www.ecocharger.org/docs/BIOconsortium%20%20EuP%20lot%207%20draft%20final%20report.pdf> p285]

5.4.3 Chargers with low standby consumption

The results of the Ph.D. project have partly been implemented in Bang & Olufsen TV sets in a modified version, with a less efficient performance in no-load (0.03–0.04W) due to strict technical design requirements. [Dynamo may 2006 nr.5]

The design solution of the Ph.D. has been presented at conferences and in academic papers, as well as to Nokia and other Original Equipment Manufacturers and is freely available on the Internet. In spite of this, chargers that come with new mobile phones today have a performance that is not anywhere near the one developed during the PhD more than 6 year ago. However, Prof. Michael Andersen told that Asian companies have had clarifying questions to the design of the power supply, and he has seen commercial implementations of the design with changes due to cost considerations [Intw. Andersen].

The Salcomp charger is in contrast to the DTU design developed by a market actor and can be put on the market with short notice. However it

is developed to establish BAT rather than to fulfil certain market demands. [EuP LOT7]

5.4.4 Constraints for low standby consumption in chargers

The market for chargers to mobile phones has focused on one thing: price. The brand holders, who are the largest customers to the power supply producers, are reluctant towards increasing prices, even a few cents is considered problematic [Intw. Salcomp, 2007; [www.ecocharger.org/docs-BIOconsortium_EuP_Lot_7_Final_Report.pdf](http://www.ecocharger.org/docs/BIOconsortium_EuP_Lot_7_Final_Report.pdf) p. 115]

Technologies that involve increased cost are rejected as too expensive. This is a significant obstacle for adopting front-end technologies even in cases, when they are available. Energy efficient chargers need to be price neutral, if the brand holders should adopt them voluntarily.

5.4.5 Environmental benefits of energy improved chargers

Energy consumption in mobile phones chargers is too low to be considered important from a private economic view. However, considering there are more mobile phones than people in Nordic countries, then efficient chargers suddenly become a large potential for energy savings.

A report conducted by NRDC indicates that if all phones in the US were equipped with an efficient switch mode charger with a standby consumption of 0,1W, and efficient control of the charge process it would lead to energy saving of 300 million KWh per year compared to the consumption in 2004, where the general charger had a standby consumption of 0.2W. [NRDC 2004]

Furthermore, other devices in the households such as mp3 players, cameras, light etc. also need an energy efficient power supply, and for many of these devices the linear technology is still dominating. The environmental impacts will be even larger if all external power supplies and chargers were addressed at EU or global level.

5.5 The effects of environmental regulations

The costs of standby consumption is not paid by brand holders and as consumers generally pay no attention to the issue, then the market forces are not initiating the brand holders to improve the energy efficiency of chargers. Therefore, policy initiatives are needed in order for improvements to take place.

5.5.1 Voluntary Agreements

The European Union has launched a Code of Conduct (CoC) on external power supplies, which stipulates a maximum standby consumption of 0.3W for chargers below 15W. Most large brand holders have adopted the CoC, which might have had an effect on the change towards switch mode bases chargers. However, the target is not ambitious as the BAT performance levels is a factor 30 less, and much lower values can be achieved with cost neutral actions. The targets in CoC can even be achieved with linear chargers [Intw. BenQ-Siemens; Salcomp]

Even though, improved technologies have been known for several years the energy consumption level was still in 2004 in the area of 0.2W in an average switch mode charger.

In spite of the above findings, the IPP pilot project on mobile phones concludes that improvements of the chargers' efficiency are an ongoing process, and that no regulatory interference is needed. Instead, a voluntary agreement is proposed. The agreement is to motivate mobile phone producers to adopt a visual reminder on the phones screen that reminds the user to unplug the charger when it is fully charged [Nokia stage III and stage IV].

A visual reminder is not likely to alter consumer behaviour significantly, and the IPP pilot project does not argue, why the reminder should have an effect e.g. based on experience with already available reminders.

Voluntary agreements as a tool to improve standby performance of chargers is not likely to work, since the brand holders don't get any competitive advantages by improving energy efficiency. The IPP pilot project is expecting that "ongoing processes" of minimising no-load consumption will improve the chargers. However, it seems rather unlikely by voluntary means to reach a reduction of a factor 20 to 30 in the near future without market demands and with no standards from public regulation.

5.5.2 The EuP regulation of external power supply

The EU has decided that external power supply including mobile phone chargers has to be regulated under the EuP framework, and a Preparatory study has been made to identify the technological potentials and regulatory needs in this area. The study identifies that it is possible to reduce the energy consumption in standby to 0,01W as proved by Salcomp. Besides, efficient switch mode chargers are identified as being beneficial from both an economical and environmental perspective. These benefits will be more dominant if low standby values were implemented together with a standardisation of the interface of the chargers, since this would improve their durability, as they could be used by several brands, and do not need to be replaced with the phone.

