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Energy Consumption of Information and Communication Technology (ICT) in Germany up to 2010

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1 Problem, objective and methodology

The energy demand for information and communication technology (ICT) is estimated at almost 1.5 % of the total final energy consumption in Germany, or 7.1 % of the electricity consumption (Geiger/Wittke 2002). This field of application has the greatest significance in the household and the tertiary sectors. It is generally accepted that the demand for information and communication services will increase and thus also at first the associated electricity consumption. This is valid both internationally (IEA 2000) and for Germany (Prognos/EWI 1999; Ziesing et al. 1999; Böde et al. 2000a). However, the future development of electricity demand is especially difficult to estimate in the information and communication sector since the technologies and applications are changing and expanding so rapidly. In addition, the data situation on energy consumption is unsatisfactory for both the present and the past in the household and tertiary sectors in general and in the application field information and communication in particular (Diekmann et al. 2000).

The electricity demand caused by electrical and electronic appliances in households and offices and the associated conservation possibilities have been the subject of increased research for some time (for Germany, among others, in Rath et al. 1997; Rath et al. 1999; Brohmann et al. 2000; Böde et al. 2000a; Böde et al. 2000b; Wuppertal Institut/ebök 2000; Barthel et al. 2001; internationally, among others, in Huber/Mills 1999; Kawamoto et al. 2001; Mitchell-Jackson 2001; Roth et al. 2002). On a policy level, there are a series of initiatives dealing with this topic on a European level by the IEA and the European Commission and also on a regional level. These activities focus on the reduction of the no-load or standby consumption of electrical and electronic appliances. For example, the Standby Initiatives of the IEA and the European Commission, the recent adoption of the Energy Star-Label for office appliances in the European Union and, in Germany, the 1999 Standby campaign conducted with the support of the Federal Ministry for the Environment (Brohmann et al. 2000), the "Aus - wirklich aus?" ("Off - really off?") campaign of the Energiestiftung Schleswig-Holstein[1] and the "Initiative EnergieEffizienz" launched in Autumn 2002 by the Associations of the Electricity Industry (VDEW, VRE, VKU) and the German Energy Agency (dena)[2].

Increasing power consumption for ICT applications represents a basic risk both with regard to climate protection and against the background of the expected shutdown of nuclear power stations in Germany. On the other hand, the prospects for improved energy use due to ICT applications should not be neglected. These are found in existing electricity saving potentials in the ICT sector itself, which could

1 www.wirklich-aus.de

2 www.initiative-energieeffizienz.de

be exploited to a greater extent, as well as in possibilities to save energy in other sectors through increased use of new ICT applications (e.g. through remote monitoring in the transport sector, in the intelligent home, in energy technology auxiliary systems, especially in contracting and in logistics). Neither aspect has been the subject of much research so far. Nor have the indirect impacts of ICT on energy consumption been analysed to any great extent so far. This is particularly true for transport services which, on the one hand, may become unnecessary due to electronic services (e.g. electronic banking services, telephone conferences, decentralised printing of daily newspapers), but, on the other, may create additional transport services (e.g. e-commerce).

Against this background, the **objectives** of this survey are,

- to qualitatively and quantitatively analyse the direct and indirect influence of modern appliances, systems and services of information and communication technology on the energy consumption in Germany up to the year 2010,
- to develop an "early warning system" which indicates in good time the danger of increasing power consumption or opportunities for rational energy use or the substitution of applications as well as
- to make concrete suggestions on this basis for energy policy at a national and EU level.

The current and future direct electricity demand of ICT appliances and the associated infrastructure was methodically determined based on a model consisting of the following components (Figure 1-1):

- the **stock** of today as well as the expected stock development including new appliances or uses up to 2010.
- **Electricity consumption of the appliances** in the different operating modes as well as the energy consumption of the underlying infrastructure. Following Böde et al. (2000a), the following four operating modes are distinguished in this study: normal, standby, off-mode, and off. The definitions on which these modes are based are shown in Figure 1-2 [3].
- **Operating times** in the various modes, i. e. the respective intensity of use.
- The future power demand is further influenced by the existence of (technical and behavioural) **saving potentials** with regard to the energy consumption in the different modes and their actual implementation.

