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MIPS of the Italian Mobile Telephone Network

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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. 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 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.

Introduction

The current unsustainable production and consumption pattern in our society is characterized by a massive use of material and energy extracted from the environment. There is agreement now that this flow can be used as a proxy for estimating the roaring human pressure on the environment. 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.
A reduction of the material throughput in OECD countries by an average of a Factor 10 during the coming decades is imperative, especially when taking into account the expected economic and demographic increases in the "Third World". 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 following:

- Material Input (MI): the sum of all material requested for giving a service, such as a mobile telephone call. It is the sum of the primary natural resources including their "hidden flows" or ecological rucksacks. The unit used is kg.
- Material Input per Unit Service (MIPS): the material input of a system or product can be compared with the service it offers. Products, services and infrastructures must be compared and designed from the beginning under the aspect of ecological criteria of resource efficiency. This is where the MIPS concept can play a decisive role. The used unit will depend on the service offered. For the telephony example could be Kg/(sec of conversation).

Dematerialization requires diminishing the material throughput of our economy while keeping many of the services it offers. Information and Communication Technology (ICT) can play an important role in the dematerialization. It can reduce unnecessary travel e.g. in vehicles traveling to and from the workplace, and diminish the stress and pollution associated with commuting. It can also facilitate the access to information that, many believe, is a key issues for a democratic achievement of a sustainable development path.
In this paper an analysis of MIPS, for the mobile telephone service in Italy, is carried out. Many of the data we use are from Ericsson where all production units implement certified Environmental Management Systems and LCA (Life Cycle Analysis) according to ISO 14001, by the end of 2000.

History

During the early 1980s, analog (TACS) cellular telephone systems were experiencing rapid growth in Europe. Each country developed its own system, which was incompatible with everyone else's in equipment and operation. This was an undesirable situation, because not only was the mobile equipment limited to operation within national boundaries, which in a unified Europe were increasingly unimportant, but there was a very limited market for each type of equipment, so scale economies, and the subsequent savings, could not be achieved.
The Europeans realized this early on, and in 1982 the Conference of European Post and Telegraph (CEPT) formed a study group called the Groupe Spécial Mobile (GSM) to study and develop a pan-European public land mobile system.
In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and phase I of the GSM specifications were published in 1990. Commercial service was started in mid-1991, and by 1993 there were 36 GSM networks in 22 countries, with 25 additional countries having already selected or considering GSM . The acronym GSM now stands for Global System for Mobile telecommunications. The most basic service supported by GSM is telephony. From December 1999, 66% of all digital mobile subscriptions in the world used GSM phones on GSM networks. At the beginning of 2001 the number of subscriber in Italy was exceeding 41 millions.

The Network Architecture

GSM network uses a cell system in which the network coverage is broken up into cells, each of which has its own base station for receiving messages from other cells and also for passing them on. A GSM network is composed of several functional entities (picture 1):

- 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. In urban areas there are few BSC controlling several BTS;
- 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). To manage the user's mobility the MSC exchanges continuously information with the Visitor Location Register (VLR) where informations on MS present in the area are temporary stored;
- The Home Location Register (HLR), the central data base owned by every telephone company. In this data base static and dynamic information on users is stored. When a

MS enters a cell of a MSC then it is inserted in the VLR of that MSC, removed from the VLR of the MSC of the cell left, and then the HLR is updated;
- The Operation and Support Subsystem supervises and manages the whole network.

Trends

Since 1987 the dimension and the weight of mobile telephones have been strongly reduced. A simple comparison of the 2kg Ericsson model “Hotline NMT” (1987) and our days Ericsson model “T28” (80 g) gives the idea of the material abatement. The initial nickel cadmium battery system has been substituted by the lithium ones and the maximum “stand by” time for the telephones has drop from 5 hour to nearly 300 days. Picture 2 shows the trends in both weights and stand by times during .the last years.
The subscribers in Italy (Censis) 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.

Methodology overview

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. We assume the last is related only to energy consumption from the electric network. For the production we consider raw materials plus transportation.

