LCA Case Studies

Life Cycle Assessment of the Mobile Communication System UMTS

Towards Eco-efficient Systems

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Abstract

Goal, Scope and Background. Goal of this study is an evaluation of the environmental sustainability of the UMTS mobile communication system in Switzerland by means of a Life Cycle Assessment (LCA). A baseline environmental impact profile across the full life cycle of the UMTS (Universal Mobile Telecommunication System) and its predecessor, the GSM (Global System for Mobile Communication) is presented. The baseline assessment was a necessary first step to evaluate the environmental impacts of the mobile communication systems use and growth, thus permitting the evaluation of its environmental sustainability.

Main Features. Two functional units are defined: a data set of 1 Gbit (1.000.000 kbit), and the yearly mobile communication of an average customer. In the UMTS, both data packages and calls can be conveyed. In order to be able to standardize the results, an equivalence between these two kinds of transmission is formed.
Two different options are defined, which represent different ways of transferring the data: mobile phone to mobile phone, and mobile phone to fixed network. All components of the UMTS network like the mobile phones, base stations, antennae, switching systems and the components of the landline like cable system and switching centers, are assessed. The environmental impacts are assessed taking into account all major life cycle phases like raw material extraction, manufacturing, use, disassembly and disposal of the product and the needed infrastructure. Electronic components like printed wiring boards and integrated circuits are assessed using a simple model based on the size (for IC) or number of layers (for PWB), respectively. Mining of precious metals (gold, silver) is included.
The study was carried out by ESU-services, Motorola, Swisscom and Deutsche Telekom. Thanks to the industrial partners it can rely on primary data for the production of mobile phone and base station, and for the operation of the networks. As the UMTS network is still being built, no actual data of network operation is available. Data from the GSM (Global System for Mobile Communication) were used in case of data gaps.

Results and Conclusions. About 25 kg CO_2 are emitted and 800 MJ-eq (non-renewable) primary energy are required for the transfer of 1 Gbit information from mobile phone to mobile phone in the UMTS network. For a transfer from mobile to fixed network, these values are 20 kg CO_2 and 640 MJ-eq, respectively. On the other hand, the fixed network requires more resources like copper (0.07 kg for the mobile to mobile option vs. 0.12 kg for mobile to fixed network).

From an environmental point of view, the mobile telephone is the most important element of the mobile communication network (UMTS and GSM). The short service life of the mobile phone plays a substantial role. Increasing the utilization period of the mobile phone (e.g. by leasing, re-use, extension of the innovation cycles, etc.) could thus represent a large potential for its improvement. The second most important components are the base stations. In the assessment mainly the use phase proved to be important. The lower environmental impact (per Gbit data transfer) as compared to the mobile phone can be explained by the longer service life (around factor 8). Main impacts are caused by the electricity consumption, in particular the energy needed for cooling the base stations. By choosing an environmentally benign electricity mix and/or by increasing the portion of renewable sources of energy, the network operators have a substantial potential of lower the environmental impacts (in particular the greenhouse gas emissions) of mobile telecommunication. Furthermore, the manufacturing of electronic components, the life time of the appliances and energy consumption are key parameters influencing the environmental profile of the networks most.
Given its larger data transfer rate, the UMTS is ecologically more favorable in terms of data transfer rate than its predecessor, the GSM system. The higher energy consumption and the more complex production of the devices in the UMTS system are compensated by the faster data transmission rate. Per customer, the result is inverse, however, since the higher efficiency is compensated by the higher data communication per user in the UMTS system. The UMTS network in its state of 2004 according to the 2001 planning and with the accordingly calculated number of customers and data transfer causes 2.1 times more CO_2 emissions and requires 2.4 times more (non-renewable) primary energy per customer than for the GSM system in its current state. It must be noted, however, that the UMTS technology supports other services than the GSM system. The development of the UMTS is accompanied with an increased consumption of resources and emissions of pollutants and greenhouse gases regarding the entire system for mobile telephone communication.
The GSM system is a mature technology, while the UMTS is still at the beginning of its learning curve. Thus, it can be safely assumed that large improvement potentials are still present for the UMTS network components concerning expenditures and emissions both at production and by the use of the devices. This study provides the necessary information where such improvements are most effective in environmental terms.

Keywords: Base station; eco-efficiency; GSM (Global System for Mobile Communication); mobile phone; UMTS (Universal Mobile Telecommunication System)

Introduction

The demand for mobile communication services is globally on the rise. Mobile phone networks are being built rapidly and are mainly steered by economical and legislative drivers. Environmental aspects are mainly incorporated only for singular aspects like non-ionizing radiation of antennae and mobile phones, or the energy use of switching centers. A complete picture of the different environmental impacts of the UMTS (Universal Mobile Telecommunication System) allows operators and manufacturers to intensify actions concentrating on the components of the whole system with the highest potential of improving their environmental properties.

Several studies have assessed environmental aspects of telecommunication systems (e.g. Oiva 2000) for a mobile phone, (Harada 2001) for the fixed network in Japan, (Blazek 1999) for the telecommunication systems of two cities). A study of the complete UMTS network is being done for Ericsson components; first results were presented in (Malmodin 2001). The study presented in this article is the first environmental assessment of UMTS in Switzerland.

1 Goal and Scope

Goal of the project is to assess the environmental sustainability of the Swiss UMTS network, which is currently being built by different telecommunication operators in Switzerland (Faist Emmenegger et al. 2003a). In order to do this, a life cycle assessment was carried out. The goal of the LCA is to assess the environmental impacts caused by a call via the UMTS mobile phone system. The results of the life cycle assessment (LCA) are used to quantify the environmental impact of the use and growth of the total UMTS mobile phone system and its components, thus making an assessment of its environmental impacts possible. All the components of the UMTS like the mobile phones, base stations, antennae and switching systems, and the components of the landline like cable system and switching centers, are assessed. The environmental impacts are assessed taking into account all major life cycle phases like raw material extraction, manufacturing, use, disassembly and disposal of the product and the needed infrastructure. A baseline environmental impact profile across the full life cycle of the GSM (Global System for Mobile Communication) was also done and allows the comparison between the two networks.

1.1 Mobile networks

GSM, which was first introduced in 1991, is one of the leading digital cellular systems. Eight simultaneous calls can occupy the same radio frequency. It provides integrated voice mail, high-speed data, fax, paging and short message services capabilities, as well as secure communications. Originally a European standard for digital mobile telephony, GSM has become the world's most widely used mobile system in use in over 100 countries. GSM networks operate on the 900 MHz and 1800 MHz waveband in Europe, Asia and Australia, and on the 1900 MHz waveband in North America and in parts of Latin America and Africa.

UMTS is the name for the third generation mobile telephone standard in Europe. 3G is a generic term covering a range of future wireless network technologies, including UMTS, WCDMA (Wideband Code-Division Multiple-Access), CDMA (Code-Division Multiple-Access) 2000 and EDGE (Enhanced Data rates for GSM Evolution). 3G combines high-speed mobile access with Internet Protocol (IP) based services.