[www.ecocharger.org/docs/BioConsortium_EuP_Lot7_Task%207.pdf].

The preparatory study indicates that the CoC levels are sufficient. As described, the CoC is not ambitious and since the preparatory study has identified BAT with much better performance levels it seems odd that they promote the levels from CoC. However, mandatory levels as in CoC will have an effect on other products as DECT-phones, routers etc.

Besides, an Eco-profile is suggested, where different parameters incl. better energy performance levels, BOM (Bill-of-materials) information and aspects of standard interfaces are aggregated to provide a total performance that need to be above a certain requirement, providing flexibility for companies to choose different strategies for compliance. [www.ecocharger.org/docs/BioConsortium_EuP_Lot7_Task%208.pdf].

Such an eco-profile score system is appropriate for addressing the fragmented mobile phone industry as the suppliers of chargers is providing the same chargers with small adjustments for several brands and thus may need to act on different requirements from the different customers (see background report for further discussions).

However, the draft for implementing measures by the EU Commission is only setting up requirements to energy efficiency, and is not including the other ideas regarding policy instruments mentioned above.

5.6 Conclusion – chargers and policies

The shift from linear technology to switch-mode chargers for mobile phones has been analysed in respect to improved energy performance and to the possibilities for further optimisations of switch-mode technology. In this conclusion on the case study, the general findings will be summarised based on the concepts: knowledge, resources, market and policy instruments.

The *knowledge* to develop and produce switch-mode technology has been known since the late 60th within aerospace industry. However, the technology has developed since, and was introduced to the mobile phone industry by Salcomp in late 80es but did not become market dominating until the beginning of the new millennium. Today, both industry and academia in the Nordic countries have excellent competencies within low power switch mode suppliers. A PhD thesis from DTU shows that it is possible to improve today's average power supplies with at factor 20, and recently Salcomp has developed a charger matching the DTU technology in terms of stand by power consumption. Conclusively, the knowledge to develop mass produced and cheap chargers with much lower energy consumption is present in the Nordic industry.

The case shows that the mobile phones industry spends limited *resources* and attention on chargers in general. However, Salcomp has managed to be technological ahead of their competitors and is a market leader today.

The reluctance of brand holders towards spending money on chargers is probably also a reason why the charger developed at DTU still is superior. The DTU project has mainly received funding from the Danish government through a fund focusing on minimising the overall energy consumption. However, B&O has also contributed to the project with the aim to gain competence to create an energy efficient power supply to reduce their TVs standby consumption.

The case clearly shows that in contrast to the energy consumption of the phone and its components, the energy consumption of the chargers is of limited interest to consumers – energy consumption of chargers is not an issue on the *market*. The priorities on the market are price, charging time, size and flexibility in respect to power input. These priorities, except the price, have evolved as the market has become more globalised, phones have become more energy demanding and expectations of consumers in respect to charge times and flexibility has increased. This has lead to a change in technology, but due to the price the linear chargers has until a few years ago been market dominating, while switch-mode chargers were an option for upgrade or came with the high-end phones.

A market pull for chargers with improved standby performance can not be expected, as the energy use of a charger is insignificant from a private economic view. Therefore, this is not an option for differentiation to the brand holders. Funds for research and knowledge generation on energy efficient chargers is not sufficient for these chargers to be introduced on mass markets, other policy instruments have to be applied.

The case study, the Code of Conduct (CoC), and the prospects of the IPP pilot show that voluntary agreements are insufficient to facilitate the industry to adopt energy efficient chargers. The CoC threshold is a factor 30 higher than best available technology (BAT), and the IPP pilot are not recommending strict regulations based on BAT.

Therefore, stricter demands have to be established as normative binding regulation in relation to the EuP directive. The current *draft* in spring 2008 for implementing measures is setting up minimum performance requirements for standby and off mode that power consumption shall not exceed 1.0W one year after the regulation has come into force. After four years the requirement is tighten to 0.5W.

6. Energy savings in 4G

This case takes a look into the future and addresses the constraints and potentials of a strategy for the 4th generation (4G) mobile communication system. As described, the industry agrees that a 4G network will call for:

- Radical improvement in data rates
- A seamless communication platform
- Multifunction terminals that contain features such as video streaming, gaming, music player, GPS features etc.
- Terminals equipped with multi-accessibility enabling to access distributed networks, cellular network, local area networks etc.

A shift in network technology entails increasing energy demands in hand-sets as well as in the base stations. This case study analyses this trend by investigating the options to reduce the energy pull of the terminals, while increasing the user's accessibility to high data rates by rethinking the whole communication system. The approach is based on a paradigm shift in the understanding of the basic organisation of a wireless communication system. The shift can be achieved with existing technology. However, the approach can be significantly improved with technological innovations.

