

13th Discussion Forum on Life Cycle Assessment

Environmental Impact of Telecommunication System and Services

(Short presentations and further contributions)

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Short presentations

Ing. Antonio Federico, Dr. Fabio Musmeci, Dr. Daniela Proietti Mancini, ENEA

“Material Input per Unit Service (MIPS) of the Italian Mobile Telephone Network”

Gabor Doka, Zürich

“Yield losses in electronics production are significant to LCA”

Dipl.-Ing. Martin Schäfer, Siemens AG, Dr. Robert Arenz, T-Systems, debis Systemhaus, Competence Center EDM

“Life Cycle Inventory Results for the Cordless Phone Gigaset 2010”

Mireille Faist, Prof. Susanne Kytzia Regionalen Stoffhaushalt, ETH Zürich

“Importance of system borders and scenario assumptions in the evaluation of new media technologies”

Gerald Rebitzer, Prof. David Hunkeler, EPFL-LPBM

“E-commerce – an opportunity or a threat for LCA and sustainable development?”

Dipl.Ing. M. Spielmann ETH- UNS, Fraunhofer IZM, Berlin

“Potentials of LCA for Environmental Management Systems in the Semiconductor industry”

Dr. Lorenz M. Hilty , EMPA SG

“Sustainability in the information society”

Dr. Pierre Rossel, EPFL, Projet ESST

“LCA of complex systems: examples from the domain of telematics and transport”

Prof. O.Jolliet, EPFL- GECOS

“Environmental impacts of the EPFL internet network”

Further contributions

Prof. Dr.Niklaus Kohler, Institut für Industrielle Bauproduktion, Universität Karlsruhe
“Sustainability of new work practises and building concepts”

Rydberg, T., Östermark U. and Eriksson E., Chalmers Industriteknik, Göteborg, Sweden.

“Life Cycle Assessment of a Videoconference -a comparative study of different ways of communication”

“Material Input per Unit Service (MIPS) of the Italian Mobile Telephone Network”

Ing. Antonio Federico, Dr. Fabio Musmeci, Dr. Daniela Proietti Mancini, ENEA

Abstract

The material flow in our economy is a measure of the human pressure on the environment. The Material Input per Unit Service (MIPS) is an index of such pressure that can be computed for different products or services.

Products, services and infrastructures must be compared and designed from the beginning under the aspect of ecological criteria of resource efficiency.

A survey has been carried out on the material requirement for offering the mobile telephone service in Italy. The T28 Ericsson mobile telephone has been analyzed as typical device. A 75 kg ecological rucksack has been found for the telephone. This takes into account the production, transportation and use for one year. Transport has shown not very important in this computation. Taking into account the network structure, especially considering the Radio Base Station building phase and its energy consumption and maintenance during operation, an hidden flow of 2.416 Millions tons a year is required by the network to operate. Considering the 41.4 millions Italian subscribers, this gives 183.85 Kg/user. The rucksacks of the mobile telephone of the network are of the same order of magnitude. As service as units we consider both the minute of telephone call and the SMS message. This gives estimated Material Input per Unit of Service (MIPS) of 0.207_ Kg/(minute of telephone call) and 0.632 Kg/SMS. If we assume one SMS is the substitute of 10 sec of telephone call then a final MIPS of 0.196 Kg/minute can be obtained.

Figure description

Fig. 2

The massive use of material and energy extracted from the environment is estimated, in EU, to be about 45 Tons/year per capita. This flow comes from a variety of different activities offering a growing set of products and services. A deeper insight is gained when the flow is analyzed for each product or service.

In order to reliably achieve the necessary dematerialization, decision-makers in politics and economics, but especially the individual consumers, need valid, understandable, and internationally compatible information about the ecological qualities of goods and services on the market.

This kind of effort brought to the development of several useful concepts like the Material Input and the Material Input per Unit of Service.

Fig. 3

A GSM network is composed of several functional entities:

- The Mobile Station (MS), it is the familiar mobile telephone device;

- The Base Station Subsystem (BSS) which control the radio connections with MS and covers the area of one or more cells. It is made of two sub units: the Base Transceiver Station (BTS), also known as the Radio Base Station, and the Base Station Controller (BSC) which control one or more BTS and manages the radio channel settings.
- The Network subsystem, where the main part is the Mobile service Switching Center (MSC) engaged with the connections between the MS users and the other networks (fixed or mobile).
- The Home Location Register (HLR). In this data base static and dynamic information on users is stored.
- The Operation and Support Subsystem supervises and manages the whole network.

Fig. 4

Since 1987 the dimension and the weight of mobile telephones have been strongly reduced. The picture shows the trends in both weights and stand by times during the last years.

The subscribers in Italy increased from 6.4 millions (1996) to 39 millions at the end of the year 2000 (TIM, OMNITEL, WIND press releases). This number is expected to exceed 48 millions for the year 2004. The picture shows the OMNITEL subscriber growth.

Fig. 5

The material input (MI) for the mobile service in Italy can be estimated as the sum of the different components in the network architecture. For each component we estimate the MI for the production and the MI of use of the product itself. For the production we consider raw materials plus transportation.

To quantify the material input required by a MS we consider the T28 from Ericsson. Data for the BSS is been gained from Di Virgilio Virgilio & C. S.n.c, an industrial construction company based in Rome, specialized in Radio Base building. A typical radio base station project and an environmental impact assessment report have been. r the other component estimates are made based on the BSS structure.

Fig. 6

Raw materials: data of materials from the Wuppertal Institute and from Data Bases has been used for the basic material (silver, copper etc.) of parts composing a MS or a BSS. These data account for the ecological rucksack of each material up to the production plant. What they give is the Material Input Factor (MIF) that is used as a multiplier for the physical weight of material used in a product

Fig. 7

The sum on all the material inputs, multiplied by the MIF, gives 30.4 Kg. Assembling requires 3.3 KWh/Telephone. Taking a MIF for electric power of 4.7 Kg/KWh (referred to the public network in Germany) this gives an extra 15.5 Kg/Telephone

Fig. 8

Integrated and printed circuits are manufactured in South East Asia and sent by air covering a distance of about 10000 km. We assume 20 grams for each telephone are shipped using a Boeing 747-400 with a 75% of its cargo capacity. We consider the airplane cargo capacity of 17.1 tons, the fuel consumption of 10230 Kg/hour, the cruising

speed of 927 Km/h and the MIF for petrol of 2.9 kg/kg we can estimate the MI for air transportation to be 0.3 Kg/Telephone.

Battery charger also are produced elsewhere but the estimated trip is taken by boat. The input factor for Ocean shipping is 0.006 kg/kg. If we consider 230 grams of battery chargers for 10000 km we get an extra of 0.0138 Kg/Telephone.

Printed material, packaging and the plastic body, for about 270 grams, came from North Europe by trucks with an estimated distance of 1000 km. Taking a MIF 1 kg/kg for road transportation this adds other 0.27 kg to MI.

Finally an other transport is needed to get the MS in the Italian network. The product shipped is the telephone, the battery charger and the user manual.

Fig. 9

For evaluating the MI from the MS usage let us consider a battery charger as a 220 Volts, 25 mA device (5.5 W). If we suppose each subscriber recharges his battery every day for 3 hours this means a consumption of $5.5 \times 3 = 16.5$ Wh per day. During one year we have about 6 kWh. If we assume a MIF of 4.7 Kg/kWh we obtain 28.2 Kg/Year.

Fig. 10

The Material Input for the mobile telephone is comparable with the weight of a man.

Fig. 11

We suppose the radio station commercial life is 10 years. This means $2294/10 = 229$ Tons/Year. During operation the main energy consumption is due the air conditioning. The consumption is 6-8Kwh a day during winter and rise to 12Kwh during the hottest days in summer. If we take an average of 9Kwh and assuming a MIF of 4.7 Kg/kWh we get $9 \times 4.7 = 42.3$ Kg/day. Every day maintenance teams check the BTS working conditions. A team check 3 station/day covering 100 Km by car. Assuming a consumption of 6 liters for one hundred kilometers and taking a MIF of 2.9 kg/l we get 5.8 Kg/day. This gives $42.3 + 5.8 = 48.1$ Kg/day or a or about 17 Tons/year for keeping the radio base station in working conditions. This give a total MI each year of $229 + 17 = 246$ Tons/Year for the service offered by one BTS.

Fig.12

From a recent survey there are 7675 BTS in Italy. A BSC controls from 4 to 5 BTS but can arrive to 50. If we take 4 as an average we have $7675/4 = 1919$ BSC in Italy. Any MSC controls around 10 BSC. So we can estimate the number of MSC as 192. Today, in a modern network, to each HLR are associated 5 or 6 MSC. This bring to an estimated 35 HLR. If we assume the “weight” of each components similar to a BTS we have an equivalent BTS number of $7675 + 1919 + 192 + 35 = 9821$ nodes.

If we multiply this number for the MI we have a total of $9821 \times 246 = 2415966$ Tons/Year or, for short 2.416 Millions tons a year required by the network.

Fig. 13

There are 41.4 subscribers of the 3 main italian mobile telephone companies at the end of the year 2000. If we take the MI for one MS and multiply this number for the subscribers we get:

75.5×41.4 Millions = 3.126 Millions Tons/Year.

The MI of the entire system is:

$3.126+2.416=5.542$ Millions Tons/Year.

The service offered is related to telephone calls and to SMS (Short Message Service).

Fig. 14

The 2.416 Millions ton of MI of the network can be divided by the number of subscriber. This give a 58.35 Kg to add to the MI for the MS.