1.2 Functional unit

Functional Unit Data Transfer. As a functional unit, a data set of 1 Gbit (1,000,000 kbit) is defined. For most of the network components, the normalization of manufacturing, installation, operating and disposal expenditure per transferred data set is required. In the UMTS, both data packages and calls can be conveyed. In order to be able to standardize the results, an equivalence is formed between these two kinds of transmission. This is based on the assumption of an average transmission rate of data packages and calls as well as on assumptions for the average use of the UMTS equipment by the customer. Based on an average minute of use the time share of data transfer in 2004 was determined. The total kb per year were calculated on the basis of an average data throughput (kb/s), the anticipated number of users and utilization ratio of the data throughput. Data used are based on planning network data and anticipated number of users for 2004. It can be assumed that the calculated network has some over-capacity as the licence asks from the operators to secure a certain coverage independent of the actual demand.

As a basis for the GSM (Global System for Mobile Communications) mobile network, the 'taxed minutes of calls' are taken in the year 2000. The 'taxed minutes of calls' are assessed by the operator on the basis of selling figures.

Some components in the network are used symmetrically, e.g. the mobile phone is used twice regarding a call between two mobile users. Therefore, these components were accounted for twice.

Energy use of the equipment is not proportional to the data transfer; however, the number of elements in the network is proportional to it, as the amount of the data transfer defines the capacity of the network and therefore the devices needed.

Functional Unit Total System (Network). As another functional unit, the yearly mobile communication of an average customer of the total UMTS and GSM networks is considered. Since the UMTS technology supports other services than the GSM system, the comparability is only limited. However, this functional unit allows one to evaluate how the total impacts of telecommunication are likely to develop.

1.3 System definition

Two different options are defined, which represent different ways of transferring the data:

- Mobile phone to mobile phone
- Mobile phone to fixed network

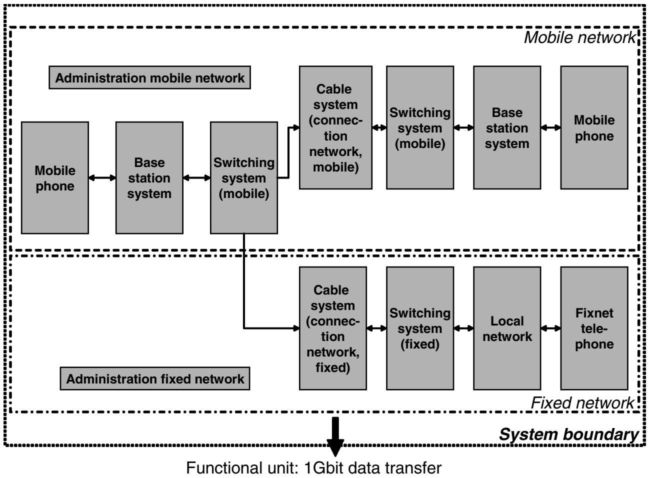

Fig. 1: Elements of the UMTS network. The study includes the mobile network and the fixed network, which are necessary for data transfer from the mobile to the fixed network

Mobile Phone. The mobile phone is used for receiving and sending calls and messages. A mobile telephone consists of a housing, printed wiring boards with integrated circuits and electronic components, an LCD display, an antenna as well as further parts.

Base Station. The message sent by the mobile telephone is first received by an antenna, which is usually followed by an amplifier. The base station converts the radio signals into digital signals. To ensure a proper function of the base station, a cooling system is needed. The antenna is connected to the base station with coaxial copper cables.

Switching System. The switching system summarizes the network elements which control the base stations and the calls on the mobile network. The first element after the base station is the radio network controller (RNC), controlling the base station. One RNC controls 100–150 base stations and controls, among other things, the change between cells and/or antennae and the strength of the radio signal emitted. The mobile switching center (MSC) is a network computer, which controls the routing of calls. Location register as well as further databases make services and data available. The relationship between the number of necessary MSC to RNC is about 1:1. Cables connect the MSC among themselves and/or the MSC with the RNC.

Cable System. The cable system can be divided into a connection network, which interconnects the switchboards, and a local network, which connects the switchboards with the fixed network users. Optical wave guides are used increasingly in the cable system, the local network, however, still consists mainly of copper cables.

Administration. The administrative burden of the mobile communication network operator and the fixed network carrier includes the energy for the operation of the buildings, paper and water use, wastes and the business travel.

2 Life cycle Inventory

2.1 Data sources

The tool used for this study was the internal LCA-software of ESU-services, eco^{mc}, which supports the user in managing large amounts of data and in modeling product life cycles. The database contains inventory data taken from projects of industry, research institutes and governmental agencies as well as literature data and model calculations. The following data sources were used:

- Motorola data for the production of the mobile phone, the base station, and the electronic components (Faist Emmenegger et al. 2003b)
- Swisscom data for the use phase of the switching systems, for the administrative burden of a network and for the data flow in the network (Faist Emmenegger et al. 2003b)
- Deutsche Telekom data for the cable system (Faist Emmenegger et al. 2003b)
- Data from various companies for production of antennae, coaxial cables, cooling systems, battery systems.
- Environmental reports, literature (electronic components (AT&S 2002), precious metals (Faist Emmenegger et al. 2004)
- Background data for energy systems (Frischknecht et al. 1996), transport (Maibach et al. 1995), waste treatment (Zimmermann et al. 1996) and building materials (Weibel & Stritz 1995)

2.2 Assumptions

As the UMTS network is still being built up, no actual operation data are available. Data from the GSM are used in the event of data gaps. For example, electricity use for switchboard and administration are assumed to be the same in the UMTS and in the GSM network. Due to the lack of data, i.e. energy and material flows of the infrastructure and operation of the network, these values are assumed to be proportional to data quantity for the operation of a UMTS network.

The service life of the network components is taken into account in the calculations. It is assumed to be one year for a mobile phone; for the rest of the infrastructure and for the fixed network telephone it is 5–15 times higher. The assumption of this very short service life for the mobile phone is justified by the rapid innovation cycles of this device and the linked offers of device, and 6-months to one-year subscriptions of the network operators in Switzerland and partly in Europe.

Electronic components like printed wiring boards (PWB) and integrated circuits (IC) were assessed using a simple model based on the size (for IC) and number of layers (for PWB), respectively. Mining and refining of precious metals (gold, silver) was included. However, due to lack of data, some metals like antimony were approximated with similar metals.

2.3 Data quality

Thanks to the industrial partners, the study relies on primary data of good quality for the production of mobile phone and base station, and for the operation of the networks. However, no operation data is available for the UMTS net-

Table 1: Data quality of the studied components. ++ very good, + good, +/– fair, – strongly based on estimations

Components	Composition of device	Production of components	Production of device	Energy use in operation	Service life	Data quantity
GSM mobile phone	++	+	+	+/–	++	+
UMTS mobile phone	+	+	+/–	–	+/–	–
GSM base station	+	+	+/–	+/–	+/–	+
UMTS base station	+/–	+/–	–	+/–	+/–	–
Antenna	+	+/–	+/–		+/–	+/–
Switching system	–	+/–	–	+	+/–	+
Cable system	+	+/–	+/–		+/–	+
Administration				++		+

work. Consequently, requirements of the network and energy use of the components had to be estimated for this study. Due to the delay in the introduction of the UMTS network, there are no data about customer behavior and therefore no data on the amount of data transfer in the network. The figures used in this study are based on the penetration rate of mobile phones and estimations of use time and data transfer rates for Switzerland in 2004. **Table 1** sums up the data quality of the components for their different life phases.