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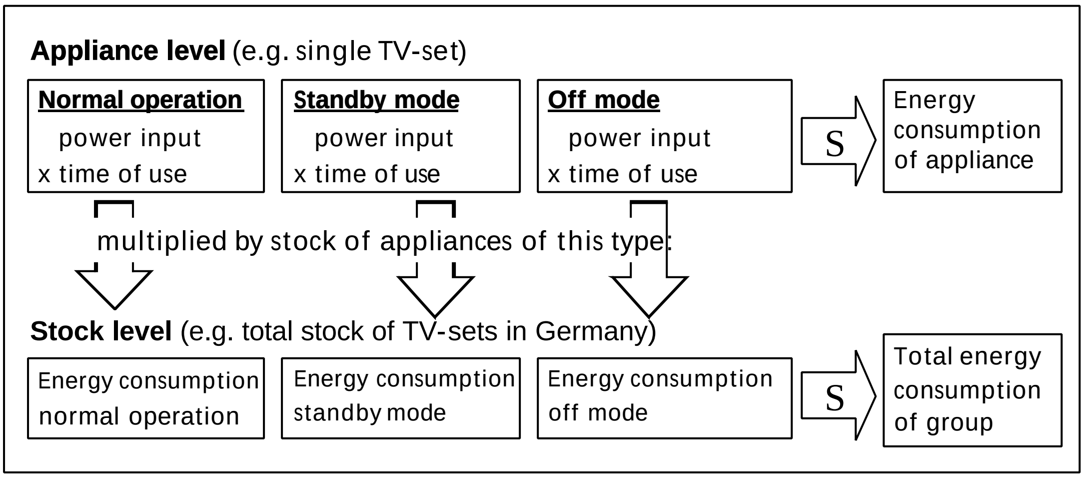
3 As yet there is no uniform definition of the operating modes, but several different approaches have been developed. Especially the term "standby" is used inconsistently. When naming the individual modes, there is the additional problem that not every German term has a corresponding unambiguous English translation and vice versa.

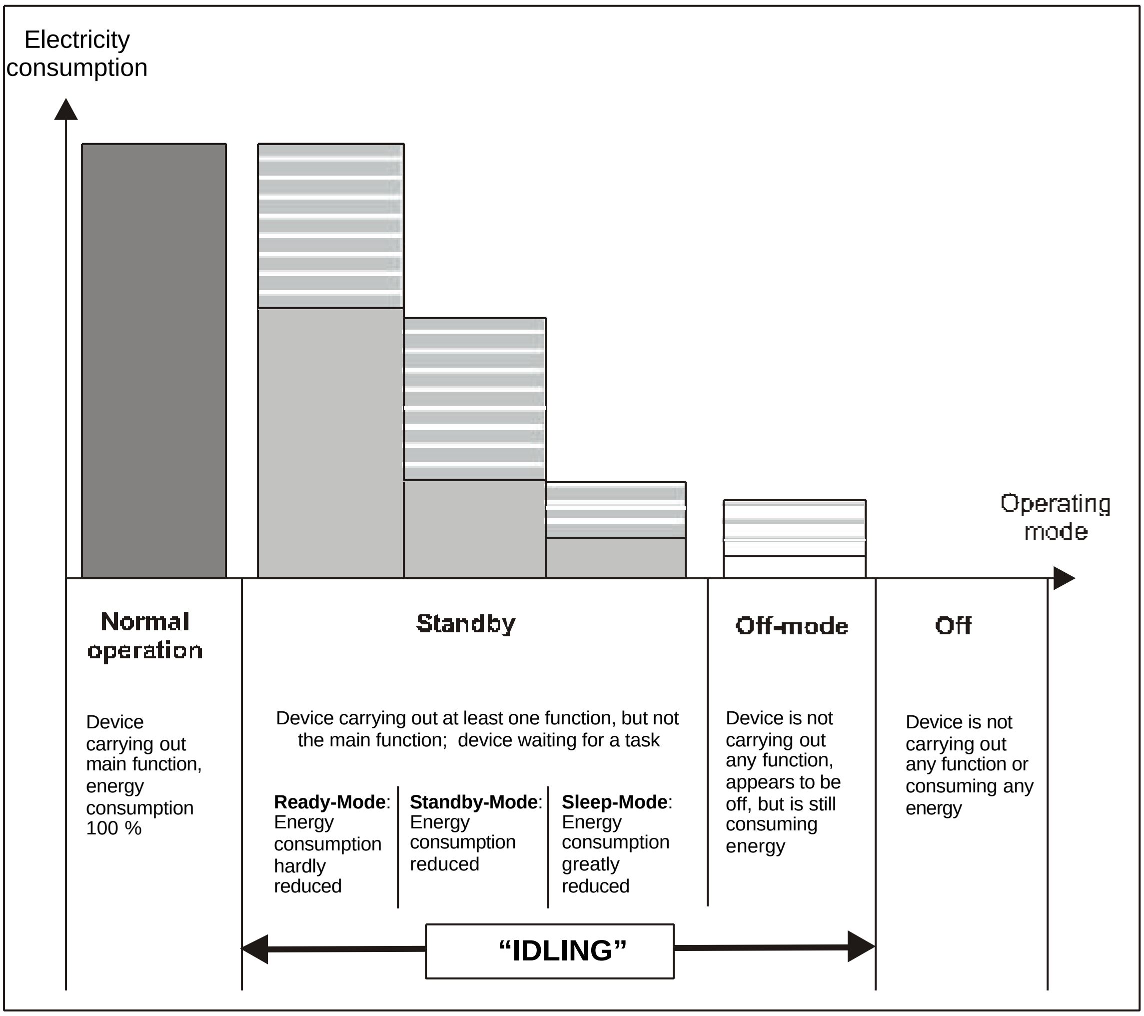
Figure 1-1: Model to determine the power demand of ICT appliances and the associated infrastructure