6.1 Background and basic concept

Before 3G there was no synergy between independent networks. This was changed with the introduction of 3G, as technological innovation has allowed hand-over between different networks, enabling operators to reduce the roll out costs of 3G networks. The principle is simple: to provide 3G services in dense populated areas with large market potential first and then secure wireless communication to consumers in the less dense populated areas via the already existing 2G networks.

In this case of 4G, the synergy between different networks is taken one step further by creating large potential energy improvements both in the network as well as in the terminals.

The basic idea is to combine *high speed, energy efficient and short-range* network technology as Bluetooth with traditional *long-range low energy efficient* network technology as 2G and 3G. In traditional networks for phone communication, the network and the data processing account for about 50 % of the power used. This fact makes the network an obvious area of concern for energy savings, and by combining these

two types of networks, the energy saving is achieved [Katz, Marcos and Fitzek, 2006, p. 481].

The principle is that terminals within close proximity to each other establish a cluster via their energy efficient short-range network. In this cluster, they can exchange the data that each terminal receives from the base station, hence they can reduce the use of their high energy consuming connection to the base station and reduce their energy consumption, or they can increase the data rate without increasing the energy use. As the short range networks are much faster as well as more energy efficient, the energy use in these networks can almost be neglected compared to the cellular network (*long range low energy efficient network technology*) [Intw. Fitzek; Katz, M and Fitzek, F (2006); Frattasi, S et al (2005); Zhang, Q, Fitzek, F and Katz, M (2006)]. (See figure 4)

Figure 4: Central controlled peer-to-peer cooperation [Frattasi, S et al, 2005]

Besides, the energy efficiency gained in the terminals, the base station improves their performance, as the capacity in the base station is improved [Intw. Fitzek, 2006].

6.2 Increases in Energy Consumption

As mentioned the shift from one network generation to the next has historically entailed rising energy demands. The introduction of the third generation network was no exception, and the first 3G terminals came with several batteries in order to provide acceptable time for talking. [Katz, Marcos and Fitzek, Frank (2006)]

The 3G terminals performance has improved radically, but a recent comparison of seven 3G terminals talk time (see figure 5) indicate that energy consumption is much higher, when the same phone is using the 3G net compared to when using the 2G net. In average, if Sony Ericsson is not included, the talk time on the 3G net is about 75% to 80% of what the 2G net. Sony Ericsson stands out, as their talk time on 2G is much better than their competitors, while their performance in 3G is slightly worse.

Figure 5: Talk time in 2G and 3G networks

		Talk time		Talk time in 3G as % of 2G
	Phone	2G	3G	
Sony Ericsson	K610i	7 h	2,3 h	33 %
	M600i	8,15 h	2,1 h	26 %
Nokia	N91	4 h	3 h	75 %
	N93	5,1 h	3,7 h	73 %
	6233	4 h	3,1 h	78 %
Samsung	SGH-Z540	3,2 h	2,5 h	78 %
	SGH-Z710	3 h	2,6 h	87 %

The comparison includes seven phones of different brands. The data is from the brands web-pages and the phones are chosen randomly from available 3G terminals

According to Fitzek the energy pull in a phone from before 2000 is around 2W, while today's most advanced phones is approaching 6W and is expected to rise in the future. 6W is estimated to be the limit for when active cooling is necessary – otherwise the phone will become so hot, that they will be unpleasant to carry in the pocket. Active cooling will require energy as well putting extra energy pull on the batteries. Consequently, a linear extension of the historical development is doubtful [Intw. Fitzek; Katz, Marcos and Fitzek, Frank (2006)]

Figure 6 Energy vs. quality trend

These are the arguments supporting Fitzek's point that, if 4G network is to become a success, the *power trap* must be solved. The industry will need to provide better quality, in terms of use time and data rates, with the same or lower energy pull (Figure 6) [Intw. Fitzek; Katz, Marcos and Fitzek, Frank (2006)].

Some actors in the industry hope that new batteries or fuel cells technology will solve the problems. However, fuel cells technology are not

mature yet, and in average the battery performance has only improved 60 % over a 5 year period, while the energy demand has been doubled in the same period.

6.3 The ad-hoc central controlled cooperative cluster

The concept of cooperation in ad-hoc clusters is strongly promoted by a research group at the Department of Electronics, Aalborg University. AAU has a strong research group within wireless technologies and with several EU projects, including the MAGNET Beyond focussing on personal networks in respect to the interconnectivity of different digital appliances. www.ist-magnet.org/technicalapproach

The approach of the Magnet projects builds on the same thoughts about 4G as a platform of many different access technologies working together, but in contrast to the ad-hoc cluster centre on the individual cluster. In contrast to the Magnet projects, the cooperation approach hasn't received the same attention and the research is mainly based on funds from the university. However, some companies have shown interest in the research, and are providing different kind of support e.g. Samsung has been active in a project called JADE, which is focused on an user centric approach for 4G and introduces the idea of cooperative networks, while Nokia are sponsoring AAU with terminals for general setups including the working group on cooperative networks [Intw. Fitzek].