2.4 Network components

Table 2 and **Table 3** show key figures and main assumptions for the calculation of the UMTS and GSM networks in Switzerland. Due to confidentiality reasons, the figures are given as a range.

The fixed network includes cables and switching system; user terminal is a telephone. We did not assess specifically data transfer in the fixed network but chose a functional unit which makes an equivalency between voice and data. The fixed network, therefore, doesn't include computer and modem.

2.5 Electricity use in the networks

The study assesses the Swiss UMTS network. Therefore, Swiss electricity mix is assumed for the operation of the networks and mobile devices. The electricity mix of the production of the components reflects, as far as possible, the country of origin of the component (e.g. Germany for mobile phones). For unknown or various origins, European electricity mix was used (e.g. for production of electronic parts).

There are differences in the specific electricity demand of the components of the UMTS and the GSM network (**Table 4**). Table 4 shows the energy use of all devices in the network divided by the total Gbit data transfer in the network. The high data capacity in the UMTS network leads to the lower energy use per Gbit as compared to the GSM phone. On the other hand, the UMTS network requires about 50% more base stations than the GSM network, and the energy de-

Table 4: Electricity use in the operation of components of the mobile communication. Figures for switchboard and administration are assumed to be the same in the UMTS and in the GSM network, due to the lack of data for the operation of UMTS network

Element	UMTS-Network	GSM-Network
Mobile network	**kWh per Gbit**	**kWh per Gbit**
Mobile phone	2.3	13.9
Base station	16.8	7.7
Switchboard	4.1	
Administration	5.2	
Fixed network		
Fixed network telephone	2.8	
Switchboard	7.7	
Administration	1.2	

Table 2: Basic assumptions for the calculation of the UMTS network

Element	Total (in 1.000)	Life time	Remark
Mobile telephone	300–600	approx. 1 year	Service life corresponds to an average for Europe
Base station	ca. 1	approx. 10 years	
Pylon	ca. 1	10 to 15 years	2–6 antennas per pylon

Table 3: Basic assumptions for the calculation of the GSM network

Element	Total (in 1.000)	Life time	Remark
Mobile telephone	3'300	approx. 1 year	Service life corresponds to an average for Europe
Base station	3.8	approx. 10 years	
Pylon	3.8	10 to 15 years	2–6 antennas per pylon
Switching system (MSC, BSC, GSC, HLR)	0.1	10 to 15 years	The allocation of switching system infrastructure is based on the share of electricity use of the network elements (about 8% of electricity use of the switching system is used by network elements of the mobile system).

mand of UMTS base stations is about four times higher. Consequently, the energy consumption per Gbit is significantly higher for the UMTS network as compared to the GSM technology. As there are more phones than base stations, the GSM mobile phones have a higher energy use than GSM base stations. In the UMTS network, electricity of its base stations is much higher than for GSM base stations; for mobile telephones, energy requirements of UMTS devices is a little lower than for GSM devices. This results in a higher energy use per Gbit for the base stations than for the mobile phones, in opposition to the GSM devices.

2.6 Allocation

The allocation of the fixed network to the different services (fixed network, mobile communication system) is done using the accounted 'taxed minutes of calls' or data sets, respectively. The total annual data set estimated for 2004 in the UMTS network, on the basis of projections from 2001, is taken as a basis for the calculations. The total kb per year were calculated on the basis of an average data throughput (kb/s), the anticipated number of users and utilization ratio of the data throughput. Data used is planning network data and anticipated number of users for 2004. We assumed a mixed voice and data use in the UMTS, so that the data rate is not the maximum possible, but about three times the data rate in GSM. 1 Gbit corresponds to approx. 1670 'taxed minutes of calls' in the GSM system, and to approx. 500 'taxed minutes of calls' in the UMTS network. For the allocation of the impacts of the administration, the ratio of sales of the fixed network and the mobile communication business of Swisscom is used.

3 Results

3.1 UMTS network

Cumulative expenditures and emissions. Table 5 shows selected cumulative resource expenditures and emissions of data transfer in the UMTS network for the two options of mobile phone to mobile phone and mobile phone to fixed network. The cumulative resource expenditures, on the one hand, provide information on the materials used (e.g. copper, which is mainly used in cables) and, on the other hand, on the need for primary energy carriers (e.g. uranium for nuclear power plants).

The air emissions are partly due to processes and partly originate from energy generation. The CO_2 emissions are caused by the electricity demand, the use of plastics and from the fossil energy consumption. The NO_x and SO_x emissions are linked to the use of fuel oil and natural gas, the HCl emissions are linked to the use of coal in production processes, similar to the emissions of NMVOC (Non-methan Volatile Organic Compounds) to air and COD (Chemical Oxygen Demand) to water, which are linked to the use of oil. The zinc emissions are mainly caused by the use of gold, copper, and zinc as well as by the supply of electricity.

Except for the use of copper (cables), the data transfer of 1 Gbit from mobile phone to mobile phone requires more resources and causes more emissions than the option mobile phone to fixed network. This is due to the high electricity demand of the mobile network and the short service life of mobile devices.

Table 5: Selected cumulative resource expenditures and emissions of data transfer in the UMTS network

		Mobile phone to mobile phone, UMTS network	Mobile phone to fixed network, UMTS network
	Unit	Gbit	Gbit
Resources			
Copper	kg	0.07	0.12
Brown coal	kg	4.90	3.42
Hard coal	kg	4.94	3.96
Crude oil	kg	2.92	2.77
Uranium	kg	1.01E-03	7.65E-04
Natural gas	Nm^3	1.32	1.13
Water	kg	3 880	2 320
Emissions to air			
NH_3	kg	1.08E-04	8.20E-05
CH_4	kg	0.05	0.04
CO_2	kg	24.7	20.1
HCl	kg	0.003	0.002
NMVOC	kg	0.03	0.03
NO_x	kg	0.06	0.05
SO_x	kg	0.13	0.11
Emissions to water			
COD	kg	0.09	0.09
Sulfate	kg	1.37E-01	1.02E-01
Zinc	kg	0.0002	0.0001