To determine the individual components of the model, the following methodology was selected:

- systematic analysis of already existing studies, statistics, brochures and manufacturer's information about appliances, the total system of stationary and mobile communication services and their direct and indirect (induced) energy consumption (and reduced demand) as well as expected developments in the near future in Germany.
- Conducting questionnaire-based expert interviews on several groups of appliances for which insufficient data was available. These interviews focused on the sector of telecommunications and data processing infrastructure (mobile communications, fixed network, internet, servers).
- Conducting own measurements for a series of appliances, especially to determine consumption in the off-mode because the current data situation is still relatively poor in this area.
- Own estimations of power consumption and potentials for electricity conservation based on the information gathered for those areas of application for which, up to now, no or only incomplete data are available.

Figure 1-2: The definition of operating modes for ICT devices used in this study



The starting-point for the study was a detailed list with all the main ICT appliances which were examined for Germany with regard to their current stock and energy requirement as well as the expected development up to 2010 (see Table 1-1). This list differentiated between the main functions of entertainment, communication, data processing and intelligent home (wired home), in which the individual appliances were additionally grouped according to functions within a main group. A distinction was made between private households and offices as areas of use. End-use appliances and the associated infrastructure are examined separately. In the latter, a further differentiation was made between in-house infrastructure and the infrastructure of the telecommunications companies.

Table 1-1: List of the ICT appliances and the associated infrastructure considered in this study

Function Main group	End-use appliances Households	 Offices	Infrastructure (in-house) Households	 Offices	Infrastructure of the tele-communications companies
Entertainment (audio, video)	**Audio (stationary)**		**Television**		
	Compact system		Satellite receiver		
	Stereo system		Antenna preamplifier		
	Hifi amplifier		Set-top box		
	Cassette recorder		LNB		
	CD player				
	Minidisc player				
	Audio-DVD player				
	Clock radio				
	Audio (portable)				
	Radio-tape deck				
	Television				
	Cathode ray TV				
	LCD TV				
	Plasma TV				
	TV projector				
	Video recorder				
	Video recorder (analog)				
	Video-DVD player/recorder				
	Cameras				
	Video camera/Camcorder				
	Digital camera				
	Others				
	Video game console				
	Mains power supply [1]				
Communications	**Telefony (fixed network)**	**Cameras**	**Internet-Infrastructure**	**Networking**	**Fixed network**
	Cordless phone	Video camera/Camcorder	DSL splitter	Router (19 inch rack)	Power demand per channel
	Smart phone	Digital camera	DSL modem	Hubs	Power demand per DSL line
	Answering machine	**Telefony (fixed network)**	CATV modem	Switches	**Mobile communications**
	Fax machine	Cordless phone	Satellite modem	**Telephone system**	Mobile base station GSM
	Telefony (mobile)	Smart phone	PLC (powerline communication) adapter	Private branch exchange	Mobile switching centre GSM
	GSM	Answering machine	PLC house coupler	**Others**	Mobile base station GSM
	UMTS	Fax machine	Router (DSL)	Intercom	Mobile switching centre GSM
		Telefony (mobile)	Telephone modem		
		GSM	**Telephone system**		
		UMTS	ISDN box		
			Others		
			Intercom		

[1] Mains power supplies are balanced for the appliances.

Table 1-1 continued ...