$58.35+75.5=133.85$ kg/telephone

This is already the MIPS for being “connected” and for enjoying the average usage of the telephone.

Finally we could assume a SMS saves about 10 sec of telephone call. With this assumption 8774 millions SMS are then the equivalent of 1462 millions minutes. We could add this amount to the estimate service offered by the network.

$5.542/(26815+1462)= 5.542/28277=0.196$ Kg/minute

Fig.2)

Material Input Facts

- The current unsustainable production and consumption pattern in our society is characterized by a massive use of material and energy extracted from the environment.
- Material flow be used as a proxy for estimating the human pressure on the environment.
- Material Input (MI): the sum of all material requested for giving a service (Kg)
- Material Input Factor (MIF): account for the ecological rucksack of each material. It is a multiplier for the physical weight of material used
- Material Input per Unit Service (MIPS): the material input of a system or product can be compared with the service it offers




Fig. 3)

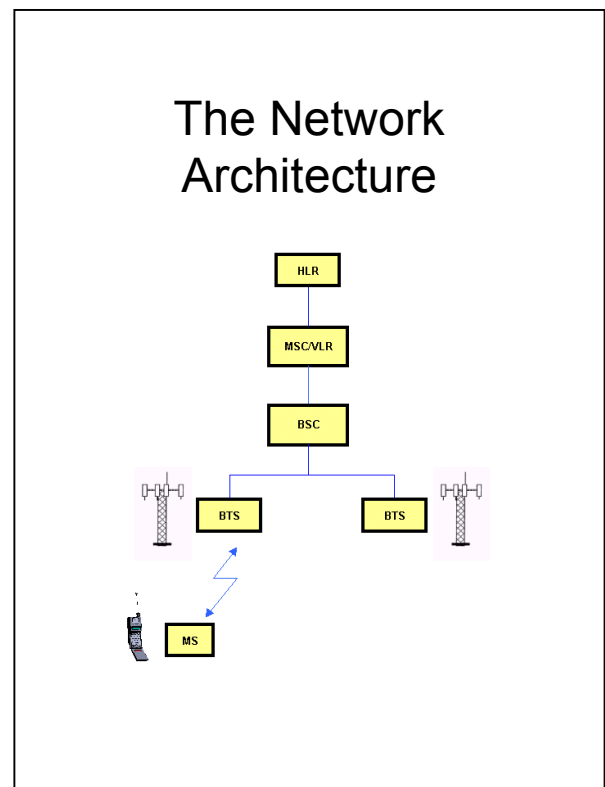


Fig.4)

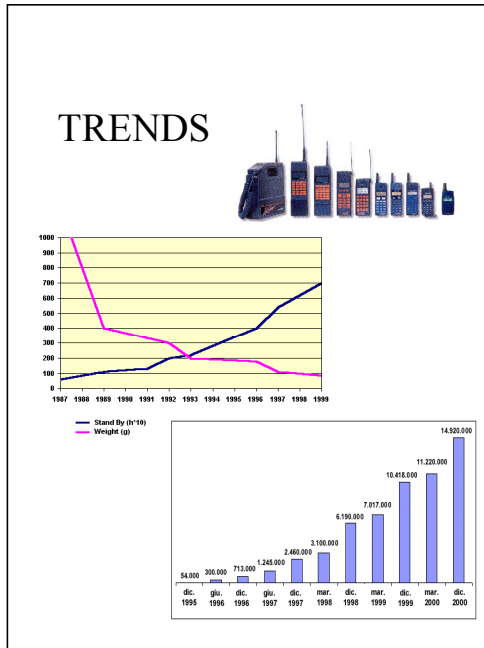


Fig. 6)

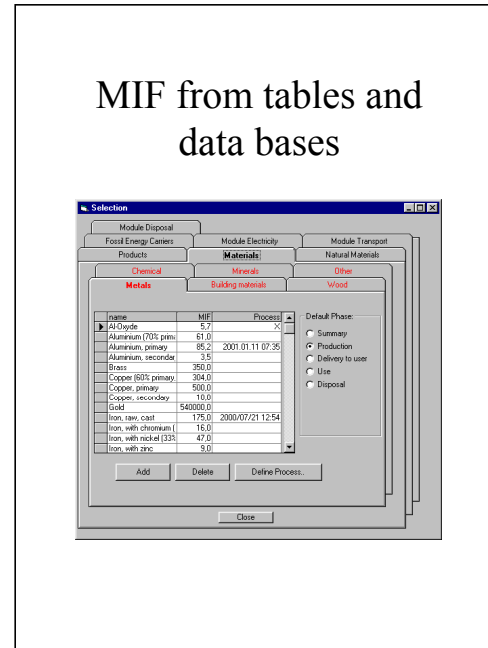


Fig.8)

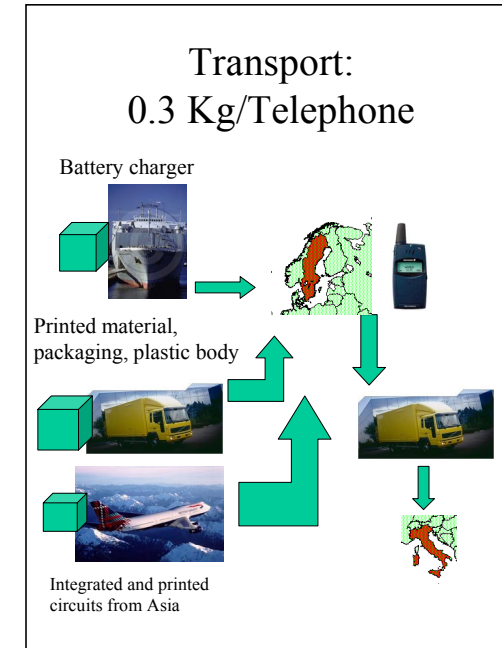


Fig. 5)

Methodology overview

- Sum of Material Requirements for each components of the network
- MI for the production, delivery and use for each component
- For the production raw materials plus transportation considered
- For the MS the example of the Ericsson T28
- For the BTS a typical radio base station project and an environmental impact assessment report have been analyzed.

Fig. 7)

Material input for the MS: sum=30.4 Kg

Components	Silver	Aluminium	Copper	Nickel	Iron	Magnesium
Integrated Circuits	0.0860	0.0020	0.5800	0.1300	0.0400	0.0000
Front and Frame	0.0000	0.1000	0.1300	0.0200	1.8000	0.0000
Printed Wiring Board	0.0000	0.0750	4.0800	0.2500	0.0000	0.0000
Antenna	0.0000	0.0000	0.3900	0.0000	0.0000	0.0000
Other Mechanic Parts	0.0450	0.0020	4.8500	0.0930	3.1000	13.8000
Lcd	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000
Total	0.1310	0.1810	10.0300	0.4930	4.9400	13.8000

Components	Silicon	Zinc	Epoxy	Polyamide	Polyethylene	Acrylate Resin
Integrated Circuits	0.2900	0.0080	0.0900	0.0000	0.0000	0.0000
Front and Frame	0.0004	0.0200	0.0000	0.2000	0.9500	0.6300
Printed Wiring Board	2.1000	0.0000	2.2500	0.0000	0.0000	0.0000
Antenna	0.0000	0.2500	0.0000	0.0000	0.1000	0.0000
Other Mechanic Parts	2.9500	0.4000	0.0090	0.0900	0.2000	0.6570
Lcd	2.6000	0.0000	0.0010	0.0000	0.0700	0.0000
Total	7.9404	0.6780	2.3500	0.2900	1.3240	0.6870

Components	Polyphenyl	Polycarbonate	Thermoplastic Elastomers	Acrylonitrile	Tungsten	Silicone Rubber
Integrated Circuits	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000
Front and Frame	0.0230	5.9045	0.0000	4.4500	0.0000	0.0000
Printed Wiring Board	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Antenna	0.0000	0.0000	1.0700	0.0000	0.0000	0.0000
Other Mechanic Parts	2.4000	0.0600	0.0000	0.0600	0.5800	2.0000
Lcd	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	2.4266	5.9645	1.0700	4.5100	0.5830	2.0000

Components	Lead	Phosphorus	Gold	Glass-Fibre and Lcd	Total
Integrated Circuits	0.0120	0.0004	0.0121	0.0000	1.2450
Front and Frame	0.0000	0.0001	0.0000	0.0000	14.2192
Printed Wiring Board	0.0000	0.0000	0.0075	0.2500	9.0050
Antenna	0.0000	0.0000	0.0000	0.0000	1.8250
Other Mechanic Parts	0.0060	0.0800	0.0050	0.0000	39.8606
Lcd	0.0000	0.0750	0.0007	7.3100	10.0570
Total	0.1270	0.1555	0.0262	7.5600	67.2118

Fig.9)

MS Operation

- Battery Charger: 220V, 25 mA= 5.5 W
- Recharge: 3 hours/day=16.5 Wh/day
- MIF 4.7 Kg/Kwh

28.2 Kg/Year

Fig.10)