6.3.1 *Benefits of cooperation – three scenarios*

The research group has tested different setups of corporate networks in their lab. Basically the setups can be divided in three scenarios according to their focus on different parameters and slightly different approach.

- a. Shared service – large data package, fast download
- b. Shared service – streaming in high quality
- c. Individual service

The first and second scenario has many similarities and will be described together. The third scenario is described separately as it differs in respect to greater dependency on the operators, but draws on the same principles.

Scenario 1 and 2: The basic principle is to divide the data into small packages that can be distributed by different routes. Once the phone receives them, the data can be put together again to form the full data. The difference in the two scenarios is the priorities, which also relates to the character of the services that are downloaded.

In scenario one, the data rates and energy consumption are prioritised. Phones requesting the same service e.g. download of a specific content

can establish a cluster, where they each download a share of the package via their long-range high energy consuming radio link and exchange it in the cluster using their high speed low energy link. In this way, it is possible to increase the data rates dramatically, almost proportionally with the number of participants in the cluster, while at the same time reducing the energy consumption equally, as the short-range link is extremely energy efficient per MB. This scenario is suitable for online gaming, for downloading programs, features etc. The potential energy savings has been estimated to 44% in a scenario with only two participants [Zhang, Q; Fitzek F and Katz, M (2006)].

In scenario two, the priority is high quality streaming. Again the service is split into small packages. However, the phone doesn't need all the packages, but the more it receives the better quality will be achieved. As one phone only has a limited bandwidth via their long range link, they will experience drastically increase of quality by joining a cluster streaming the same service, as they can download different packages and share them in the cluster. This technique is suitable for different kind of streaming, as music, video etc. As the short-range link consumes low energy the quality can be improved manifold using only slightly more energy improving the ratio quality / energy consumption. If focus instead is to minimise energy while maintain same quality, the AAU research group has estimated savings on more than 60% with 15 participants, and after six participants the savings is around 50% [Intw Fitzek; Fitzek, Kyritsi and Katz 2006].

The last scenario is, when phones don't request the same service e.g. download e-mail, phone conversations, and videoconferences. In this case there are still potentials for energy savings, increased bandwidth and increased capacity in the network, but it becomes more complex. 3G, WLAN and other networks are designed so all users in the same cell are receiving the same package, but are only able to decode their own data. This opens for cooperation as such packages can be send through varies ways e.g. through another terminal. This means that the participants closest to the base station actually could take turns receiving the full package from the base-station and distribute the coded sub-streams in the cluster increasing both the capacity of the network as the cluster count as one unit, and saving energy in the terminals as they take turns in the download.

The data rates in these networks are furthermore dependent on the terminal in the cell with worst connection. In the case illustrated by figure 7, terminal A has the worst connection and will force the cell to reduce the data rates for all terminals in the cell. Terminal E, C and A could form a cluster and E and C could take turns forwarding the data to terminal A, hence the cell could improve the overall data rate.

Figure 7: A, B, C, D and E represent terminals in a cell. The percentages indicate the covering rate. A are setting the standard.

Nearly in all wireless communication there is some packet lost, because there is always a need to resend parts of the data. This can potentially be handled internally in the cluster, by letting the phones buffer the common data.

In contrast to when terminals request the same services, the benefits by cooperation when demanding different services are not as obvious to the consumers. The potential energy savings are increased if cooperation is coordinated from a central place. Hence there might be a need for an active role of the central operators and the network provider in order to gain the full potentials for more efficient communication systems, and of the brand holders as well in order to dedicate the phones to cooperation.

6.3.2 Technical implications

The technology needed to establish a cooperation ad-hoc clustering is already available. At Aalborg University, they have developed a small program that enables the phone to establish a cluster and to receive and make retransmission of data in the cluster. It needs however the user's active involvement and a phone with an open operation system. The potential market is therefore rather limited as few actually have a phone with open software and the constraint for users to take active action on this. For having any application, the cluster approach needs to become widely spread. The user needs to know other people with a phone with an open operating platform and the program installed, and who wishes the same service at the same time in order to establish a cluster.

If the cooperative ad-hoc cluster approach is to be widely implemented and the full potential utilised, then the involvement of the network operators as well as brand holders is needed. [Intw. Fitzek].