Function Main group	End-use appliances Households	 Offices	Infrastructure (in-house) Households	 Offices	Infrastructure of the tele-communications companies
Data processing	**Computer** Personal Computer (PC) Notebook PDA **Monitor** Cathode ray LCD **Printer** Inkjet Laser Matrix **Others** Scanner Copier (Desktop) Active boxes (PC)	**Computer** Personal Computer (PC) Notebook PDA **Monitor** Cathode ray LCD **Printer** Inkjet Laser Matrix **Others** Scanner Copier Projector		**Server** lower price range (<25 k€) medium price range (<100 k€) upper price range (>100 k€) **UPS** for routers for switches for servers (lpr) for servers (mpr) for servers (upr)	**Data centres/DP centres**
Intelligent home	**Household appliances** Microwave Cooker Extractor hood Coffee maker Dishwasher Refrigerator Fridge/freezer combination Freezer Washing machine Dryer Washer/dryer combination **Heating/hot water** Small boilers Hot water boiler Continuous flow Heating system **Security equipment** Surveillance camera Motion detector Operating terminal/monitor Automatic doorlock Alarm systems Smoke detector **Others** Time switches Sensors/actuators Lighting	Not considered for offices.	**Networking technology** Gateway System Central Control Unit Intelligent home bus system	Not considered for offices.	

2 The stock and energy demand of modern ICT appliances in Germany up to 2010

This study centred upon determining the current and future electricity demand of ICT devices and their associated infrastructure using the model described above (Figure 1-1). The main results are presented in a summarised form below. All the input data to the computational model can be taken from the detailed tables in Appendix 1. These include data on the stock, power consumption and times of use as well as the results obtained for the development of the electricity demand of the ICT devices listed in Table 1-1 in Germany for the base year 2001 and the predicted dates 2005 and 2010.

2.1 End-use appliances in private households

Stock development

Determining the stock of ICT end-use devices in German households in 2001 and estimating the development up to 2010 was based on the equipment of households with these appliances. The stock of devices was extrapolated using the number of private households. Following Schlesinger (2001), it was assumed that the number of households in Germany will increase slightly in the near future (especially due to the growth of one-person households) from 38.16 million in 2001 to 38.31 million in 2005 and to 38.5 million in 2010.

The following information sources were used to determine the stock of devices/the household equipment in the base year 2001:

- official or semi-official statistics (Federal Statistical Office, Eurostat, RegTP, OECD, ITU, German Federal Labour Office),
- statistics of associations (ZVEI, GfU, BVT, BITKOM, EITO),
- statistics of market and opinion research institutes (ACTA, Media-Analyse, Verbraucher Analyse, Typologie der Wünsche Intermedia),
- statistics from relevant studies.

These data sources were systematically harmonised in order to obtain a consistent data set for predicting future stocks. For the prediction of future household equipment, saturation values were able to be determined for the majority of not completely new market appliances and the future household equipment was calculated using a non-linear regression analysis from past trends.

The resulting underlying stock development of ICT end-use appliances in private households in Germany for 2001, 2005 and 2010 can be derived from the tables in Appendix A1.1. The following main trends can be ascertained:

- *audio devices*: these are largely saturated markets so that only a slight increase in stock should be expected in the near future.
- The number of *televisions* increases from almost 55 million in 2001 to 59.5 million in 2010, i. e. by about 8 %. Since the majority of households are equipped with at least one (first) television, this increase is mostly caused by the growth in second and third TVs. Even if there are no publicly accessible data on the stock of televisions according to screen technology and size, experts agree that the conventional CRT technology will continue to dominate the market for several years, but will then probably be replaced by LCD and possibly plasma TVs. For this reason, it is assumed that cathode ray TVs are increasingly substituted by LCD TVs and that there is a strong percentage growth in plasma screens within the group of televisions from 2005, although the latter are still likely to only occupy a niche market in terms of numbers even in 2010.
- There has been a strong rise in the number of *video recorders* in households over the past years. This trend can be expected to continue in the future with a further increase in the stock of VCRs by 30 % up to 2010. This is predominantly due to the increased spread of video-DVD players and recorders, whereas the stock of conventional video recorders will decline. However, a complete substitution of conventional VCRs by DVD devices is not expected before 2010.
- Between 2001 and 2010, the stock of *video cameras* or *camcorders* will almost double again, while digital cameras are expected to experience a massive increase in stock from around 2.3 million in 2001 to 19.3 million in 2010. The number of *game consoles* has increased clearly over the past ten years, but strong saturation effects can now be observed so that only a slight future growth is assumed.
- The stock of *fixed network telephones* already reached a level close to saturation several years ago in Germany. Recently a clear structural shift - relevant for power consumption - within the stock of appliances away from simple telephones to so-called "smart phones" (multi-function) with many additional functions as well as to cordless phones consisting of a base station and one or more handsets has begun. This trend will continue in the near future so that further growth can be expected in the numbers of these devices.
- There has been enormous growth in Germany among the number of users of *mobile communications* especially since 1999. For 2001, the number of actual mobile users is estimated at 47 million. The total number is frequently given as higher than this[4], but it can be assumed that there are many unused telephones

4 For example, NGO Infratest (2001) assumes 65.9 million mobile communications users in 2001.

and mobile communications connections that are not relevant with regard to electricity consumption and are thus not considered here. A continued increase of mobile communications users up to around 70 million by 2010 is expected. In spite of the currently still uncertain development prospects of UMTS, following Büllingen/Stamm (2001), it is anticipated that, by 2010, there will be roughly the same diffusion of UMTS and today's predominant GSM devices.