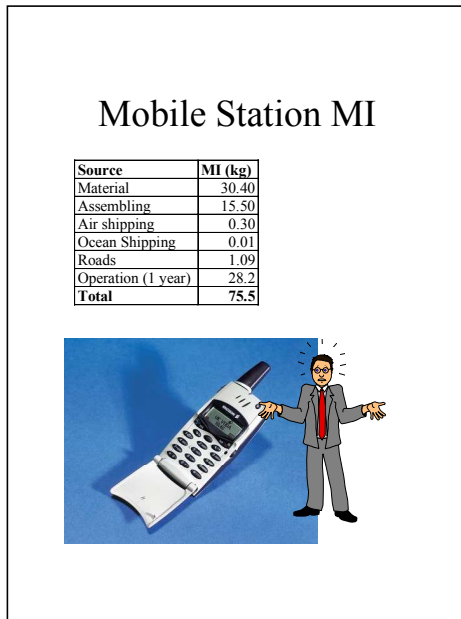


Fig. 11)

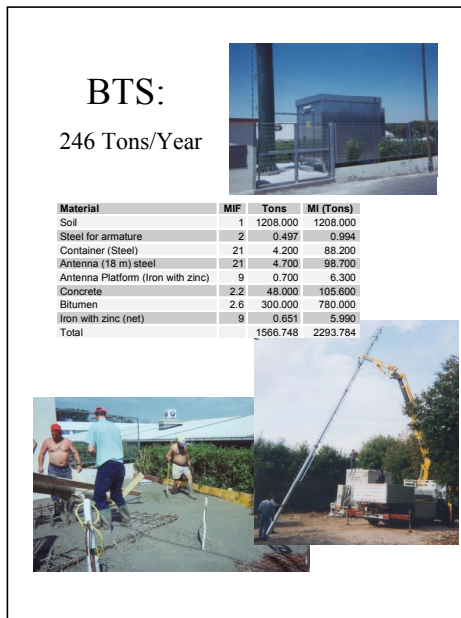


Fig.12)

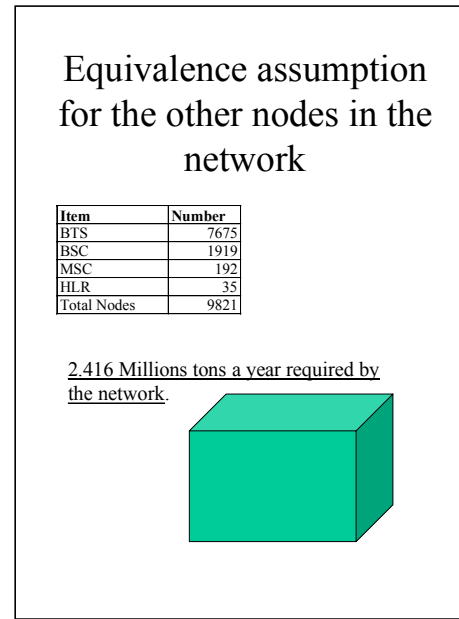


Fig.13)

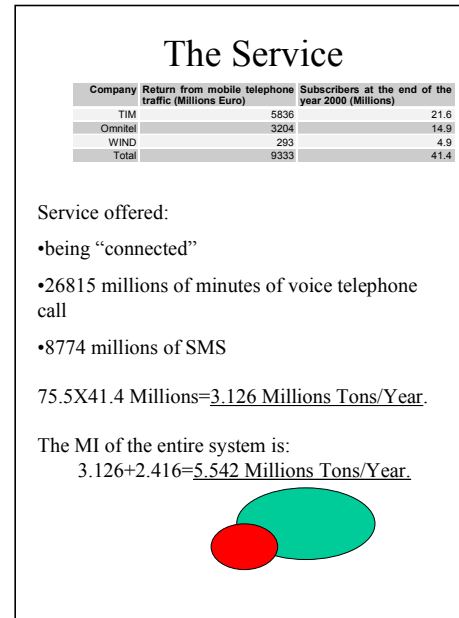
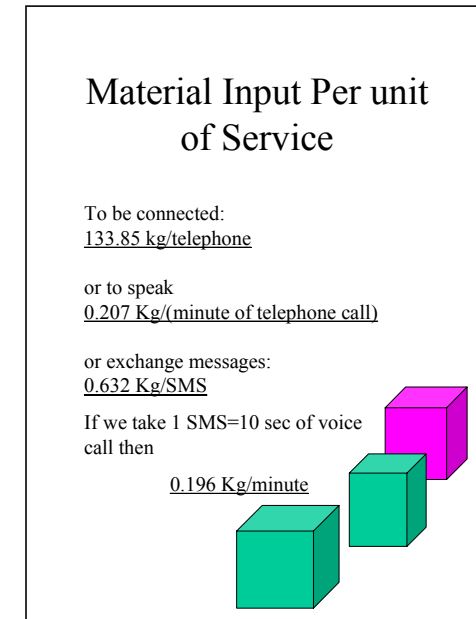


Fig.14)



“Yield losses in electronics production are significant to LCA”

by Gabor Doka; Doka Ökobilanzen, Zürich; e-mail: doka@unite.ch

Problem Description

In LCAs of electronic products and components the direct material demand of the product is often assessed by looking at the materials remaining in the final product (eg. Reichart and Hirschler 2001, IZT 1998, Hofstetter 1989). This shortcut inventory procedure gives a fairly good assessment if waste rates in production are low, i.e. most of a material input into production will end up in the product. However, in electronics production this assumption does often not hold true.

The reject or fail rate in the quality control step of electronic component production can be rather high. Cumulative losses can amount to significant changes in material and energy demand of production.

Examples

For modern silicon microchips the typical overall fail rate of production from silicon disks (wafers) is between 84% at technology introduction and 22% for mature production (data for Ultra-Large Systems Integration ULSI chips like eg. the 486 or Pentium processor given by Van Zandt 1997). Usually the flawed products cannot be directly fed back into production and need to be disposed of as waste (where some recycling may or may not occur).

Figure 1 The total losses of highly purified silicon during wafer and microchip production are not negligible.

Additionally, producing rectangular microchip dies from circular silicon wafers will have a waste rate (waste material per input) of at least around 15% for geometric reasons alone.

Figure 2 Cutting rectangular microchip dies from circular silicon wafers leads to geometric losses (in red).

Further upstream in the process chain, wafers are produced sawn from crystalline silicon columns (Czochralski column). With current wafer thicknesses of approx. 250nm and sawing gaps of approx. 150nm the sawing losses of silicon are at least 37.5% (typical figures). These and similar material losses and associated waste streams and energy demands are often not heeded in the LCA of electronic products and components, but they are probably a not negligible part of the burden from production. In the example of microchip production the overall loss of silicon from Czochralski column to shipping of functional ICs is between 92% and 58% (or yields are 8.5% to 42%). These losses increase the high-purity silicon material demand by a factor of 12 to 2.4.

Due to the highly progressive electronics market situation with ever shorter production cycles there is often an increasing lack of time to optimize component production and minimize fail rates. Higher mature yield demands exponentially higher fabrication costs as shown in figure 3 (Jensen et al. 1998).

Figure 3 Fabrication cost vs. mature fabrication yield of Very Large Systems Integration VLSI microchip production (Jansen et al. 1998). Note that these are mature fabrication yields that go as low as 12%.

Quality fail rate and its counterpart - the yield - are highly sensitive and confidential information in electronics production and data is hard to obtain.

For simpler electronic components losses are probably lower than for complex microchips, but might still be relevant to include in the assessment.

Example 2: Production of thin-film-transistor liquid-crystal displays (TFT-LCDs) has high defect rates. Current production has typical defect rates (quality control reject) of 50% to 70%. The input to TFT-LCD production are large format glass substrates of various sizes of approximately 60 cm by 72 cm. From one glass substrate six LCD displays with 13.3- or 14.1-inch diagonals are produced. Hence there is a purely geometric loss of 15% to 23%. The material loss from glass substrate to shipping of functional displays is hence between 40% and 62% (or yields are 60% to 38%). These losses increase the material demand by a factor of 1.7 to 2.6.

Apart from these material losses the use of auxiliary materials in production, which do not remain in the product (eg. solvents; masking, etching and cleaning agents etc.) or direct emissions from production are completely neglected by only assessing the materials in the final product. However, direct energy input to electronics production is usually heeded.

Conclusions

With respect to these special circumstances the often encountered inventory procedure of assessing what materials remain in the product needs to be reconsidered for LCAs of electronic products and components. Ignoring production yield needs to be verified since it can significantly underestimate the environmental burden from the infrastructure of electronic products, i.e. overemphasize the relative importance of burdens from the use phase. Electronics infrastructure might be environmentally more important than current studies suggest.

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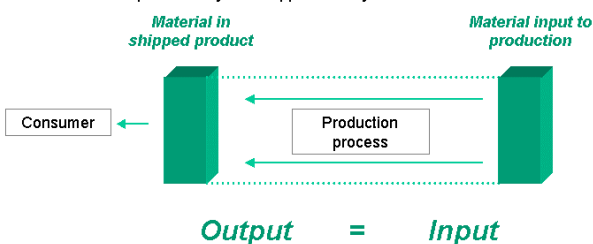
Van Zant 1997 P. van Zant, 'Microchip Fabrication', McGraw-Hill Companies, 1997

Fig.2)

Fig.3)

Simplified Inventory procedure

- ◆ Material inventory determined by **disassembly of shipped product**
- ◆ **This approach is often used in LCA studies of electronic products**
- ◆ Assumes a production yield of approximately 100%...



Inventory heeding yield losses ...