The operators already have the knowledge of the whereabouts of the terminals and which services they are requesting. This knowledge can be used to identify potentials for cooperation. However, the base stations will further need to know which coded signals are for what terminals and

the character of the services that the terminals are interested in as well as the capabilities of the terminals in respect to different radio technology. [Intw. Fitzek, 2006]

The brand holders need to design the phones so they are able to engage in a cluster. Today, only the phones with an open operation system can be enabled to establish a cluster; the brand holders have the option to develop software that enables both new and existing phones to establish clusters. This could be achieved by software changes, and existing phones could be upgraded via the operator's networks without the user knowing it. [Intw. Fitzek, 2006]

Furthermore, there are some options for hardware upgrade that would improve the potential of the cluster approach. This includes modifications of range radio link with cooperation in mind, and relates to the hardware and the software platforms. These option for improvement with cooperation in mind include to enable the phone to switch-off the long range high energy consuming radio link, when it is not needed, as in situations when they link to the base station via the cluster rather than via own long range radio. Another potential is the introduction of smart radios equipped with flexibility in respect to the use of frequencies and able to allocate spectrum on the fly to the different radios according to needs – e.g. if the 2 or 3G radio were not needed, all spectrum could be allocated to the short range radio link. This is called cognitive radio technology and would provide increased bandwidth in the individual links and better use of resources. At AAU, they are also engaged in developing cognitive radio technology, but the technology is not ready to be commercialised in the near future. [Intw. Fitzek, 2006]

6.3.3 Limited commercial interest

Some industrial actors have shown interest in the concept, but AAU has not been able to find partners to commercialise the ideas. The companies interested are mainly brand holders, while the operators and network providers have been more reluctant towards the project.

A possible explanation of why the operators are not active in spite of better energy per bit potentials, better spectrum use etc. could be that they are not sufficient convinced that it is possible to establish proper payment structures securing their businesses. Furthermore, the operators have in general a reactive approach towards new technology – they rely on the product portfolio of their network providers, and have historically been slow to introduce new technologies e.g. roaming due to concerns about payment structures. Finally, new technologies need to be accepted by the large players in the game; hence some kind of compromise is needed. Such a compromise will likely concern the large industrial players share of patents in the standard, as this secure them a income in terms of royalties [Int. Fitzek, 2006; Phone conversation, Vandrup, Nokia, 2007].

In addition, the industry is in an insecure position as it is not clear what 4G will bring, besides increased band-width. Some operators and network equipment providers advocate for a 4G system based on a new generation of networks, as it has been known from the change to 2G and 3G, which would allow them to continue with their existing business models and providers of network equipment could expect increased orders. Others operators seem to realise, that a change in the market structure might be on the way and they are working to initiate alternative service products using the new technological options with focus on end-user needs. [Intw. Telia DK; Intw. Fitzek, 2006]

The handset manufacturers have a bias approach as they generally expect that their direct customers (the operators) are resistant to allow peer-to-peer (p2p) communication, as payment systems are not in place. On the other hand, p2p could be an attractive technical feature, which can help to drive the market for handsets. [Intw. Fitzek, 2006].

As Fitzek has not succeeded in attracting network providers and operators as partners to commercialise the ad-hoc network approach, then they try to commercialise the idea by distributing the previous mentioned program. If enough services and content are provided with an option to partial download and exchange such, and several consumers adopt the autonomous cluster approach, then the operators will be forced to consider the ad-hoc cluster as part of their business models.

Status for this strategy is that several content providers are beginning to allow partial downloads of their content and services by different terminals and sharing of downloads, whereby services and content are present [Intw. Fitzek, 2006]

6.4 Conclusions – Energy savings in 4G

The options for energy savings by combining different networks in a common wireless infrastructure – cooperation in ad hoc networks – have been investigated in this case. The conclusions are structured in three categories, *knowledge*, *resources* and *market*. Finally, the policy recommendations from this case are outlined.

The *knowledge* needed to establish ad-hoc wireless network with cooperation in mind do already exist as the approach of Fitzek and other researchers show.

In general the knowledge in the sector is immense, and many different actors invest money in research. The Nordic countries have a history within the wireless mobile communication system from NMT over GSM to the research in fourth generation network. For instance, in Northern Jutland, a cluster with AAU in a key position has emerged and new knowledge within wireless mobile technology is generated, attracting new investments as well as new companies. For example, AAU adminis-

trates the MAGNET and MAGNET Beyond project co-financed by the EU sixth framework program.

Furthermore, the Nordic countries have a leading position on the market for network infrastructure with Ericsson as the largest actor, and Nokia and Siemens in a new joint venture on network infrastructure becomes the second biggest player.

As described, the research group working on cooperative network lacks to some extent economic *resources* and cooperation propositions from the industry. A major reason is that economic support from the industry is limited, because the industry is in an uncertain position, where different parts of the industry are working to secure their interests in respect to a future network structure. The market is unpredictable and for this reason are operators, network equipment producers and terminal producers reluctant to invest in only one technology path. Besides, a general scepticism towards p2p technology is present, as the industry fear they will loose control, and that their payment systems will not be able to handle p2p services in a satisfactory way.