- The number of *computers* in German households totalled around 21.2 million in 2001, including 2.6 million notebooks. A continued increase by 30 % is expected up to 2010, in which the greatest growth is in the number of notebooks. The trend towards mobile IT and telecommunications which can be observed in many sectors, can also be seen in the growing number of *PDAs* (Personal Digital Assistant). Around 7.5 million appliances are estimated up to 2010 and thus a much higher prevalence than today (2001: around 2.8 million appliances).
- The overall number of *computer monitors* increases parallel to the number of desktop PCs. Up to 2010, today's customary CRT monitors will be successively replaced by the thinner LCD displays, although this development will probably take place at a slower pace in households than in offices due to the relatively high prices for LCD screens. *Printers* also form part of the standard equipment of an ordinary PC household in Germany so that the development here will probably mirror that of PCs.

Power consumption of the appliances

The respective power consumption selected for the base year 2001 in normal, standby and off-mode operation is mainly based on values found in the literature or own measurements. The estimates made for 2005 and 2010 take into account both expected increases due to higher performance requirements and expected decreases in power consumption due to autonomous technical progress or already ongoing measures to increase energy efficiency.

The power consumption for all the ICT end-use appliances in households selected in the study can be drawn from the tables in Appendix A1.1. The power consumption of the appliances in the modes distinguished in this study - normal, standby, off-mode - develops in opposite directions in some appliance groups between 2001 and 2010:

- a decrease in power consumption between 2001 and 2010 is only assumed for a very few appliance groups in *normal mode.* Technical possibilities to reduce the electricity demand are usually compensated or frequently even overcompensated by increased performance or additional functions. This is especially valid for ICT appliances so that the assumption of a constant power consumption seems plausible. On the policy side as well there are as yet no measures to reduce the energy demand in normal mode worth mentioning (see Chapter 6). For these reasons, a constant power consumption in normal mode between the base year 2001 and 2010 is assumed for appliances which are technically already very mature and for which no strong demand is expected for higher performance or complex additional functions. This applies to all audio devices, video recorders, cameras, fixed network telephony devices, PDAs, many peripheral devices of PC use (LCD displays, printers, scanners, active boxes) as well as copiers and projectors. The continuous drop in the power consumption of appliances observed in recent years is assumed to continue only for mobile phones. Exactly the opposite, i.e. a future increase in power input, is anticipated for several appliances due to continued increases in performance or convenience requirements which overcompensate the technically possible consumption reductions:

– the electrical power in normal mode is currently around 75 W on average for televisions with today's predominant cathode ray tube technology. It was assumed for the near future that the share of appliances with large screens and higher frequencies (100 Hz) will continue to increase, so that the average power consumption up to 2010 could increase to approx. 120 W. Televisions with LCD technology have a much lower electrical power consumption (2001: approx. 40 W). Again, an increase - albeit a moderate one - to 50 W is anticipated here by 2010.

– For game consoles, the measured values showed that the new appliances from Sony and especially the Microsoft X-box have much higher power requirements than the previous appliances. The trend towards increased performance due to increasingly complex games will probably continue in the future so that a clearly increasing power consumption is expected here as well up to 2010. The same applies to PCs and notebooks, at least in the household sector it is assumed that the trend towards ever more powerful appliances with correspondingly high electricity demand will persist in the future.

- It is also anticipated that the power consumption will remain constant in *standby mode* for most ICT end-use appliances in the household sector. A decrease, albeit a moderate one, up to 2010 is assumed for televisions and video recorders because of the manufacturers' voluntary self-commitment here at EU level. No significant changes in power consumption are expected for the *off-mode operation* for most groups of appliances under the present conditions up to 2010.

Operating times of the appliances

The respective operating times in the various operating modes are the third significant component determining the electricity demand of ICT end-use appliances (see Figure 1-1). Independent surveys can be used to a large extent to determine operating times for the household sector, although these only cover the normal mode of these appliances. Media studies have been carried out in the Federal Republic of Germany since the 1960s. For instance, the eighth survey of the ARD/ZDF-Studie Massenkommunikation, which was first conducted in 1964, is now available for

2000 (see van Eimeren/Ridder 2001). In addition, data of Media Analyse (MA) can be used for the analysis of media operating times. The MA is the largest comprehensive survey conducted in the Federal Republic of Germany[5]. The division of the remaining operating time in to stand-by, off-mode and off is mainly based on own estimations which in turn are based on figures in the literature. Furthermore, it was possible to refer to a current survey of the Initiative Energieeffizienz[6] on the behaviour of German citizens with regard to the standby operation of their electronic appliances (dena 2002).