To quantify the material input required by a MS we consider the T28 from Ericsson. The company plant is based in Sweden. The manufacturing process is based on components produced elsewhere, mainly in Asia and some from the US for the electronic parts, from Morocco and Finland for the batteries and battery chargers, from North Europe for the telephone body, the packaging and the user manual printed material. Finally the product is shipped, for the Italian market by trucks.

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 analyzed (Di Virgilio 2000, a,b).

For the other component estimates are made based on the BSS structure.

Raw materials: data of materials from the Wuppertal Institute and from the Mainstain’s Data Base 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.

Material input for the MS

In a mobile station is possible to recognize the following parts: integrated circuits, front and frame, printed wiring board, antenna, battery, LCD, other mechanical parts. To this material we should add the battery charger, the user manual (100 grams of paper) and the packaging. Material used for batteries are mainly related to lithium use, for the other components the material list is given in Appendix 1. The MIF for the considered material

are in Appendix 2 together with the quantities used and the resulting Material Input (MI). The sum on all the material inputs gives 30.4 Kg.
To assembly this material energy is needed. For energy we assume a MIF of 4.7 Kg/kWh (referred to the public network in Germany). A LCA (Life Cycle Analysis) at Ericsson shows that energy requirement for a single telephone unit is 3.3 Kwh. So we should add 15.5 Kg to the amount above. But not all the parts of the telephone is produced at the Ericsson plant in Sweden and the transportation component of MI comes in.

Integrated and printed circuits are manufactured in South East Asia and sent by air covering a distance of about 10000 km. There are not information about MIF for air shipping. We limits our analysis to energy factors from fuel consumption only. A more accurate analysis should include the airplane itself, the airports etc. 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 (British Airways) 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. The time taken for the trip is 10000/927 =10.8 hours. During that period the fuel consumption is 10.8X10230= 110484 kg. This to transport 17.1X0.75= 12825 kg of payload. This means 8.6 kg of fuel for one kg of good transported for 10000 km. If we multiply this for a MIF 2.9 we have 24.9 Kg/Kg. Because we consider only 20 grams of material (Integrated and printed circuits for a telephone) we estimate a MI, due to transportation from Asia, of 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, in a way similar than the air shipping, 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. This means

80 + 230 +100= 410 grams of product shipped in Italy

The trip takes 410 grams for 2000 km by track and consequently adds on a MI of 0.82 Kg. Adding this numbers we get:

30.4 (materials)+15.5 (assembling) +0.3 (Air shipping)+0.01 (ocean shipping) +1.09 (road) = 47.3 kg/MS

Notice that the transport does not influence much the final results.
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*3=16.5 Wh per day. During one year we have about 6 kWh. If we assume a MIF of 4.7 Kg/kWh (referred to the public network in Germany) we obtain 28.2 Kg/Year.
From now on we assume a MS life time as 1 year. This due the continuous technological improvements in this field and consequent rapid obsolescence of this kind of product.

Adding the two MI we finally get 47.3+28.2=75.5 kg as MI for a telephone service of one year.

Material input for the Radio Base Station (BTS)

The BTS is the main material component of the BSS. Following the Di Virgilio Virgilio & C. S.n.c, the material input for building a BTS is related to soil movements. After the site preparation a metal container is settled. Finally the antenna is based on a platform. We assume the weight of 1 m^3 of soil equal to 1600 kg. The station is connected to the nearest main road by a path of 300 meters by 3.5 meters.

Material	MIF	Tons	MI (Tons)
Soil	1	1208.000	1208.000
Steel for armature	2	0.497	0.994
Container (Steel)	21	4.200	88.200
Antenna (18 m) steel	21	4.700	98.700
Antenna Platform (Iron with zinc)	9	0.700	6.300
Concrete	2.2	48.000	105.600
Bitumen	2.6	300.000	780.000
Iron with zinc (net)	9	0.651	5.990
Total		1566.748	2293.784

Of the 2294 Tons of MI about half are from moved soil. Notice that this underestimate the MI of a BTS. The telephone company usually rent the area for the BTS from same local authority. Typically the minimum renting period is 9 years. 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 station we examined was with a 21.6 kW air conditioner. Staff of the TIM maintenance states that 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 9X4.7 = 42.3 Kg/day. A BTS works unattended. 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=48.1Kg/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.