Finally, the large actors in the industry such as Ericsson, Motorola, Qualcomm etc. need to agree on a standard, which they will use, hence it will need to consist patents from all actors equalizing the income on royalty fees.

EU has under the 6th framework program put focus on 4G network, and AAU has over two periods received funding to host the MAGNET projects, where also the Danish government and industrial actors are contributing.

The *market* for the cooperative, ad-hoc network approach is not present today. The idea of p2p network requires a large penetration rate in order to become a success, as more terminals within close proximity to each other needs to be interested and able to join such an ad-hoc cooperative network and create a cluster. Furthermore, in order to share data without involvement of the operator, they will need to request the same service, which further needs to allow partial downloads. Given the variety of content and services offered this further limit the changes that two persons interested in the same service are in proximity of each other.

However, as the potential benefits in terms of increased data rates, reduced complexity of the phones, and reduced energy demand looks promising, the technology might have some prospects. However, p2p networks need to be promoted though standards or at least in a joint effort with operators and brand holders.

Policy recommendations

Due to the extensive globalisation of the mobile phone industry, policy instruments need to be considered in an international perspective, and most issues has to be addressed at the European level – at a minimum. Nordic requirements for network standards do make sense at this time of the development of mobile phone networks. If the networks infrastructure is to include environmental (including energy) concerns the Nordic politicians must address these at EU or international level, as well as in standardisation organisations. However, the effect of such demands or standards will be world wide, as the standards not only are used in Europe but all over the world.

A different way to facilitate environmental innovations of mobile phone networks is for the Nordic countries to use their leading role in the industry when it comes to handset, network infrastructure and research in wireless networks, by e.g. facilitating research with an environmental focus, and for instance allow and support pilot setups where such system could be tried out in real life. This would need an active involvement of an operator, but could have potentials to influence the rest of the industry, as they have their eyes on the Nordic research community.

7. Conclusion

The characteristics of the global mobile phone industry have been highlighted in this report including its appearance in the Nordic countries, the innovation dynamics and how environmental policy instruments have influenced the dynamics.

Two cases on energy savings in mobile phone chargers and in wireless communication systems of the future by means of cooperation are presented.

The findings will be summarized in this chapter in three overall categories: knowledge, resources and market. The chapter will finally provide policy recommendations.

7.1 Knowledge

The mobile phone industry has a strong focus on knowledge both as basic and applied research. The knowledge pools and knowledge creation is spread on different actors, who cooperate in various changing networks including universities, knowledge institutions and private economic actors from different parts of the supply chain. The cooperation between the former Swedish state Tele monopoly, Telia, and Ericsson is an example of successful knowledge cooperation. In the early nineties Telia worked hard to provide mobile covering in Sweden, which provided Ericsson with a fortunate home market, that facilitated Ericsson international success. Ericsson is still market leading on the network infrastructure. The knowledge flow is important in an industry that is based on constant innovations. Also in other areas, there is a close cooperation between universities and industry, e.g. Aalborg University has been facilitating a wireless communication cluster in Northern Jutland, which are world leading in areas such as antenna, integrated reference design, and that are able to attract international actors in the sector.

The companies R&D departments are in general split into a research department, that produce knowledge for future innovations; while the development department is engaged in meeting the short term market demands by using internal as well as external knowledge. This implies that the private companies are heavily involved in the creation of new knowledge and are among the largest research institutions in the Nordic countries.

The diffusion of knowledge in the electronic industry in general is high, and different sectors as computers, gaming, audio and video are often successful in learning from each other. The increasing merging of

different product groups, as cameras, PDA's, multimedia players, GPS, computer and mobile phones can be seen as an example on this integration of different knowledge areas.

The general use of standards, both as de-facto standards as well as industrial established standards has made the diffusion of knowledge and merge of products easier. Standards establish common terms for the development of a product group, which makes it easier for sectors to implement technologies from other sectors. For instance, the memory card used in cameras and mobile phones is the same.

The standardisation of components has meant that there is less need for coordination of R&D among actors in the supply chain, as suppliers only need to produce according to a standard instead of according to specific requirements from each brand holder. This makes it easier to out-source and is one of the reasons behind the economical and geographical segmentation of the industry.

However, standards do narrow the options of improvements, as the product development needs to take place within the given terms. Large companies are therefore active in the standardisation processes and try to promote standards that will provide them with competitive advantages.

7.2 Resources

A key resource in the mobile phone industry is to adapt new knowledge to improve existing technologies and develop new features and designs. An approach, where incremental innovations are added to existing platforms, has enabled the industry to increase the ability to capitalise innovations and products. This has also been facilitated by the extended use of standards, as it enables modularity and the platform approach.