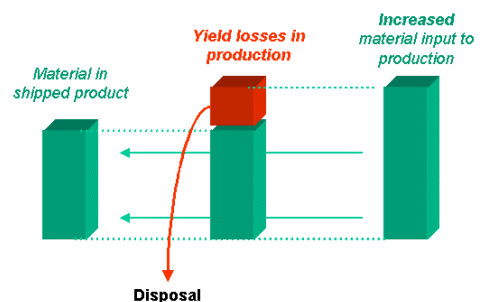


Fig.4)

..and auxiliary materials

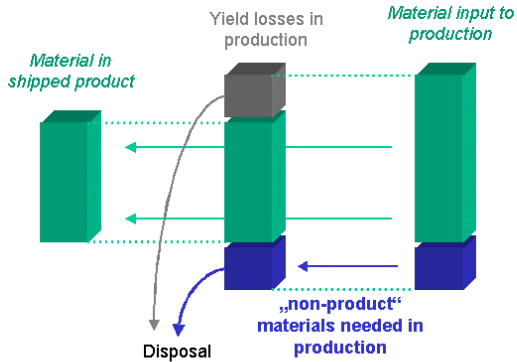


Fig.7)

Wafer Sawing Losses

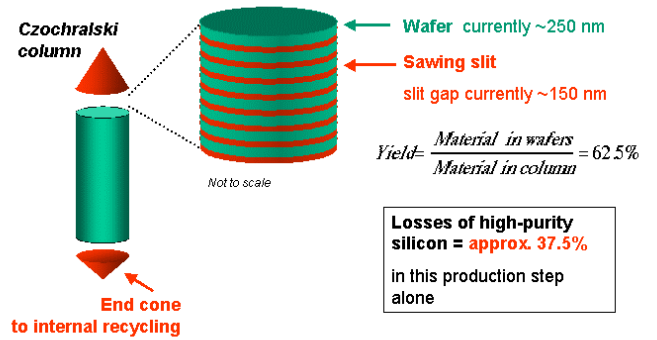


Fig.5)

The problem

Yield losses in production of electronic components are **not generally negligible** as sometimes assumed, i.e. can be much higher than a few percent.

Production yield losses can have a considerable effect on life-cycle inventories of electronic products:

- Increased material and energy demand
- Increased waste volumes to disposal

Fig.8)

Geometric Losses Wafer/Die

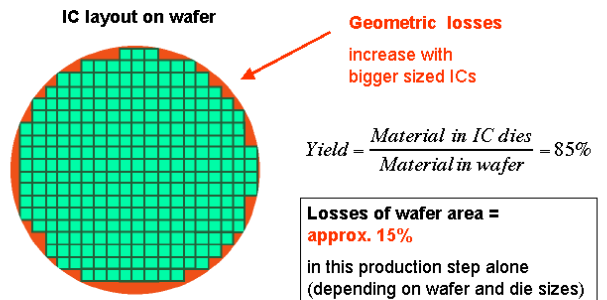


Fig.6)

Example 1: Integrated Circuit (IC) production

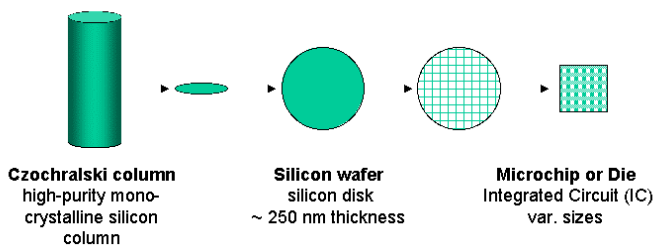


Fig.9)

Yield losses in quality control

Not all produced ICs are functional due to defects. **Yield losses** increase with IC area. **Yield losses** decrease with development time and money.

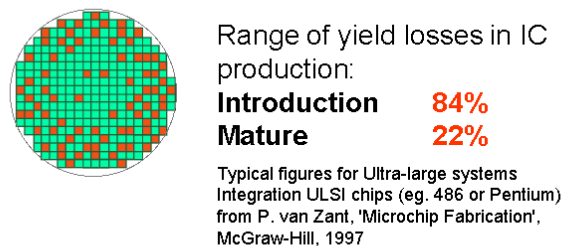
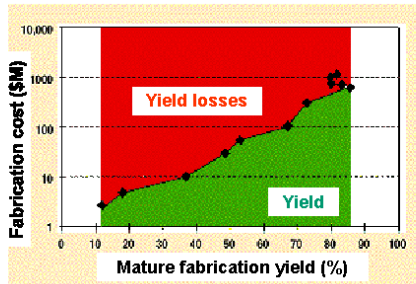


Fig.10)

Yield and fabrication cost



Fabrication cost vs. mature fabrication yield of Very Large Systems Integration VLSI microchip production. Yield losses decrease with development time and money. (D. Jensen, C. Gross, D. Mehta, 'New industry document explores defect reduction technology challenges', MICRO Magazine, January 1998).

Fig.13)

Example 2: LCD displays

Chunghwa Picture Tubes Ltd., Taiwan, reports a current (1999) production yield of 50%, i.e. **50% of the produced displays are not functional**

Chunghwa Picture Tubes Ltd., Taiwan, hopes to achieve a yield of **70% in the future**. Still 30% of all displays would be not functional.

Other manufacturers like Acer Display Technologies (ADT) report similar future goals.

Source: China Economic News Service, Sep 29 1999

Fig.11)

Overall losses

Best case, i.e. 22% chip defect loss
Excluding other up- or downstream losses

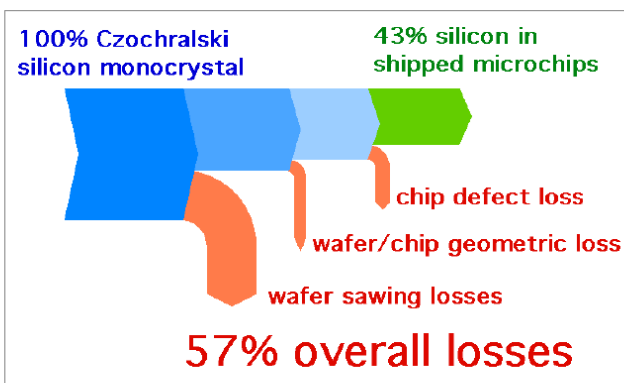
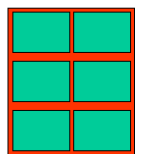


Fig. 14)

Example 2: LCD displays (cont.)

- TFT-LCD displays are produced from **glass panel substrates** of approx. 60 by 72 cm size
- Six 13.3' or 14.1' displays** can be produced from one glass panel substrate.
- A **geometric loss of 15% to 23%** of the glass substrate results.



- Overall loss** from substrate to shipped LCD display is **40% to 62%**, resulting in an **increased material and energy demand by a factor 2.6 to 1.7** (as compared to an ideal 100%-yield production).

Fig. 12)

Overall losses IC production

In the **best case** (with 22% chip defect loss) the overall loss is 57%.

This increases material and energy demand by a factor of 2.4

In the **worst case** (with 84% chip defect loss) the overall loss is 92%.

This increases material and energy demand by a factor of 12.

Fig. 15)

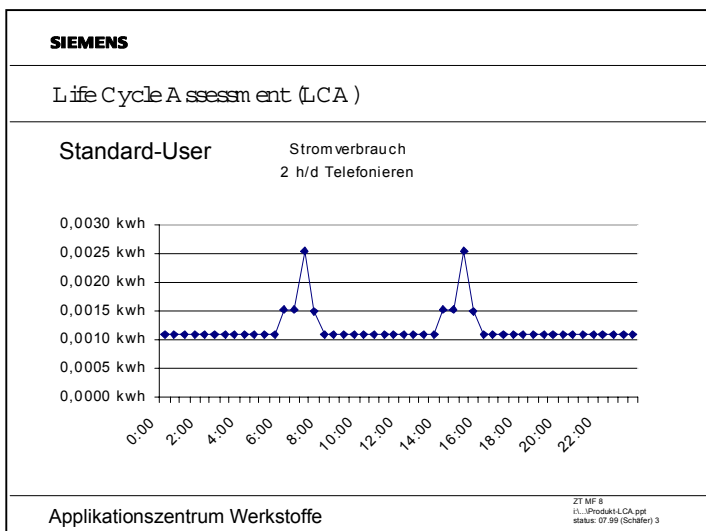
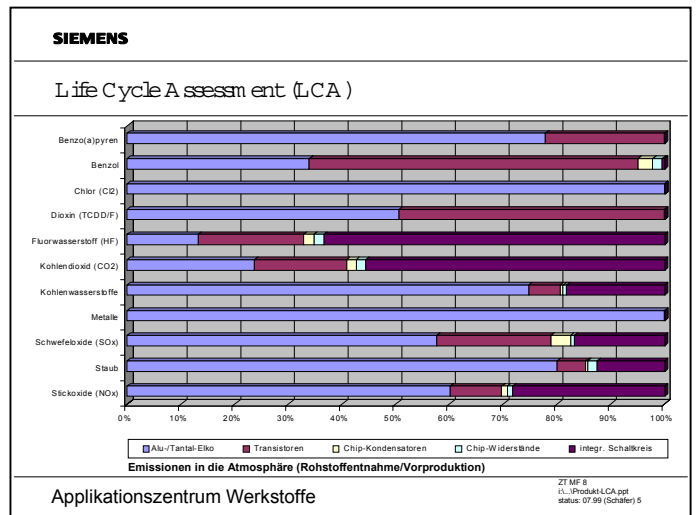
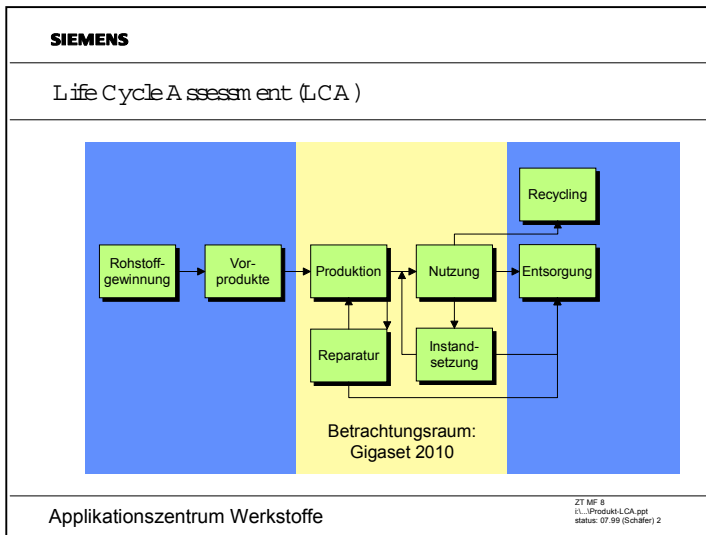
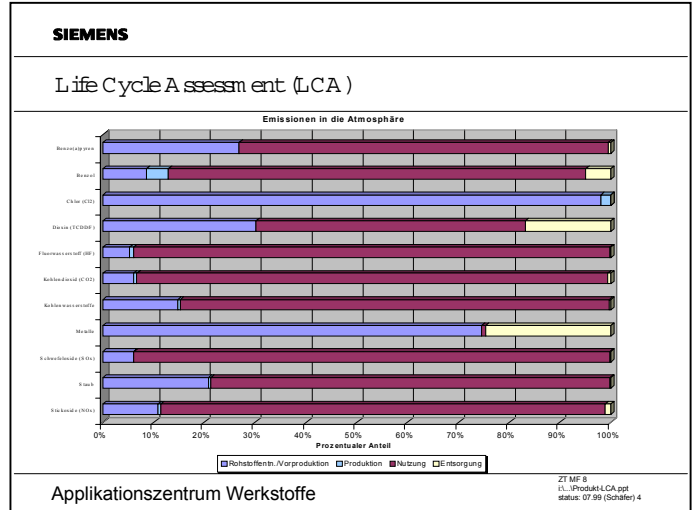
Conclusions