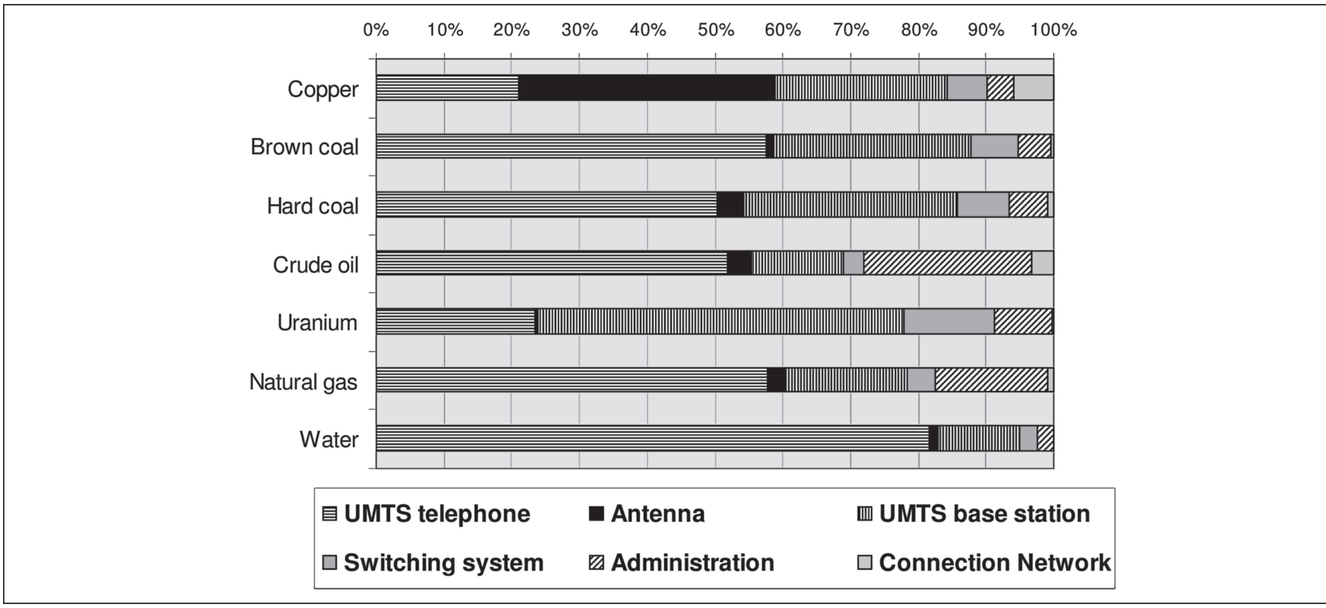

Fig. 2: Relative share of selected cumulative expenditures of the scenario 'data communication from mobile telephone to mobile telephone, UMTS network' for 1 Gbit data communication

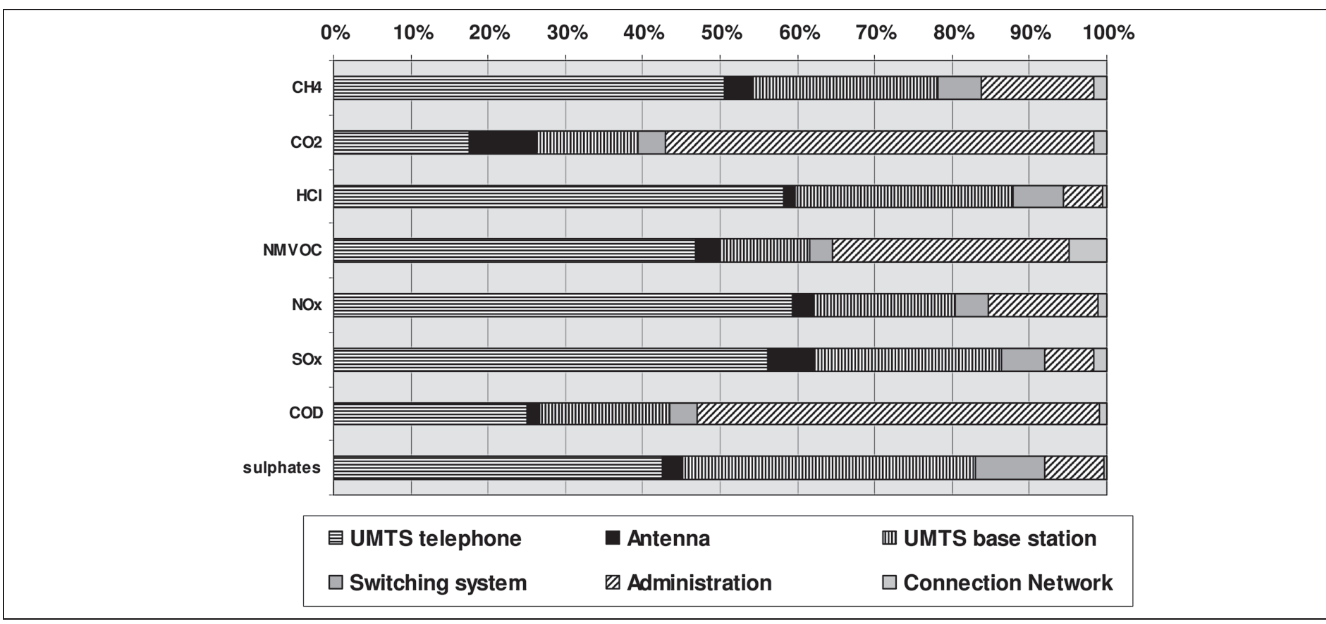

Fig. 3: Relative share of selected cumulative emissions of the scenario 'data communication from mobile telephone to mobile telephone, UMTS network' for 1 Gbit data communication COD and sulphates represent emissions to water, the rest emissions to air

In **Fig. 2** and **Fig. 3**, the cumulative expenditures and emissions of the scenario 'data communication from mobile telephone to mobile telephone, UMTS network' are shown with the system components and their relative importance.

In most categories, the mobile telephone dominates, except for the copper and the uranium. The copper can be attributed mainly to the use in cables. The category 'uranium' provides information on the portion of the nuclear power in the electricity mix, which is higher in Switzerland than in Germany. Therefore, the base stations have a relatively higher impact due to their electricity consumption, which is about 7 times larger than that of the mobile phones per Gbit. The crude oil consumption, on the one hand, results from consumption of fuel oil, diesel or gasoline and, on the other hand, from the use in plastics. The relatively high burden of the administration in these categories is due to business travels and heating. Natural gas is used mainly in the printed wiring board production of the mobile phone and the base stations. The water required is mainly attributed to the production of the mobile phone and the use of electricity from hydropower.

Fig. 4 shows the cumulative expenditures of the scenario '1 Gbit data communication, from mobile telephone to fixed line'. **Fig. 5** presents the selected cumulative expenditures of the scenario '1 Gbit data communication, from mobile telephone to fixed line'.

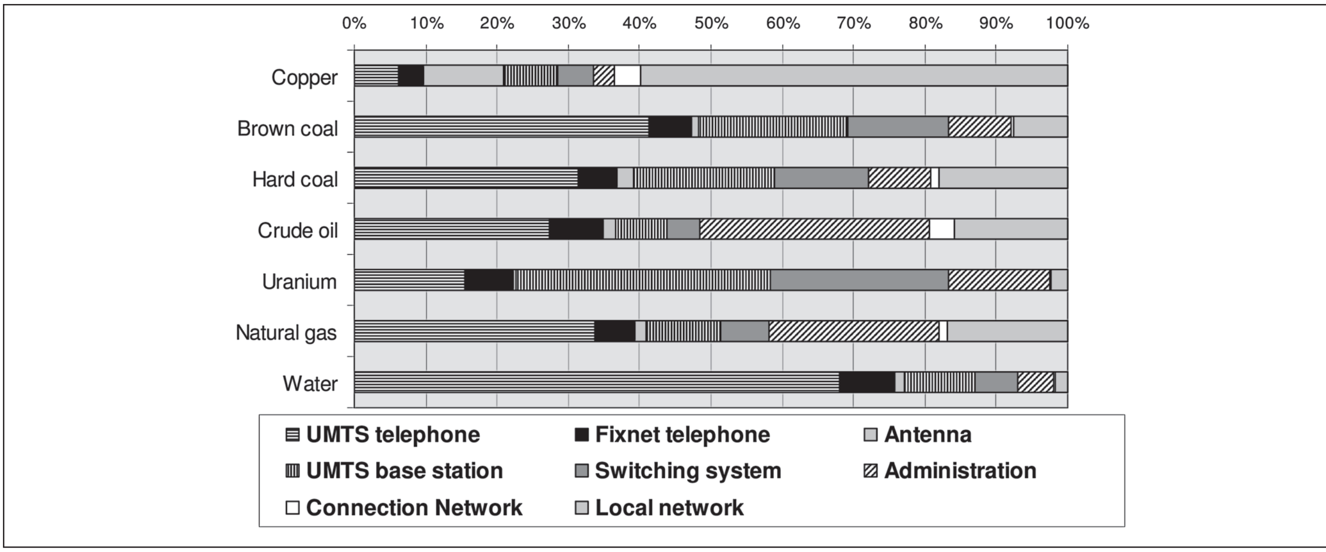

Fig. 4: Relative share of selected cumulative expenditures of the scenario '1 Gbit data communication, from mobile telephone to fixed line'