From a recent survey (Forum BTS Italia 1999-2000) 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. This somehow underestimate the higher consumption of energy of BSC (estimate around 20 kWh/day).

If we multiply this number for the MI we have a total of 9821X246= 2415966 Tons/Year or, for short 2.416 Millions tons a year required by the network.

The mobile telephone service and the MIPS

The market in Italy, for the mobile telephone service, is divided by three companies: Telecom Italia Mobile (TIM), Omnitel and WIND. Their today share of subscribers is shown in following table.

Company	Return from mobile telephone traffic (Millions Euro)	Subscribers at the end of the year 2000 (Millions)
TIM	5836	21.6
Omnitel	3204	14.9
WIND	293	4.9
Total	9333	41.4

The service offered is related to telephone calls and to SMS (Short Message Service).
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. Notice how this number is comparable to the MI of a single MS (75.5 Kg).

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. On the other hand we could look to the entire system. If we take the MI for one MS and multiply this number for the subscribers we get:

75.5X41.4 Millions=3.126 Millions Tons/Year.

The MI of the entire system is:

3.126+2.416=<u>5.542 Millions Tons/Year.</u>

A TIM Board relation (on the first results of the year 2000) reports there was a traffic of 13944 millions of minutes of telephone calls during the last year and of 12.5 millions of SMSes per day using the TIM’s network. This means 4562.5 Millions SMS per year.The number of TIM subscribers grew from 16.2 to 21.6 with an average of 18.9 millions. Because the grow is exponential we assume the above minutes of connections were made by an equivalent of 18 millions subscribers. Thus any of them used their MS for 13944/18=775 minutes last year. This means 2.1 minutes a day of telephone usage. During last year the same number of users exchanged 0.7 SMS per person a day or 255 SMS a year per person. The usage of the MS as a voice telephone or SMS device are of the same order of magnitude. Thus we consider both a service offered by the network.
TIM subscribers are 52% of the total. This means the estimate communications are 13944/0.52=26815 millions of minutes and 4562.5/0.52 = 8774 millions of SMSes.
If we compare this numbers with the MI of the network we get:

5.542/26815= <u>0.207 Kg/(minute of telephone call)</u>

or

5.542/8774=<u>0.632 Kg/SMS</u>

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

Considering the Ericsson T28 weight (80 grams) this means roughly a material flow of the weight of two telephones per minute of conversation.

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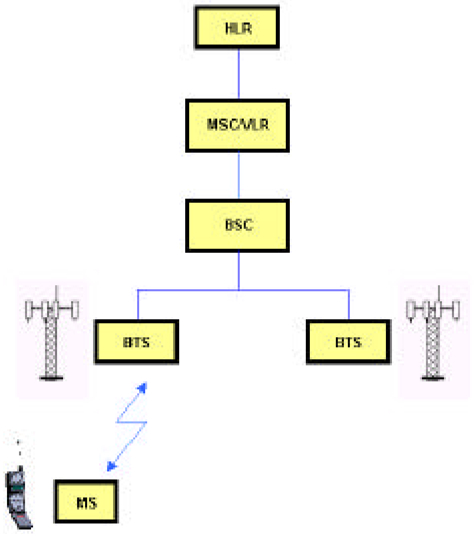
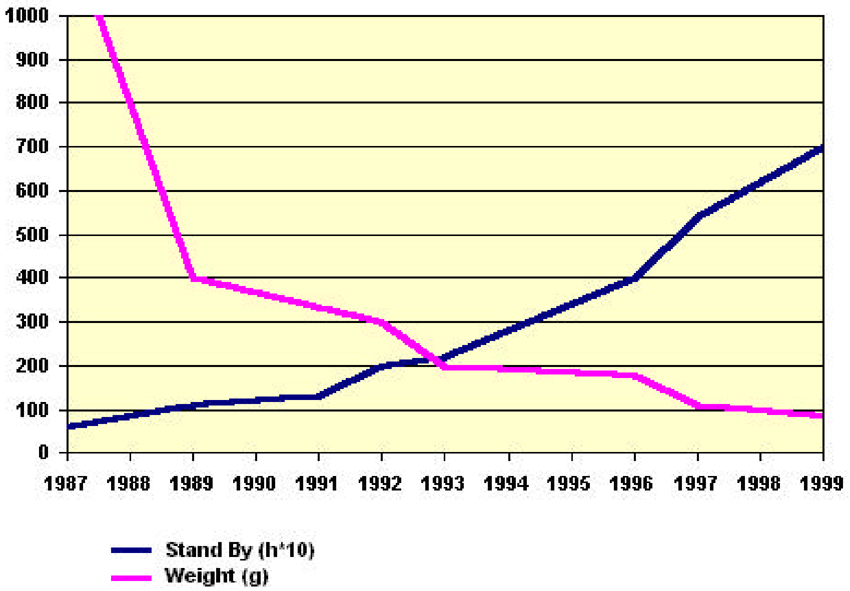