- Yield losses in production of electronic components can be **much higher than usually encountered in industrial production**.
- These yield losses can **increase the material and energy demand and waste volumes** in production inventories considerably.
- Infrastructure** of electronic products and components might be **environmentally more relevant** than currently assessed (with a 100%-yield inventory).
- Neglecting yield losses or assuming a near 100%-yield production in product inventories **needs to be verified**.

“Life Cycle Inventory Results for the Cordless Phone Gigaset 2010”

Dipl.-Ing. Martin Schäfer, Siemens AG, Dr. Robert Arenz, T-Systems, debis Systemhaus, Competence Center EDM, Ice@debis.com

Among consumers the popularity of cordless phones – similar to mobile phones – is increasing rapidly. Therefore it is getting ever more important – especially for Siemens as manufacturer of such products – to estimate the environmental impacts of cordless phones and to develop environmentally sound Gigaset-generations in the future. Before this background an inventory analysis and a weak point analysis for Gigaset 2010 has been realized. In a short presentation some results will exemplarily be introduced. Furthermore a closer look will be taken into the life-cycle phase usage



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Importance of system borders and scenario assumptions in the evaluation of new media technologies”

Mireille Faist, Prof. Susanne Kytzia Regionalen Stoffhaushalt, ETH Zürich
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New information technology influences our lifestyle; does the latter become then more sustainable? Evaluations of new technologies often fail to give a clear-cut answer. A problem of such evaluations is to define functional unit and system borders, as the studied systems are mostly multi-functional. Let's examine two examples: Internet newspaper should allow saving paper and therefore energy, telecommuting should save energy of transport and office space heating. However, depending on if a single article or a whole newspaper is compared with its Internet equivalent, the result can favor the one or the other option. By telecommuting is the assumption to what extent office space can be reduced significant. But also important is the social aspect of work: to what extent telecommuters will compensate their social isolation with higher mobility in the free time? The question is then: do we just increase consumption with these new technologies? And how can an evaluation capture these questions?

“E-commerce – an opportunity or a threat for LCA and sustainable development?”

Gerald Rebitzer, Prof. David Hunkeler, EPFL-LPBM

Abstract

E-commerce, based on the rapid development of the World Wide Web, is challenging and changing industrial practices in many business sectors around the world. Though the involved information and communication technologies as well as the emerging business operations of the new economy are rather “clean”, the resulting globalization leads to new patterns of production, distribution, and consumption. Often the possibility to act on the whole world as a market for purchasing and selling goods and services leads to new and increased transports and other “old economy” activities and thus to additional resource consumption and environmental impacts. Additionally, shifts in production locations from highly developed to second and third world countries occur. These issues significantly affect sustainable development and also the way we try to measure its success. One has to raise the question if changing consumer behaviour and business patterns have to be integrated in environmental assessments in a much broader way than being practiced today. E.g., changing needs or rather desires of the consumer might make it necessary to compare systems with different functional units (but fulfilling similar desires). Also it might likely be that LCA without the integration of socio-economic aspects is not the suitable tool to contribute to sustainable development in the new economy.

The proposed presentation is meant to be a reflection of current trends in e-commerce relevant for the environment and the (possible) implications for applying LCA in this sector of the economy.

Figure 1)

E-Commerce and Sustainable Development	
opportunities	threats
<ul style="list-style-type: none"> • dematerialization • telecommuting • improved information • global standards ... 	<ul style="list-style-type: none"> • additional transport activities • destruction of regional markets • loss of customer relationships • shifts in production to second and third world countries with lower environmental standards ...

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Figure 2)

Challenges for LCA

- Functional unit according to ISO 14040: Does the customer in the first world really look for functions?
- Changing customer behavior due to changing supplies (alternative consumption, increased consumption)
- Can globalization (varying production locations, etc.) be properly addressed in LCI and LCIA)

Can LCA contribute to more than eco-efficiency?
Can LCA contribute to sustainable innovations?

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Figure 3)

Conclusions

- LCA methodology to be adjusted to new business patterns (more creative room, less formal, more flexible, scenarios)
- Socio-economic factors have to be integrated in order to model reality (changes in markets and consumer behavior)
- LCA should learn from mistakes of the past (“efficiency trap”)

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Introduction

E-commerce and related activities, based on the rapid development of the World Wide Web, are challenging and changing industrial practices around the world. Often this is seen not only as a business opportunity but often also as an opportunity for sustainable development. Dematerialization is one of the key issues in this context. However, first one has to raise the question what the effects really are. Wasn't the office PC invented to save time and paper? We all know that it does not save paper, though it has the potential for it. I guess the question if it saves time is rather philosophical, so I won't go into that.

The second question is if LCA as practiced today can help in avoiding the mistakes of the past. Or in other words: Is LCA ready to help decision making in the new economy?**Figure 1)**

E-commerce and sustainable development: Of course there are opportunities from dematerialization, telecommuting, improved information possibilities and global environmental standards (e.g., ISO 14000), etc. However, one has to ask if dematerialization really takes place or if it doesn't rather constitute additional consumption. Also, currently the WWW probably leads to more travel activities (business and private), because of lower prices, more networking, and the option to work "on the road".

Another problem arises from the destruction of regional markets. Here mad cow disease is a prominent example of possible consequences. Also, globalization leads to higher cost pressure, so production is shifted to countries with lower standards.**Figure 2)**

Assuming that we want to use LCA as a tool for putting sustainable development to work, we have to critically reflect **on** the capabilities and limitations. LCA has been originally developed for industrial and policy decisions in the old economy (energy generation, packaging, materials selection, etc.).

In order to help in decision-making in the new economy, LCA has to be more flexible, to move away from the view of purely technical functions. Today many products are not sold for their function but rather for their "coolness".

Additionally LCA has to address changing consumption patterns and additional consumption (stronger links with material flow analysis - MFA).

Another challenge concerns the modeling of the product system, since the locations of the production facilities are virtually unknown or constantly changing. This has impacts on the inventory modeling as well as the impact assessment.**Figure 3)**

In the new economy LCA can only contribute to sustainable development if it is adjusted, if it is used **in a more flexible way**. Scenarios are a strong tool for that.

Additionally, social and economic constraints and assumptions have to be integrated in the scope and goal definition as well as in modeling in a much broader way. This way we avoid to improve the efficiency per unit without decreasing the overall impacts.

“Potentials of LCA for Environmental Management Systems in the Semiconductor industry”

M. Spielmann ETH- UNS, Fraunhofer IZM, Berlin

The strict division of labour generates a complex logistical network, in which environmental interventions occur at various steps in the production chain. The responsibility for the finished product towards the customers, however, remains undiminished. Based on these findings, it has been concluded that a strongly product-oriented EMS is required. Also, in order to improve and control the selection of materials as well as the environmental performance throughout the entire production chain LCA may be essential part of the EMS in order to answer the questions as follows:

- Which are the most significant environmental aspects with respect to both the company's activities as well as their products?
- Which objectives, targets and measures for the EMS are necessary to improve the environmental performance within the
- production chain?
- What are the most important elements of an EMS inside a logistical network for semiconductor production?

“LCA of complex systems: examples from the domain of telematics and transport”

Dr. Pierre Rossel, EPFL, Lausanne, Projet ESST

Not an object, a process, a material nor a flow of a particular kind, complex systems are sets of combinations of all that and their ecobalance is therefore particularly difficult to establish in a robust manner.