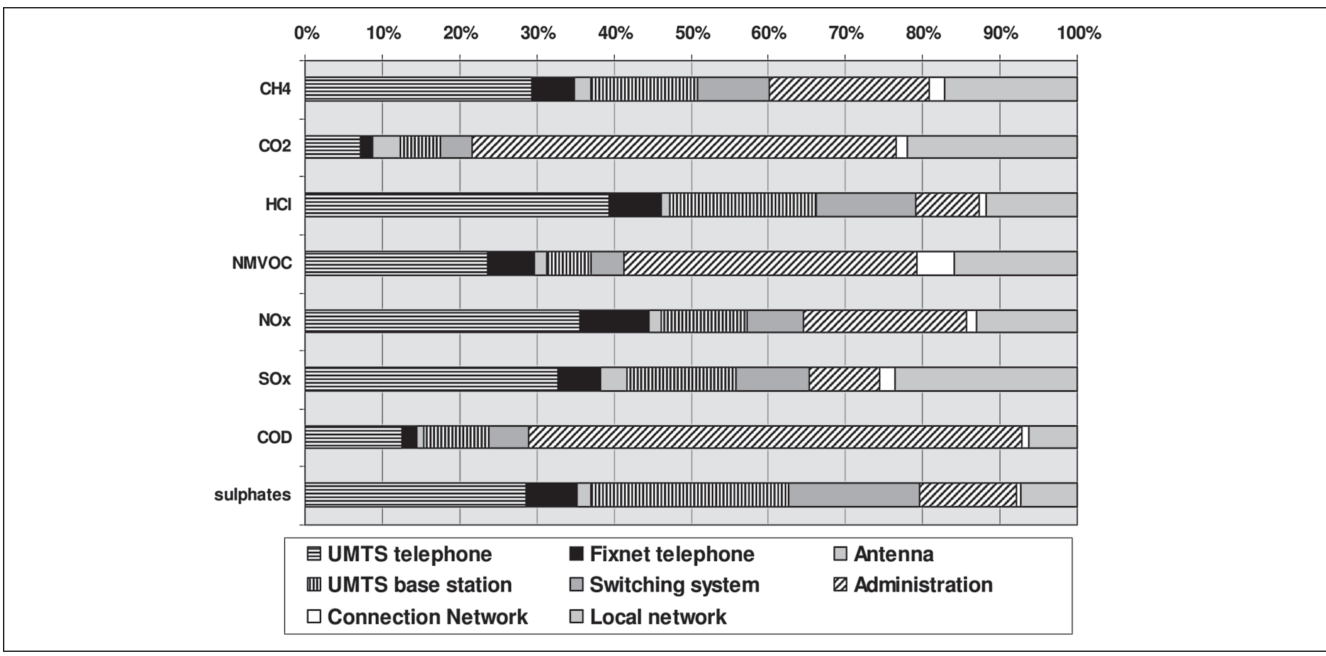

Fig. 5: Relative share of selected cumulative emissions of the scenario '1 Gbit data communication, from mobile telephone to fixed line'. COD and sulphates represent emissions to water, the rest emissions to air

The components 'UMTS mobile phone', 'antenna' and 'UMTS base station' are only needed once here, in contrast to the option mobile phone to mobile phone. They, however, keep the same contribution pattern among themselves. The components of 'switching system', 'connection network' and 'local network' contain the expenditures for the mobile and the fixed network, respectively. The copper cables of the local network are responsible for approximately 50% of the copper expenditures. The impact of the switchboards and the administration are shown in the energy consumption (see uranium in Fig. 4). The use of plastics in the connection network (tubes) is relatively high and therefore causes a high share in crude oil consumption, and/or in NMVOC and CSB emissions.

Impact Assessment Results. Table 6 shows the results evaluated with the method Eco-Indicator'99 (EI'99) Individualist, Hierarchist and Egalitarian, and the method of the ecological scarcity 1997 (ecopoints). Besides, the cumulative energy demand (renewable and non-renewable) and the greenhouse gas emissions are given.

The impacts tend to be higher for data communication between two mobile phones than between a mobile phone and a fixed connection. The EI'99 results, however, are inverse. This is due to assessment of the use of the resource copper in the fixed network (all perspectives) and for the perspectives Egalitarian and Hierarchist the impacts of the lead production (used in lead-lagged cables and lead batteries in the fixed network). In **Fig. 6**, the relative importance of the in-

Table 6: Results of the impact assessment of data transfer (1 Gbit mobile to mobile and mobile to fixed line)

		Data transfer in UMTS network, mobile phone to mobile phone	Data transfer in UMTS network, mobile phone to fixed line
Assessment methods	**Unit**	**Gbit**	**Gbit**
cumulative energy demand (non-renewable)	MJ-eq	801	640
cumulative energy demand (renewable)	MJ-eq	138	107
greenhouse gas emissions	kg CO_2-eq.	27	22
ecological scarcity 1997 (ecopoints)	UBP	39 100	35 000
EI'99-aggregated, Egalitarian	EI99-points	1.8	2.0
EI'99-aggregated, Hierarchist	EI99-points	1.8	1.9
EI'99-aggregated, Individualist	EI99-points	6.2	10.8

dividual network components for the data communication in the mobile communication network is shown, which helps to understand the difference of impacts in the two options of transferring data.

The demand for non-renewable energetic resources is caused by the need for sources of fossil energy (fuels, uranium for nuclear power, coal, etc.), the demand for renewable energetic resources is mainly caused by the need for electricity from hydropower. Since the Swiss electricity mix, which is used among others for the operation of the base stations, relies primarily on hydro and nuclear power plants, a somewhat different picture results between the energy resources used, the greenhouse effect and the ecopoints. The importance of the base stations for the greenhouse effect is smaller than for the cumulative non-renewable energy demand. This is attributed to the fact that the power requirement of the base stations is dominated mainly by the electricity consumption for the use phase, which is taking place in Switzerland. In contrast, the environmental impacts of the mobile phone originate to a large extent from the energy expenditure of the production in Germany, whose portion of thermal power stations for electricity production is responsible for its contribution to the greenhouse gas emissions. The radioactive wastes get a relatively high weighting in the ecological scarcity '97 method. Therefore, the contribution of the base stations to the total environmental impacts is higher with this impact assessment method as compared to the evaluation of the greenhouse gas emissions. With the results evaluated with EI'99 Egalitarian and Hierarchist, radioactive emissions are considered as well, although their damaging effect is smaller as compared to the pollutants from fossil power stations, so that the base stations have a lower impact again. The evaluation with EI'99 Individualist results in a high impact caused by resource use (such as copper), so that the antennae gain in relative importance due to the copper used in the cables.