Picture 1: The structure of the network

Picture 2: Trends in Weight and Stand by



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The Sustainable Europe Research Institute: http://www.seri.at
Wuppertal Institute fur Klima, Umwelt, Energie: http://www.wupperinst.org
Enea: “Progetto 2000”: http://prog2000.casaccia.enea.it/

Appendix 1: Weight (grams) of the material used for the Ericsson T28 Mobile Station. Battery is made mainly of lithium (13.26 g)

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	Polyiamide	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	0.1040	0.0000
Other Mechanic Parts	2.9500	0.4000	0.0090	0.0900	0.2000	0.0570
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	0.0030	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	0.0200	0.0000	0.0000	0.0000	1.8250	
Other Mechanic Parts	0.0950	0.0800	0.0059	0.0000	30.8606	
Lcd	0.0000	0.0750	0.0007	7.3100	10.0570	
Total	**0.1270**	**0.1555**	**0.0262**	**7.5600**	**67.2118**	

	MATERIAL (g)		
COMPONENTS	PLASTIC	PAPER	CARDBOARD (BOX), PET OR PULP MATERIAL
BATTERY CHARGER	215	0	0
PACKAGING	0	0	150
INSTRUCTION BOOKLET	0	100	0
TOTAL	215	100	150

Source: Data base; Marda: Material declaration for Ericsson Mobile Phone T28. R:1, 1999-08-04

Appendix 2: The materials MIF, the quantities used in the MS T28 and the Material Input (MI)

MATERIAL	WEIGHT (g)	MIF (g/g)	MIF x WEIGHT (g)
SILVER	0.1310	7.500	982.5
ALUMINIUM	0.1810	85	15.39
COPPER	10.0300	500	5015
NICKEL	0.4930	141	69.51
IRON	4.9400	5.6	27.66
MAGNESIUM	13.8000	10	138
SILICON	7.9404	823	6534.95
ZINC	0.6780	23	15.59
EPOXY	2.3500	13.7	32.2
POLYAMIDE	0.2900	3.6	1.04
POLYETHYLENE	1.3240	5.4	7.15
ACRYLATE RESIN	0.6870	2.7	1.85
POLYPHENYL	2.4266	3.6	8.74
POLYCARBONATE	5.9645	5.4	32.21
THERMOPLASTIC ELASTOMERS	1.0700	4.3	4.6
ACRYLONITRILE	4.5100	2.7	12.18
TUNGSTEN	0.5830	141	82.2
SILICONE RUBBER	2.0000	8	16
LEAD	0.1270	5.6	0.71
PHOSPHORUS	0.1555	16	2.49
GOLD	0.0262	540.000	14.148
LI-POLYMER	13.2600	16	212.16
GLASS-FIBRE	7.3100	6.2	45.32
PAPER	100.000	15	1500
PACKAGING	150.000	1.7	255
PLASTIC	215.0000	5.8	1247
MI PRODUCTION			**30407.45**