Our reflection has, as an origin, the analysis of the various ecobalance studies carried out in regards with the Swissmetro maglev technology, including the identification of serious limitations such as: heterogeneity of sources, relevant domains and measuring units, local or temporary dramatic course of events, always difficult to introduce in the picture, external dimensions, critical yet nearly impossible to frame in, induction effects and cross-interfering with the ecobalance of other transports modes, and in general a severe deficit of standardisation which could make possible comparison or complementarity of the obtained results in a wider ecobalance agenda.

Telematics and transport intertwine quite in similar critical paths and patterns. If, among the twelve-or-so categories of applications we typically deal with (for several dozens of actual sorts of different services), we choose as example a trendy development such as the telematics used to make motorised traffic more fluid, we can indeed identify an interesting series of problems to be overcome:

- success = solution (traffic more fluid), but also traffic induction towards new congestion horizons;
- co-related effects, either directs (on traffic in general and on safety) and external (on health, risk assessment and management, noise, pollution) which fits to our heterogeneity-featuring issue;
- real-cost and financing, translating the expected favourable ecobalance into both feasible investment and efficient payment schemes
- learning potential (through statistics, behaviour and mobility-chain modifications, new policy and later public investment adjustment)
- macro evaluation and comparison, with benchmarking, hubbing, differentiation and complementarity re-design.

Altogether, ecobalance of such complex system is about assessing with robust yardsticks and reference frameworks, a dynamic process and its potential consequences, according to various possible scenarios, each one influencing to a certain extent the ecobalance of any other existing modal systems.

“Environmental impacts of the EPFL internet network”

Prof. Norris, G., Harvard University, Prof. O.Jolliet and Winter, M., EPFL- GECOS

The infrastructure which supports a university's use of the Internet has been comprehensively assessed using two methods of Life Cycle Assessment.

Part I: process LCA

A process-level study (fig.5) focusing on the direct as well as indirect (“embodied”) energy input requirements of the total physical infrastructure has been performed, including various scenarios for near-term technology changes in equipment and software.

The Internet infrastructure of the Swiss federal Institute of technology (EPFL) is composed of 7000 PC, 400 printer printing 9 million pages per year, together with 90 switches, 68 servers, 22 routers and 121 km cable (fig.6). Non renewable primary energy is calculated, showing that the PCs (control units and screens) are dominating the energy use, while the 90 switches play a significant role (fig.7). In the future, the foreseeable use of flat screens and the move from desktops to notebooks would contribute to reduce the energy consumption by 50%. The use phase play a dominant role for conventional PC, but the embodied energy consumption during PC production play a higher role for notebooks or flat screens (fig.8).

Part II: Input-Output LCA and Cost of ownership

An input/output-based LCA of the system (fig.9) has also been performed and compared with the process-level results. Figure 11 shows that for the CO₂ emissions, input output LCA and processed LCA indicate similar share between the different components of the EPFL network. The more comprehensive Input-Output (but coarse) LCA shows that priorities for environmental improvement change considerably when environmental impacts other than energy, such as toxic releases, are taken into account (figure 12: printers play a dominant role for VOC). The CO₂ and VOCs emissions linked to the amount of 700000 US\$/year paid by EPFL to be connected on the worldwide Internet network are rather negligible.

The analysis further expands the boundaries by considering the environmental burdens of non-hardware input requirements, such as software, training, management, trouble-shooting – the “Total cost of ownership” for the personal computer portion of the system (fig.13). These costs of ownership are indeed dominating the overall expenses related to the EPFL PC network (fig.14) and the corresponding emissions are significant (fig. 15 and 16). Results from the expanded scope analysis demonstrate that ownership cost improvements such as increased operating system stability can significantly reduce both cost and the total environmental footprint of the infrastructure supporting the internet.

Fig.12)

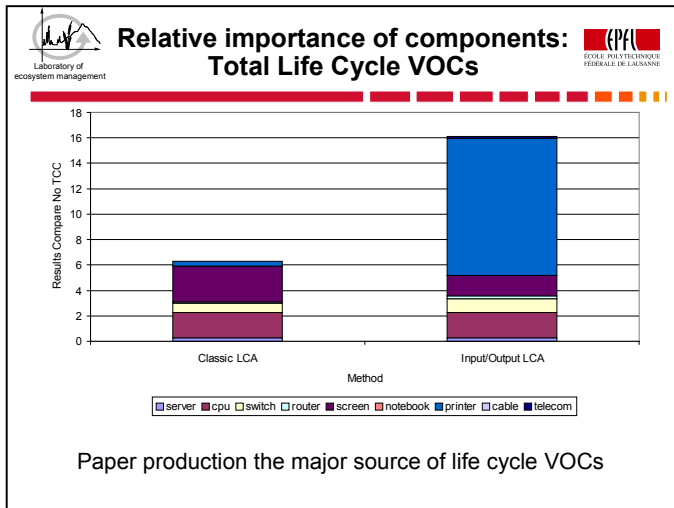


Fig. 15)

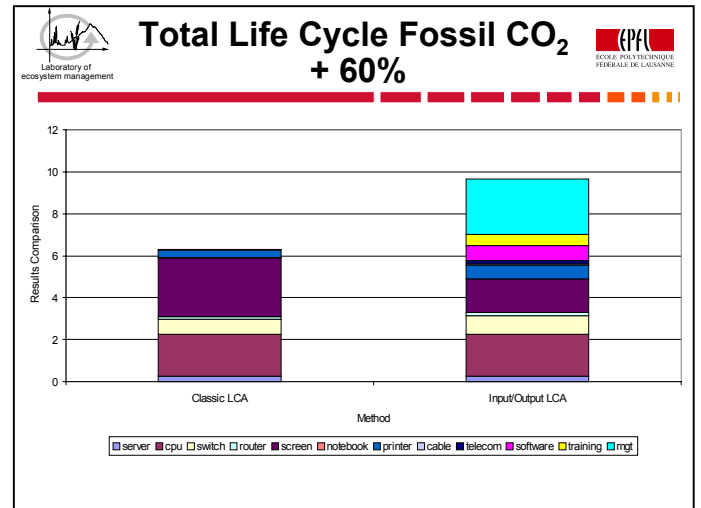


Fig.13)

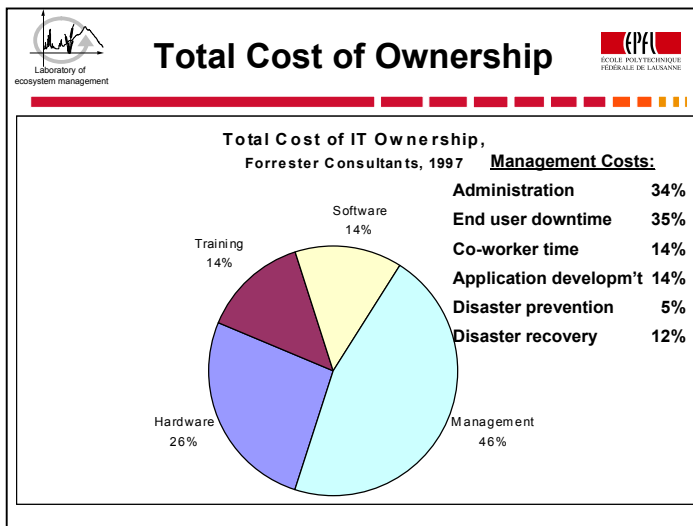


Fig.16)

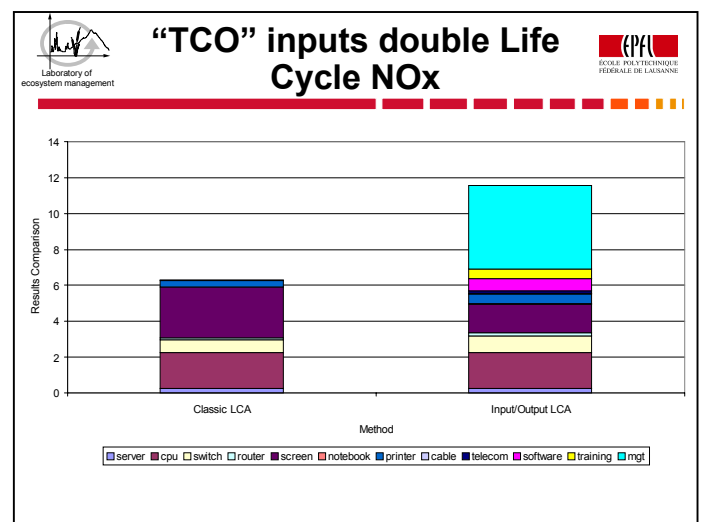


Fig.14)