Dominance analysis, mobile phone. The production phase has the greatest importance in the life cycle of a mobile phone (see Fig. 5). This is mostly due to its short service life. Despite the fact that a relatively pessimistic scenario for the disposal was selected (incineration of 20% and 80% take

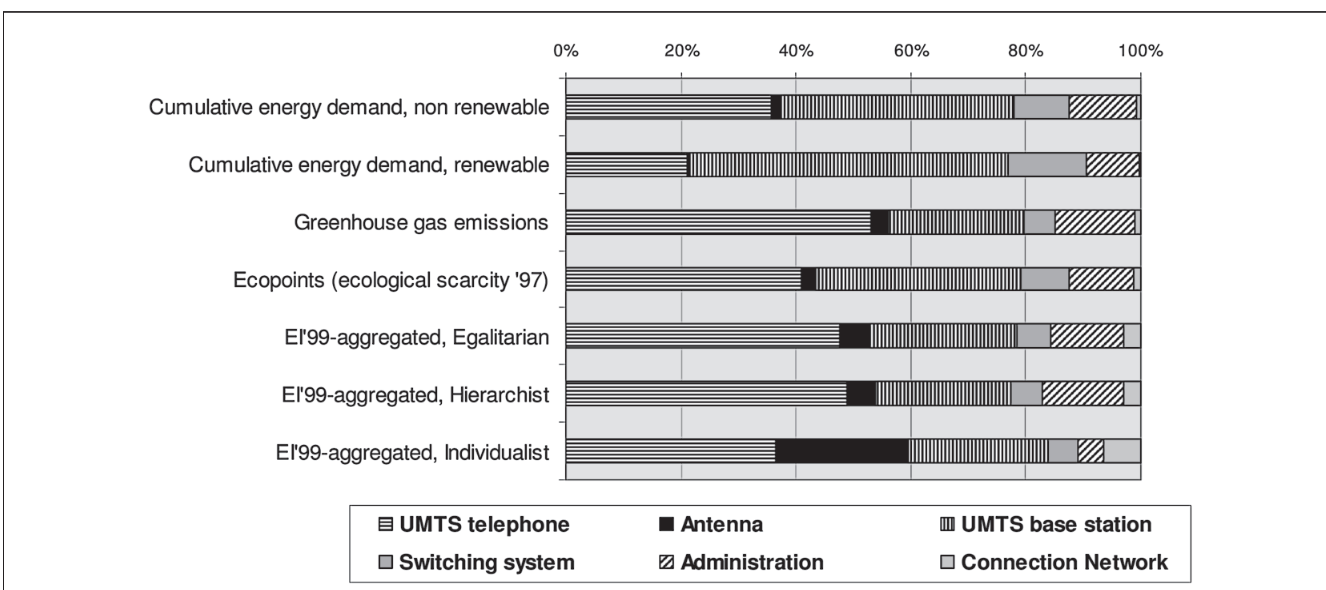

Fig. 6: Relative share of the impact assessment results of the scenario 'data communication from mobile telephone to mobile telephone, UMTS network' for 1 Gbit data communication

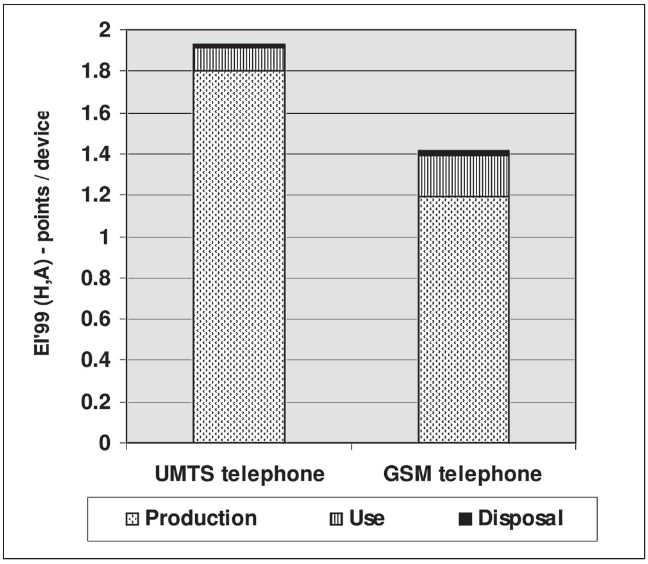

Fig. 7: Attribution of the Eco-Indicator'99 (Hierarchist, average) points for a UMTS and a GSM phone to the different life cycle phases (production, use in Switzerland, disposal). Higher energy requirements in the use phase by the GSM is due to older data and developments in the technology, so that actual UMTS devices have a better efficiency than older GSM devices

back, instead of 100% take back), the environmental impacts for this life cycle phase can be neglected. The use of the phone is responsible only for approximately 5% (UMTS phone) to 15% (GSM phone) of the impacts, respectively (**Fig. 7**). The impacts (quantified in eco-indicator 99' Hierarchist, average points) of the UMTS mobile phone is about 35% higher as compared to a GSM mobile phone.

Fig. 8 gives a more detailed picture of the production phase. The production of electronic components has the greatest importance within the assessment of the mobile telephone. This applies both to the UMTS and to the GSM phone. The production of printed wiring boards (PWB) and integrated circuits (IC) make up about 40–50% of the environmental impacts. For these components, the energy consumption, the production of semiconductor dies, and the supply of gold and partly silver is of importance for the assessment. The transport of the electronic components contributes with 18–25 % surprisingly much. This is caused by the air transport of the components.

Dominance analysis, base station. In contrast to the mobile phone, the use phase is the most important parameter of the base station, making up approximately 85% of its environmental impacts (**Fig. 9**). This difference is mainly

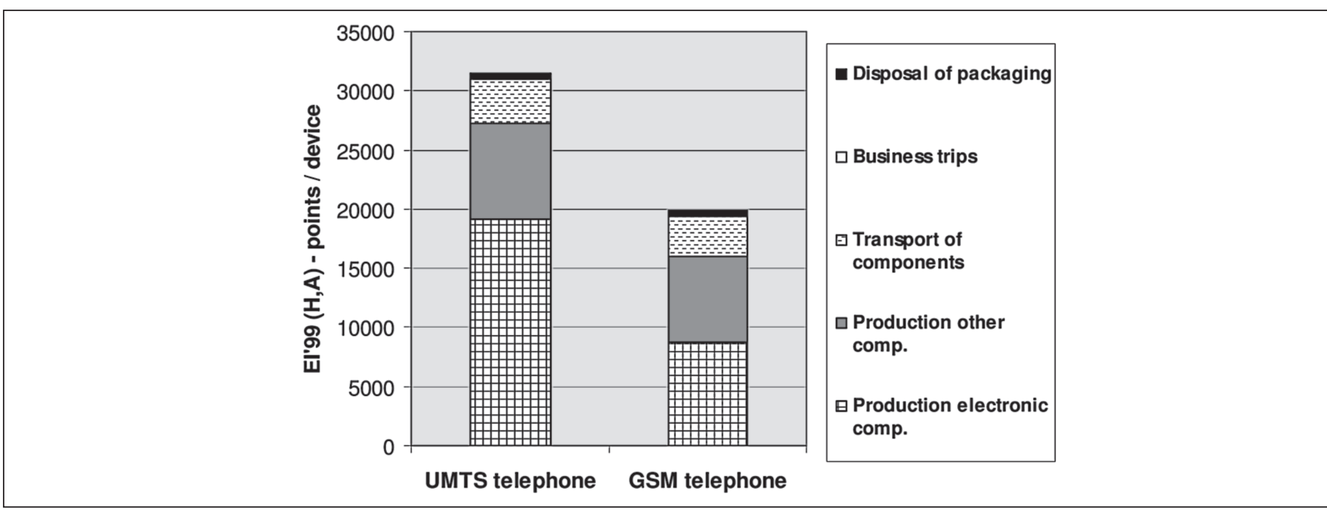

Fig. 8: Attribution to the different manufacturing stages of Eco Indicator'99 (Hierarchist, average) points for a UMTS and a GSM phone