Up to 2010 a slight increase of the viewing time of 10 % is estimated for televisions and video recorders and a much larger 30 % increase in use for PCs and auxiliary devices. There are no significant changes expected in operating times for the other appliances in normal mode. For some appliances (especially televisions) it is also assumed that the off-mode is successively replaced by the standby mode, due to new concepts of use as, e. g. digital video broadcasting.

2.2 End-use appliances in offices

Stock Development

Compared with the household sector, the available data on the stock of relevant ICT end-use appliances in offices, i.e. computers with all peripheral devices, as well as office communication devices (see Table 1-1) are much poorer. To determine the current stock as well as its development up to 2010, a similar approach was applied as in the private households. The estimate is made using the number of employees in office occupations or similar activities[7] as well as the equipment of office workplaces with information and communication end-use appliances.

The group of those employed in office occupations or persons included with similar activities has become considerably more significant over the past few years. Today

5 The MA is sponsored by the non-profit organisation Arbeitsgemeinschaft Media-Analyse/ AG.MA) which unites the 250 most important companies in the advertising industry. Using surveys, the MA researches media utilization behaviour in Germany for daily papers, magazines and also appliances of consumer electronics in the total population and their subgroups.

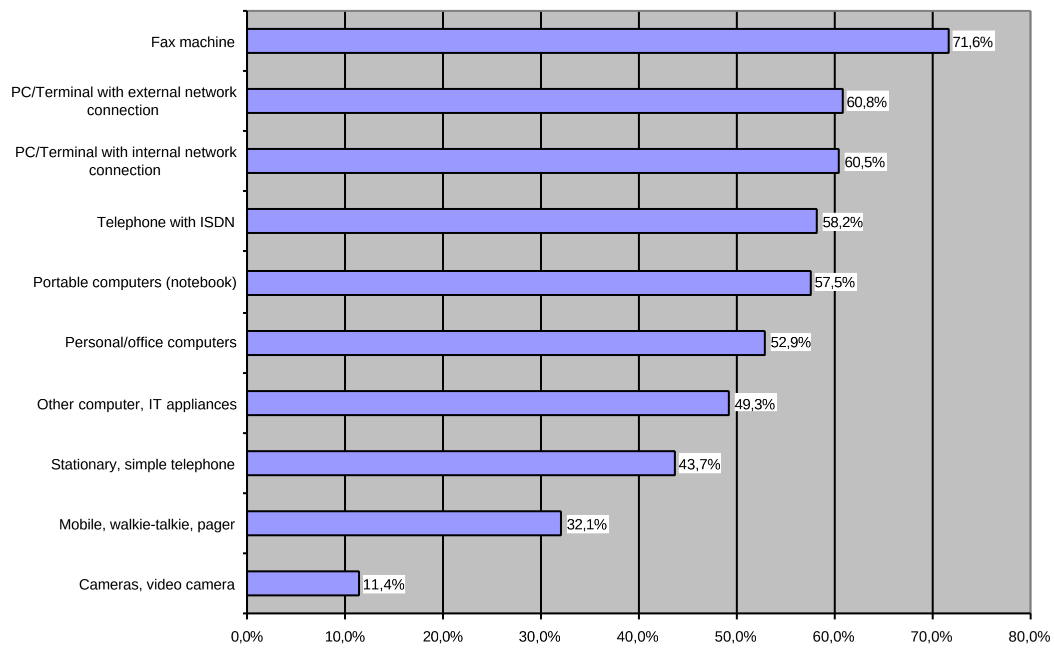
6 The Initiative Energieeffizienz (Initiative Energy Efficiency) was launched in Autumn 2002 to promote electricity efficiency and is financed by the Associations of the Energy Industry (VDEW, VRE, VKU Association of Local Authority Enterprises) and the German Energy Agency (dena) and supported by the Deutschen Bundesstiftung Umwelt (DBU) and the Federal Ministry of Economics and Labour.

7 Research and development activities, organisation and management, trading activities with managerial tasks, legal advisors or similar, publishing and artistic work, other consultation and training activities.

almost every third working person in the Federal Republic of Germany is employed in desk work (Troll 2000c). In 2000, this equalled around 11.75 million persons. A projection study on employment activities in Germany (Weidig et al. 1999) was referred to when estimating the future development. In accordance with this, the number of employees in the office sector is likely to increase to around 12.6 million by 2010.