The fast changing industry as well as the strict demand for capitalisation has made the time frames short that the companies work with in research and development. Many western companies don't work with more than a five-year timeframe. However, some Asian companies as Samsung apply a ten years horizon in their research.

EU and national institutions fund research in certain prioritised areas, as next generation of network in the MAGNET and MAGNET Beyond project as well as the DTU research on chargers described in cases. Areas can be of priority due to industrial policy, facilitating innovations, and health and environmental issues.

7.3 Market

The market for mobile phones has become a consumer market characterised by high segmentation according to various issues such as design, music, camera, business features, gaming and basic phones.

During the past decade the market has increasingly been driven by the accelerated introduction of new and improved technological functions and design features. An important driver has become the fashion and lifestyle aspects. These changes have meant the phones are replaced at an average of 1,8 year on the advanced markets.

The parameters for commercial success are depending on the ability to develop new and exciting features and visual designs that have appeal, and not least to be the first on the market with new trends or features. This makes time to market a critical aspect in the industry.

In conjunction with this focus on fashion and new features, the mobile phones face a strong price competition, especially in the mid- and low-end segments. This development has meant that many companies have left the industry with huge losses and that five brands today dominate the world market. However, upstream in the supply chain many specialised companies operate independently and deliver to several brand holders.

The case studies clearly show that without a market demand, the presence of both knowledge and resources are insufficient to establish environmental improvements of mobile phones. Nokia was the first brand to understand the importance of market driven innovations. The challenge to the policy instruments is both to understand the innovation dynamics in the mobile phone industry and at the same time influence the creation of a market pull for environmental innovations in consumer electronics.

7.4 Policy Instruments

Nordic companies have achieved a unique position in the mobile phone industry due to the early joint establishment of the Nordic standard (NMT). Learning from that, it seems evident to adopt similar strategies and promote a strong involvement in the definition of what is to become the global standard beyond 3G. At the present time, huge amount of resources are invested from both private and public actors, however only few seems to address possible energy savings. As the case on 4G shows, there are prospects that might be interesting to support – both by trying to establish trial set-ups involving different actors and also by influencing the standardisation work through means of frequency regulation.

The knowledge generated in the DTU project on energy efficient chargers has had difficulties getting commercialised and instruments to motivate the market dynamics should be considered. This indicates that funds for creation of knowledge for environmental improvements often

need to be followed up by policies in order to stimulate a demand for the technologies.

The global character of the mobile phone industry means that policy instruments only applied in Nordic countries will have a limited effect. Therefore, most policy instruments often require initiatives at minimum EU level to provide significant effects.

The Nordic countries are treated as one market by several brands e.g. in the distribution channels where phones come with manuals in all Nordic languages. In areas easily adapted to a small market it might be possible to strengthen the regulation. This could be to set stricter requirement to the charger than what EU apply, as the chargers is already equipped with various connections to different sockets in different markets.

Furthermore, the short lifetime of mobile phones is related to the commercial relations and difficult to regulate at EU level. However, a contributing aspect is that the operators subsidize new phones in exchange for binding agreements with the consumers. National/regional regulation that prohibits such subsidy might lead to more expensive phones as well as to a greater reluctance by consumers to replace the phone after the average 18 months.

The focus of Nordic politicians is primarily to influence EU regulations. The experience with the existing EU policy instruments is somehow biased. Several initiatives related to electronics to establish market incentives have had limited effect; e.g. the voluntary agreements, the labelling schemes as well as the WEEE directive. Opposite, the old-fashion bans on substances in RoHS with market exclusion as a possible result of non-compliance have lead to a joint shift in the electronic industry away from the concerned substances also in the supply chain, since the brand holders act globally with one unified standard.

However, it is more likely to influence the whole supply chain in a case with clear signals such as phasing out specific substances compared to a policy objective of increasing energy efficiency.

In the case of the EuP directive, minimum requirements are being set-up in the current drafts for implementing measures, but only for energy efficiency. The Environmental Protection Agencies in the Nordic countries have a challenge in this case in order to bring broader environmental issues from the product life cycle into the requirements of EuP.

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Sammenfatning

Miljøpåvirkningerne fra mobiltelefoner er relateret til anvendelsen af ressourcer, kemikalier og energiforbrug i de forskellige led i produktionen, og specielt ved produktion af chips, LCD og PWB. Energiforbruget i brugsfasen er en anden miljøpåvirkning, som skyldes opladerens standby forbrug såvel som energiforbruget i hele det trådløse kommunikationssystem. Mobiltelefoner er ydermere sammensatte produkter med en mængde komponenter med potentielt farlige stoffer, som kan forårsage problemer i affaldshåndteringen og genanvendelsen af materialer. Produktionen af 1 mobiltelefon er skyld i dannelsen af 75 kg. affald.