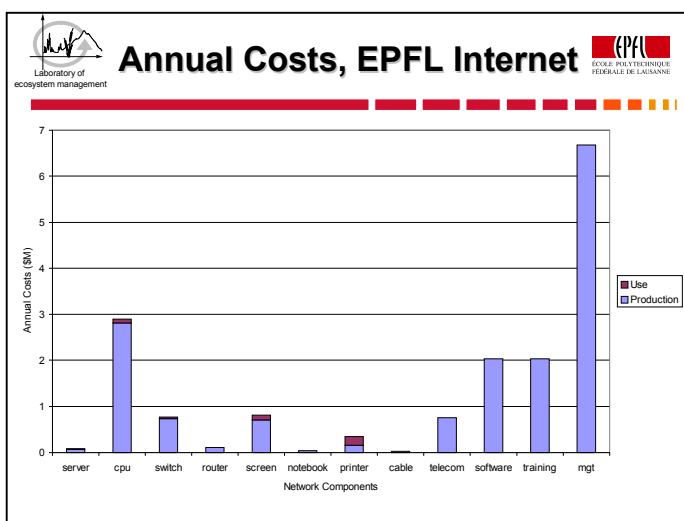
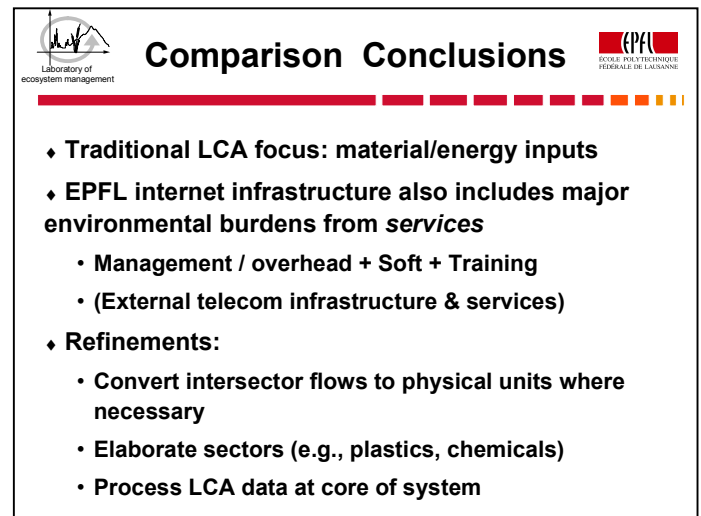


Fig.17)



“Sustainability of new work practises and building concepts”

Prof. Dr. Niklaus Kohler, Institut für Industrielle Bauproduktion - Universität Karlsruhe

New forms of communication and co-operation do not have the same environmental impact pattern as current forms of work. Environmental impacts are produced by work technologies (mainly communication technologies), buildings (construction, maintenance, operation and destruction) and transport (induced by work relations and housing). The thesis that new information technologies reduce transport and building energy consumption has not been verified in practice until now. The contribution discusses the interrelation between different impacts, gives quantitative data of environmental impact based on the combination of existing life cycle analysis and tries to estimate possible future developments. The question of the necessity of new buildings and the possible development of virtual buildings is discussed in relation with sustainable development

It has been published in :

Streitz, N. et al. (Eds.), Cooperative Buildings - Integrating Information,

Organization, and Architecture. Proceedings of the First International Workshop on Cooperative Buildings (CoBuild '98) February 25-26, 1998, Darmstadt. Lecture Notes in Computer Science. Heidelberg 1998.

Life Cycle Assessment of a Videoconference -a comparative study of different ways of communication

Rydberg, T., Östermark U. and Eriksson E., Chalmers Industriteknik, Göteborg, Sweden.

A life cycle assessment of a videoconference has been carried through at Telia from June to December 1997, under the management of Chalmers Industriteknik (CIT). The results are meant to increase Telia's knowledge of the environmental effects associated with a videoconference and to serve as a basis for communicating these effects outside the company. They are also meant to show which part of the system that should be given priority in order to obtain considerable environmental improvements. The assessment has been made according to the international standard EN ISO 14040:1997, and the report has been reviewed by Lars-Gunnar Lindfors at Institutet för Vatten- och Luftvårdsforskning (IVL).

The assessment includes the complete life cycle of a videoconference, i.e. production, use of video and network equipment, and waste management. The assessment has been carried through as a limited study of a scenario, by investigating a specific videoconference in which new technology is used. Telia chose this scenario since the study would include a comparison between the environmental impact of a meeting and a videoconference. A videoconference between one Telia office in central Stockholm and another in Göteborg is compared to a meeting at the office in Göteborg. For the meeting, one person is assumed to go by train or air (with an airport bus connection). Modern technology, widely used in 1997, has been studied. This means that opto-technology has been chosen for the videoconference, the train type is X2000 and the plane type is MD-82. The functional unit chosen is a meeting of 3.5 hours with one participant in Stockholm and the other participants in Göteborg.

The system of the videoconference is described in Figure *i*.

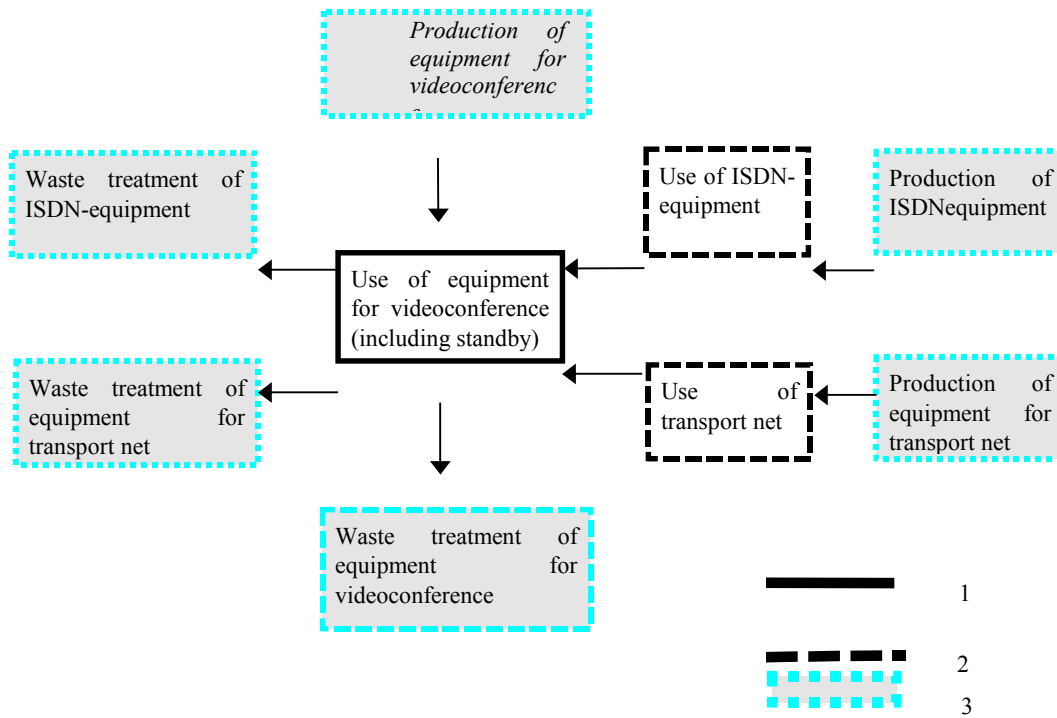


Figure i. Schematic table of the videoconference system. Level 1, 2 and 3 describe a gradual extension of the system (1. Use of video equipment only 2. Use of ISDN equipment and the transport network added 3. Manufacturing, use and waste management of the videoconference equipment, the ISDN network and the transport network added). Level 3, consequently, includes the whole of the studied system.

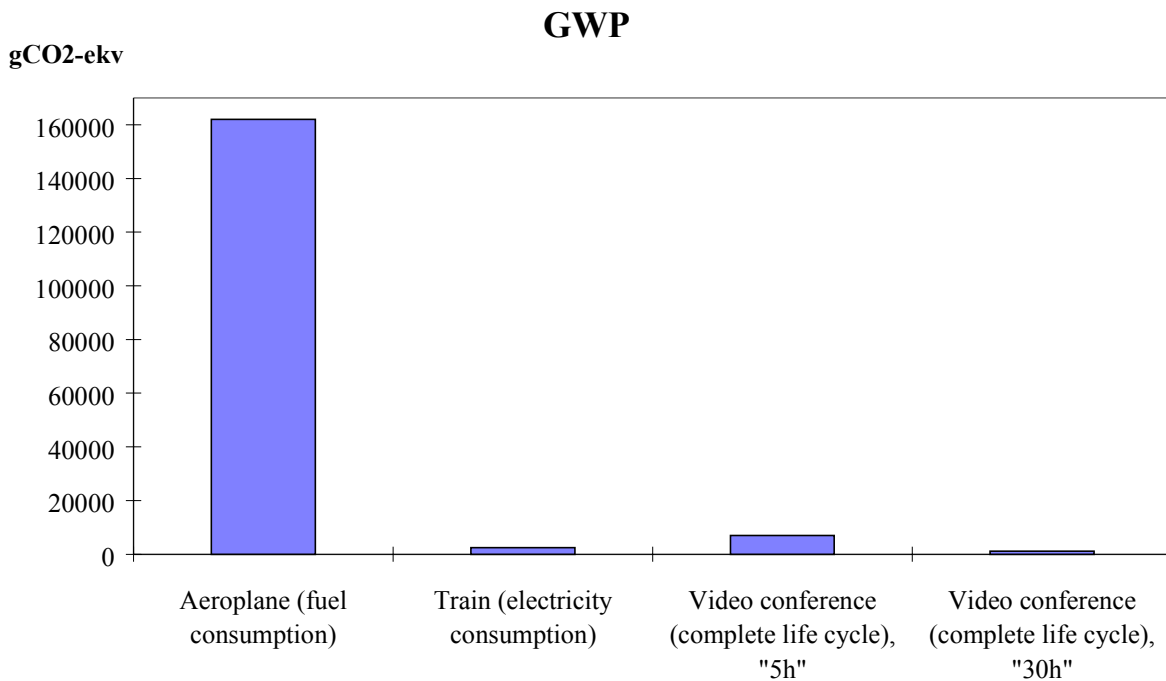


Figure ii. Potential contribution to global warming from the videoconference compared to the electricity consumption of the train or fuel consumption of the flight. 5h and 30h indicate the two scenarios of the videoconference; one with low use and long stand-by times of the video equipment (5h), and the other with high use and short stand-by times (30h).