The best source for data on ICT end-use appliances in office workplaces in Germany proved to be the most recent 1998/99 survey on qualifications and employment in Germany (Dostal et al. 2000; Troll 2000a-d). The information from this survey thus forms the main base for estimating the current stock and the expected market development of ICT appliances in offices. Supplementary statistics from associations[8] and market and opinion research institutes were referred to in individual cases. Figure 2-1 gives an overview of the use of ICT end-use appliances in offices in 1999.

Figure 2-1: ICT end-use equipment (in %) in offices in Germany in 1999



Source: Troll 2000c; own calculations

8 The European Information Technology Observatory (EITO) should be emphasised here which has published a European yearbook for the information and communications technology industry since 1993, in which the development in Germany is also documented (EITO 1993ff.).

The number of ICT end-use appliances in offices estimated for the base year 2001 as well as for 2005 and 2010 is the product of the number of employees and the respective degree of equipment. All stock figures can be taken from the detailed tables in Appendix A1.3. The following trends in development emerge:

- in the field of communication, almost all the office workplaces in Germany today are fitted with *fixed network telephones*, approx. 40 % still with simple telephones (see. Figure 2-1). Their number will decrease strongly up to 2010, whereas the number of smart and cordless phones, which are relevant for power consumption, will increase by one third from 15.8 million in 2001 to 21.7 million in 2010. In contrast, a saturation effect can be observed for *answering machines* which are predominantly widespread in small offices since these devices are being increasingly integrated. A stock increase of 3.5 to 5 million is anticipated for *fax machines*, at least up to 2005 and in spite of the substitution effect of e-mail (especially in the smallest firms and start-ups) since businesses want to be able to maintain contact with customers via various media. In doing so, however, companies will increasingly turn to multifunctional devices. The number of *mobile phones* used for business purposes was accounted for in private households since these devices are person-related and it is very difficult to segregate personal and business use.
- It is estimated that *computers* in offices will continue to increase from around 17.7 million today to almost 24 million in 2010. However, this is entirely due to the expected strong growth in notebooks and PDAs in particular, whereas the number of desktop PCs, which are still predominant today, will probably drop slightly from 10.5 to 10 million in 2010. Accordingly, the number of monitors will not continue to increase. The share of LCD screens, which is only around 10 % today, will grow to roughly 40 % in this period. Only a slight increase in stock is expected for *printers and scanners* in this decade. The same applies to *photocopiers*.
- *Cameras* are only present to a small extent in companies today and are not likely to form part of the typical office equipment in the future. A slight increase is only expected for digital cameras from 12 % today to about 15 % by 2010.

Power consumption of the appliances

The power consumption of the ICT appliances used in offices should not differ significantly from those used in private households as long as the performance requirements made are also comparable. In these cases, the same assumptions were made for both sectors about power consumption in the three different operating modes. This applies to cameras, telephones and answering machines, PDAs, matrix and inkjet printers as well as active boxes (see also Appendix A1.3).

For other appliances, the performance requirements for offices are much greater and the appliances are bigger than those in private households so that the electricity demand in normal, and usually also in standby mode, is correspondingly higher. This applies primarily to fax machines, laser printers and photocopiers. The monitors used in offices tend to be bigger than those at home and the power consumption in normal operation will probably be greater as a result. In contrast, for PCs and notebooks, it is assumed that the capacity of today's appliances is completely satisfactory for the majority of office applications and that increasingly secondary features such as noise reduction development (Windeck 2001) or energy demand will come to the fore. Accordingly, the continued increase in power demand of computers assumed in the household sector is not expected in offices (for PCs), or not to the same extent (for notebooks).

Generally, under the present conditions in the office sector, there are no major changes in the power consumption of ICT end-use devices expected for the period 2001-2010. For some types of appliance, the power demand might decrease slightly in standby mode only, also as a result of policy measures such as introducing voluntary quality labels or procurement activities (see Chapter 6).

Operating times of the appliances

Unlike households, there are no regular surveys of the operating times of ICT appliances in offices. The operating times selected here for the various operating modes represent own estimations based on existing figures in the literature.[9] No significant changes in operating times are anticipated in offices up to 2010.

2.3 In-house infrastructure

Internet infrastructure in private households and offices

Unlike the other areas, broadband internet connections cannot be separated into households and companies since there are no differentiated data available. Indeed, there is little point in making such a distinction in many cases. For example Internet access via DSL is a technology especially suited to small businesses which are often not able to be strictly demarcated from private households. This area is accounted for under the infrastructure of private households (see also the tables in Appendix A1.2 with all the assumptions on stock development, power consumption and operating times).