Mobiltelefonindustrien er meget globaliseret med 6 store kendte mærker. Nokia har mere end en tredjedel af verdensmarkedet, og Sony Ericsson er en anden af de seks store brands. Ericsson er endvidere den ledende leverandør af netværksudstyr. Nokia og Ericsson er blevet globale spillere i denne branche, blandt andet fordi de Nordiske lande tidligt var involveret i udformning af den første internationale standard for et trådløst kommunikationssystem i 1982.

Den globale karakter af markedet og af de dominerende brands stemmer overens med, at også leverandørkæderne er globale og fragmenterede. En mobiltelefon bliver produceret rundt omkring på hele kloden, hvor de specialiserede komponenter produceres i USA, Japan, Taiwan, Korea og EU, så bliver det samlet hos kontaktproducenter i Kina, Thailand og i stigende grad i Indien.

Dilemmaet mellem masseproduktion og kundetilpassede produkter er reduceret ved at udforme nogle basis platforme og modulopbygge mobiltelefonen. På denne måde er det muligt at holde priserne nede, lave mobiltelefonerne rettet mod specifikke kundesegmenter og samtidig holde tiden nede til markedsintroduktion af nye modeller. Den aktuelle innovationsdynamik i branchen er karakteriseret ved: sammensmeltning med anden forbrugerelektronik produkter og introduktion af en række nye muligheder (radio, MP3 afspiller, kamera, GPS, osv.) samt øget data transmission.

Denne innovationsdynamik og markedstendensen, hvor forbrugerne udskifter deres mobiltelefon hvert halvanden år, er nogle af de karakteristika, som må reflekteres i miljøpolitikken og i sammensætningen af et hensigtsmæssigt mix af politik instrumenter.

Indtil videre, har forbrugerne ikke stillet miljøkrav ved køb af nye mobiltelefoner. Af denne årsag tror virksomhederne ikke, at de kan opnå konkurrencemæssige fordele ved at lade mobiltelefonen miljømærke – og derfor har energi- og miljømærkerne ikke påvirket udviklingen af 'renere mobiltelefoner' i frontløber virksomhederne.

Effekten af frivillige aftaler kan være vanskeligt at opgøre, så som at virksomhederne tilslutter sig EU's Code of Conduct for opladere/eksterne strømforsyninger. Energieffektiviteten af opladere er blevet sat på dagsordenen, og centrale aktører som Nokia anvender opladere med et gennemsnitligt standby forbrug på mindre end 0,3W, som krævet i den frivillige aftale og af det amerikanske Energy Star mærke.

I forlængelse af EU direktivet om Energy-using Products (EuP) opstilles minimumskrav til produkternes miljø performance. I de aktuelle udkast til gennemførelsesforanstaltninger er der fokus på krav til energieffektiviteten, og ambitionsniveauet er forholdsvis lavt (1W i standby forbrug) sammenlignet med den frivillige aftale og bedst tilgængelig teknologi.

I modsætning hertil, har RoHS direktivet, som sætter begrænsninger for brugen af visse skadelige stoffer, påvirket mobiltelefonindustrien ikke blot i EU men globalt til at udfase disse stoffer. Specifikke krav med klare målsætninger og tidsrammer har en effekt selv i globale og fragmenterede produktkæder.

WEEE direktiver har til hensigt at forbedre affaldshåndteringen af elektriske og elektroniske produkter, men har indtil videre ikke påvirket produktudviklingen af mobiltelefoner i retning af eco-design. Affaldsminimering, øget genanvendelse og øget brug af genanvendte materialer er stadig en udfordring til mobiltelefon industrien og til myndighederne.

Det første case studie viser, at opladeres standby forbrug kan forbedres med en faktor 10 sammenlignet med de bedste opladere på markedet i dag. Men hverken forbrugerinteresser eller EuP direktivet giver incitamenter til sådanne radikale forbedringer. Konkurrencefordele kan ikke opnås ved at markedsføre nye mobiltelefoner med mere effektive opladere, da dette forhold ikke er inde i forbrugernes optik, og idet udkastet til gennemførelsesforanstaltninger for opladere i regi af EuP direktivet ikke er så ambitiøst endda, og i øvrigt kan opnås med allerede kendt teknologi.

Case studiet om 4.generations mobile netværk (4G) illustrerer 'energifælden', at øget datatransmission og nye tjenester stiller store krav til energiforbruget både i mobiltelefonen og i netværket. Med andre ord, sammenhængen mellem energiforbrug og data transmission må afkobles for at kunne udbrede 4G netværket. Transmissionskapaciteten kan imidlertid forøges ved at organisere netværket anderledes, så brugerne 'deler' fælles data fra basestationen via mere energieffektive, kortrækkende bredbåndforbindelser (fx Bluetooth og Wlan). Det bliver kaldt samarbejde, og kræver forholdsvis begrænset med ny teknologi men en helt anden måde at organisere netværkssystemet på.