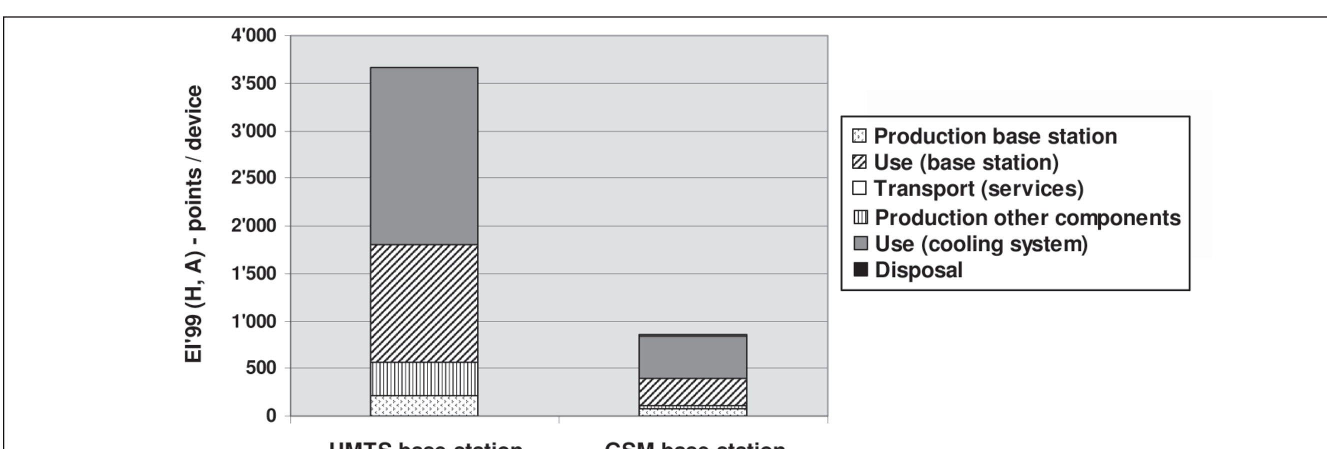

Fig. 9: Attribution of Eco-Indicator'99 (Hierarchist, average) points for a UMTS and a GSM base station to the different life cycle phases

caused by the longer service life of these devices, which is up to 8 times longer compared to the mobile phone. The calculated power consumption for the UMTS base station is not based on real operation data, but should be considered as a conservative assumption.

Important Parameters of the Local Network. Most important material is lead, followed by copper. However, copper cables encased with lead are no longer used for new local network lines. Thus, this technology is no longer relevant and therefore represents no optimization potential from an environmental point of view.

3.2 Sensitivity analysis

Service life of telephone. A sensitivity analysis shows the importance of the service life of the telephone on the results of the impact assessment (**Fig. 10**). Increasing service life from one year to four years would decrease the environmental impacts of about 40%. On the contrary, a life time of only half a year results in about 40% more impacts. The assumption on life time is also very relevant for the whole system.

Electricity mix. Fig. 11 compares the results of the assessment when operating the network in Germany (DE) with the German electricity consumption mix instead of the Swiss electricity mix. Due to the higher environmental impacts of the German electricity mix, overall results are higher for all impact categories. The importance of the energy requirements in the use phase increases also; the base station is then the most important element of the network. The operation of the network in a country with an electricity mix with higher environmental impacts as compared to the Swiss mix increases the importance of the base stations.

3.3 Comparison of the UMTS with the GSM network

Comparison per Gbit. A comparison of the data communication between the GSM and the UMTS networks shows that the transmission of 1 Gbit in all regarded categories (cumula-

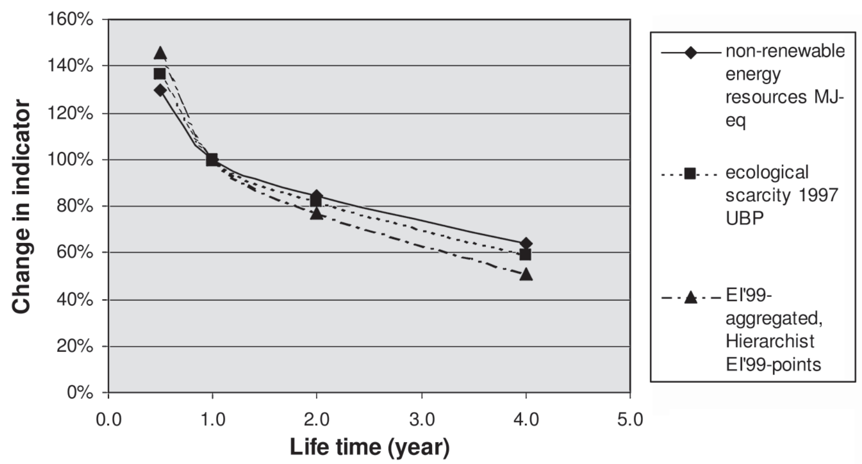

Fig. 10: Importance of the telephone's service life for the results of the assessment of one mobile phone

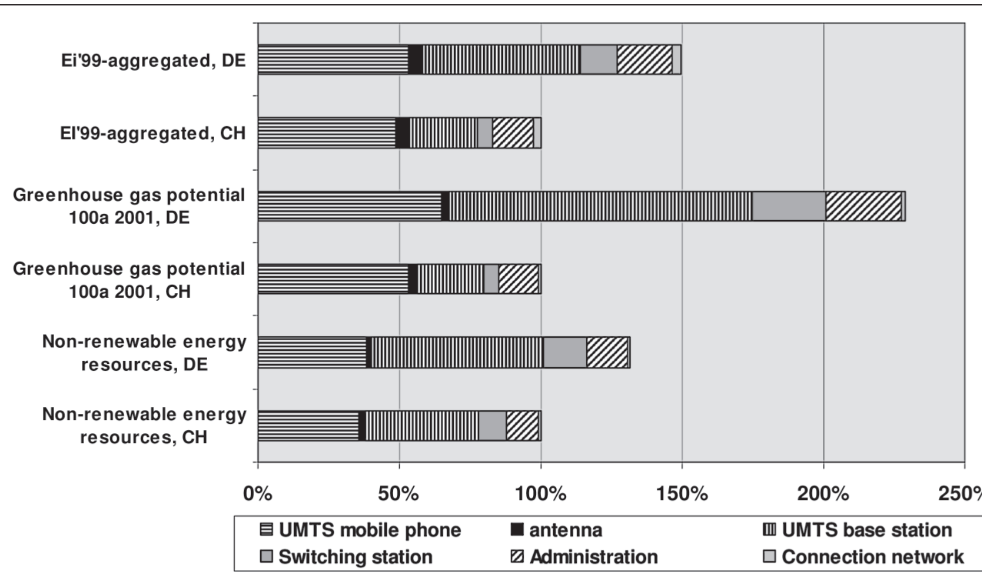

Fig. 11: Comparison of the results when operating the UMTS network in Germany (DE) instead of Switzerland (CH)