In the study of a meeting, a train trip is included, but only electricity consumption for propulsion of the train and for comfort (heat, light, etc.) has been included. Other aspects, such as production, maintenance and waste management of trains or production, use, maintenance and waste management of stations and railways have been excluded, since data are not available or known by the authors. This also applies to the flight (only the flight's fuel consumption is included).

The results of the comparison are not valid for other conditions such as other transportation distances, loads etc. In the case studied, the load is high on both train and flight. This is of course of great importance to the results of the comparison. It is also important how much the videoconference equipment is used. Therefore, two scenarios have been studied; one with five hours of videoconference per week and the equipment in stand-by position during weekdays and nights (high stand-by, 115 hours per week), and another one with 30 hours of videoconference but with the equipment in stand-by position only when it is not used during office hours (low stand-by, 10 hours per week).

Main conclusions of the comparative study

In the comparative study between on one hand the production, transports, use, and waste management of a video equipment and telecommunication network (electricity consumption and cooling, no maintenance) for the studied videoconference (i.e. level 3 in figure *i*), and on the other hand the electricity consumption during the use of engine and carriages (maintenance not included) for the studied trip between Stockholm and Göteborg, the following conclusions have been drawn:

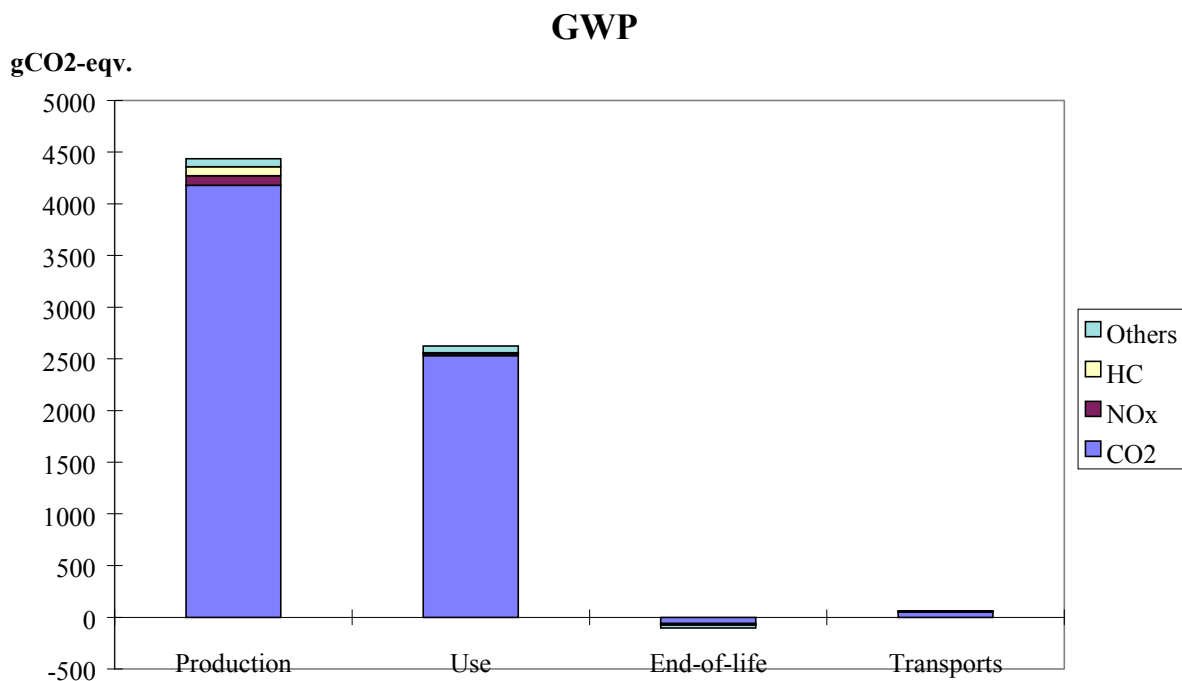


Figure iii. Potential contribution to global warming from the different parts of the videoconference system (5h). Production and use contribute the most. "Transports" refers to equipment (personal transports not included). Waste management gives a negative contribution since materials in the equipment are recycled or incinerated with heat recovery.

The videoconference gives a lower potential contribution than the fuel consumption of the flight transport (all other environmental impacts from the flight transport system excluded) to the studied environmental impacts resource depletion, global warming, acidification, eutrophication and photo-oxidant creation.

The potential environmental impact of the videoconference regarding the five above-mentioned impacts is approximately the same as that of the electricity consumption of the train trip (all other environmental impacts from the train system excluded). This is if the video equipment is used quite often and is switched off when not used (high and smart use, 30 hour scenario).

If the videoconference is used less often and set in stand-by position during a long time (five hour scenario), the videoconference will give a higher potential contribution to the five above mentioned impacts than the train.

These conclusions are exemplified with regards to global warming in Figure *ii* above. The conclusions are not valid for arbitrary videoconferences, train trips or flights since a specific videoconference is compared to a specific train trip or flight.

The most environmentally loading aspects of the videoconference

The study has shown that the parts of the videoconference system (level 3 in figure *i*) that gives the greatest potential contribution to the different studied impacts are:

The production of the videoconference equipment (the equipment in the meeting room: TV-monitor, video camera, etc.)

The use of the videoconference equipment

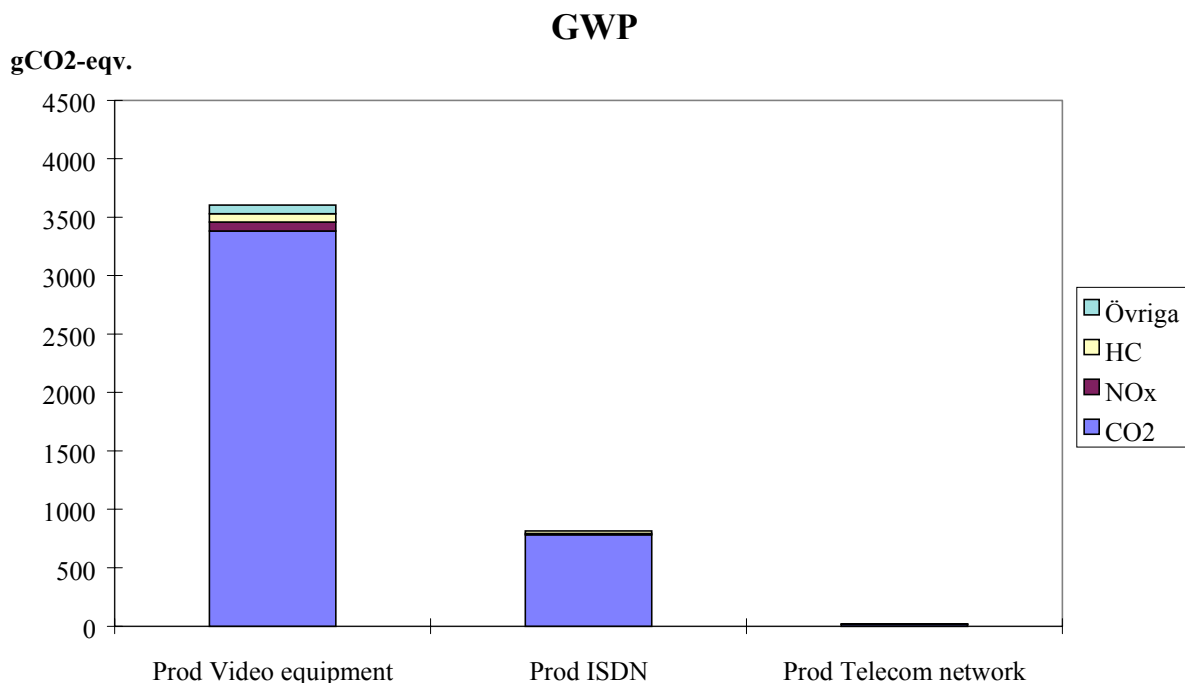


Figure iv. Potential contribution to global warming from the production of the different parts of the equipment used for the videoconference (5h). Production of the video equipment dominates, followed by the ISDN equipment. The contribution the telecom network is very small.

The production of the ISDN equipment (Integrated Service Digital Network); especially the "IC" part, which, via the residential network, is the first link of the telecommunication network

The use of the ISDN equipment (especially the IC)

The first three of these aspects are exemplified regarding potential contribution to global warming in Figure *iii-iv*.

The production and the use of the videoconference equipment have the greatest potential contribution to global warming. The reasons to this relatively high load from the production and the use of the equipment are that it is seldom used at the end of the communication link and that it during periods is set in stand-by position. If the equipment seldom is used, the resources and emissions from production will be spread over fewer hours of active use. With long periods of stand-by the equipment consumes energy of no use.

Suggestions for improvements

The following improvements would considerably diminish the potential environmental impact from Telia's organisation:

Increase the use of the videoconference equipment (and by that also the IC equipment)

Work out and initiate simple routines for switching off and on the video equipment

Raise the demands on suppliers for environmentally adapted product development

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Life Cycle Assessment of a Videoconference -a comparative study of different ways of communication (in Swedish), Ulf Östermark and Elin Ericsson, Chalmers Industriteknik, published by Centre for Environmental Assessment of Product and Material Systems, CPM report 1999:7, Chalmers University of Technology, Göteborg, Sweden.