Table 7: Comparison of the cumulative energy demand, the greenhouse gas emissions and the EI'99 Hierarchist evaluation for the data communication in the GSM and the UMTS networks, option mobile phone to mobile phone

		Cumulative energy demand (non renewable)	Greenhouse gas emissions 100a 2001	EI'99-aggregated, Hierarchist
		MJ-eq	kg CO_2-eq	EI'99-points
GSM	Gbit	1140	43.9	3.04
UMTS	Gbit	800	26.6	1.77

tive energy demand, greenhouse gas emissions, Eco-Indicator'99 (Hierarchist, average)) causes less impacts for the UMTS than for the GSM (**Table 7**). This difference is mainly caused by the higher data transfer rate of the UMTS, which leads to a better environmental performance per Gbit, as a UMTS device has a higher data throughput than a GSM device.

This difference can be clarified with the comparison of the data transfer by means of mobile systems with the environmental impact of traveling with a passenger vehicle (on a life cycle basis). While the non-renewable cumulative energy demand of a data transfer of 1 Gbit in the GSM network corresponds to traveling 220 km in a passenger car, the same data transfer in the UMTS network corresponds only to approximately 150 km.

Comparison per Customer. Considering the entire data communication of the mobile communication systems in Switzerland, another picture results. The UMTS network in its state of 2004 according to the 2001 planning and with the accordingly calculated number of customers and data transfer causes 2.1 times more CO_2 emissions and 2.4 times more energy demand per customer than for the GSM system in its current state (**Fig. 12**).

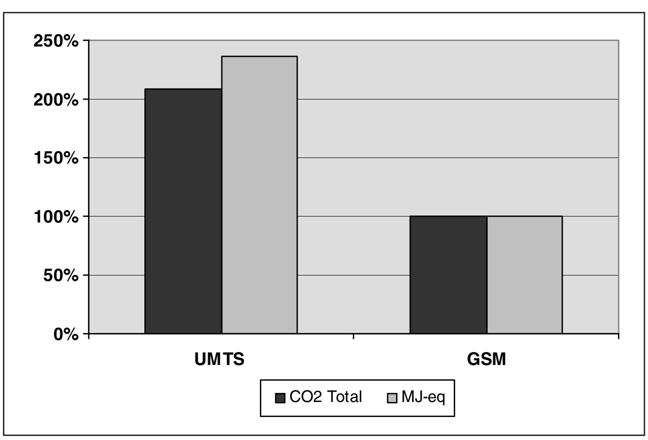

Fig. 12: Cumulative energy demand and CO_2 emissions per customer for the UMTS network in comparison to the GSM system (set to 100%)

4 Conclusions and Outlook

4.1 Network components

From an environmental point of view, the mobile telephone is the most important element of the mobile communication network. The production of the phone and its components (PWB, IC) contribute thereby the principal part (approx. 90%) of the importance of this device. The short service life of the mobile phone plays a substantial role. The service life of the mobile phone, with one year, is very short, while the infrastructure is used 4 to 10 times longer. Increasing the utilization period of the mobile phone (e.g. by leasing, reuse, extension of the innovation cycles, etc.) could thus represent a large potential for its improvement. The material consumption plays a relatively important role as well, e.g. with the use of precious metals in the mobile phone. Therefore it is very important that both manufacturers and operators undertake efforts toward the improvement of these devices. Starting point could be the production of the electronic components. The second most important components are the base stations. In the assessment, mainly the use phase proved to be important. The lower environmental impact (per Gbit data transfer) compared to the mobile phone can be explained by the longer service life (around a factor of 8). Main impacts are caused by the electricity consumption, in particular the energy needed for cooling the base stations, which presents a high potential of optimization by network operators. By choosing an environmentally benign electricity mix and/or by increasing the portion of renewable sources of energy, the network operators have a substantial potential to lower the environmental impacts (due to, e.g., greenhouse gas emissions) of mobile telecommunications. The contrary happens when choosing an electricity mix with higher impacts, as exemplified with the German electricity mix: environmental impacts increase for the whole system, especially for devices with high energy requirements like base stations.

4.2 Total network impacts per data and per customer

Given its larger data transfer rate, the UMTS is ecologically more favorable in terms of data transfer rate than its predecessor, the GSM. The higher energy consumption and the more complex production of the devices in the UMTS system are compensated by the faster data transmission rate. Per customer the result is inverse, however, since the higher data communication per user in the UMTS system compensates the higher efficiency. Per UMTS user and year a higher data transfer than in the GSM system is to be expected, due to the amount of inquired services. It must be noted, however, that the UMTS technology supports other services than the GSM system. Despite the higher efficiency in the transmission of data, an increase of the entire expenditures and emissions per customer in mobile telecommunication therefore has to be expected. The development of the UMTS is accompanied with an increased consumption of resources and emissions of pollutants and greenhouse gases regarding the entire system for mobile telephone communication.

The GSM is a mature technology, while the UMTS is still at the beginning of its learning curve. Thus, it can be safely assumed that large improvement potentials are still present for the UMTS network components concerning expenditures and emissions both at production and through the use of the devices. This study provides the necessary information where such improvements are most effective in environmental terms.

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Environmental Effects of Wired Telecommunication Networks for Local Calls in Japan

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Abstract

Goals. The goals of this study are (1) to develop a flexible LCA model and build a database of the environmental burdens imposed by representative examples of telecommunication equipment and facilities, (2) to evaluate the environmental impact of the wired telecommunication networks in use, and (3) to develop possible strategies for reducing the environmental effects of telecommunication networks.

Methods. Model-analysis LCA is considered as an effective approach, because telecommunication networks change quickly and there are many variations. We investigated the wired network model including the main equipment and facilities needed for telecommunication. Then we collected inventory data on the equipment and facilities and carried out an LCA. The environmental burden was shown as CO_2 emissions.

Results and Discussion. The heaviest environmental burden is imposed by end-user terminals. The burdens imposed by the access facility production stage are heavier than those of the use stage, but the use stage burdens are heavier than those of the production stage for other categories.

Conclusion. We constructed a model of a real Japanese telecommunication network and evaluated it with the LCA method. The environmental burden of local phone networks was shown as CO_2 emissions. Heavy burdens were generated by end-user terminals in the use stage. We obtained important information with regard to designing eco-conscious network systems including end-user terminals.

Recommendation and Perspective. For an effective reduction in the environmental burdens imposed by telecommunication networks, we strongly recommend the use of low energy consumption end-user terminals. An improvement in the energy consumption of local switches and air-conditioners should also be considered. We are now evaluating other networks, such as IP services and wireless networks, and ICT services that employ telecommunication networks.

Keywords: CO_2 emissions; access facilities; end-ffice facilities; end-user terminal; energy consumption; telecommunication wired networks