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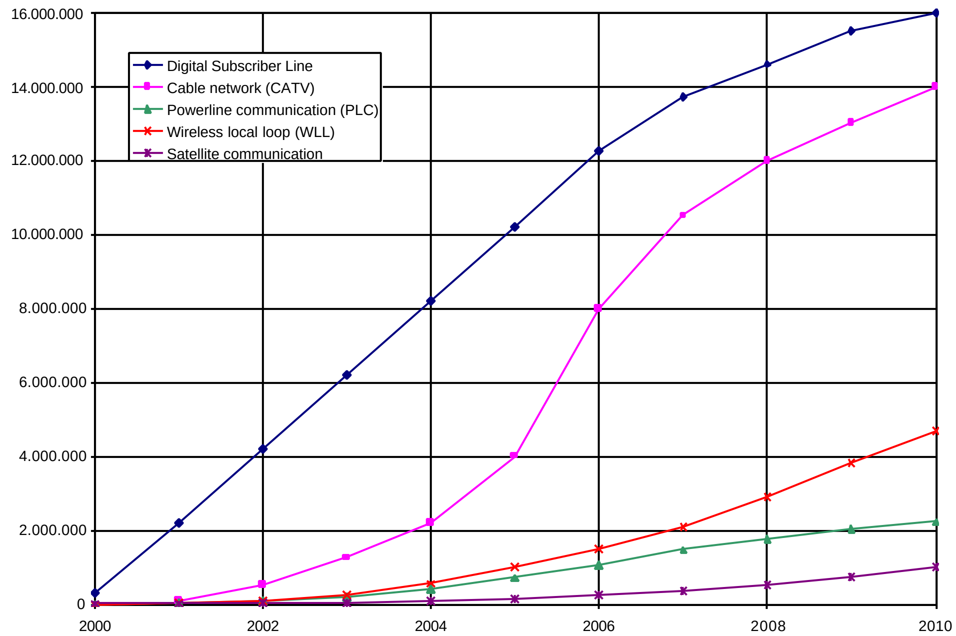
9 The following main assumptions are made: the appliances are in operation during the usual office hours for an average of eight to ten hours and for 220 working days per year. During this time, the appliances are not in continuous use but are permanently on standby.

There has been a strong growth in demand for fast Internet access using broadband technologies in Germany over the past few years. Overall, however, these technologies are still of secondary importance at present and narrowband analog modem and ISDN connections continue to dominate. In this survey it is assumed that the **stock** of external *telephone modems* will plummet in the near future and will no longer feature at all in 2010. The high diffusion of *ISDN* in households in the past was a result of increasing private Internet use. It is therefore assumed in this survey that the number of ISDN connections will continue to increase in the future and then ultimately be replaced by broadband transmission technologies (BDRC 2001).

According to the assumptions made here, the total number of *broadband Internet connections* in Germany will climb from around 2.4 million in 2001 to almost 38 million in 2010.The internationally dominant *DSL and cable-television operators (CATV)* will take the leading role here. Since telephone connections are much more widespread in Germany than cable network connections, DSL will probably become the most used access technology. Here, it is assumed that about 16 million DSL and around 14 million CATV connections will be installed in 2010. In comparison, other broadband transmission technologies such as *Powerline Communication (PLC)* which uses the electricity mains, so-called *Wireless Local Loop (WLL)* or *satellite connections* will only be of secondary importance (see Figure 2-2).

Figure 2-2: Development of the number of broadband Internet connections in Germany up to 2010



Source: Büllingen/Stamm 2001; postal and telecommunications regulatory authorities; own calculations

The **power consumption** of the appliances necessary for broadband Internet access - two devices each are necessary for DSL and PLC - does not vary significantly. It is true that the electricity demand of PLC technology is slightly lower than for DSL or CATV, but there are considerable uncertainties associated with the figures assumed here. Only satellite modems have a power demand which is almost double that of the other transmission technologies, but these are of secondary importance in terms of stock. The respective **operating times** of the appliances in the various operating modes were estimated.

Television infrastructure

The television infrastructure can once again be clearly assigned to the household sector and is accounted for here (see Appendix A1.2). The television technology change from analog to digital services also results in changes in the appliances used. The appliances of the analog infrastructure are mainly restricted to antenna preamplifiers and analog satellite receivers (Satellite-IRD). In contrast, set-top boxes are increasingly used in digital TV, since the digital signal has to be transformed into an analog one. This function could also be integrated into television sets in future, assuming a standardised protocol for all transmission channels (terrestrial, via cable and satellite). However, it is generally assumed that this will not have taken place to any significant extent by 2010.

Three types of systems are installed in private households in Germany at present to receive television broadcasts: about half the households are connected to a broadband switching network, a further third have a satellite receiver. The remainder, almost 15 % of the households, still have the traditional terrestrial reception via outdoor or indoor antennas. In the future there will probably only be minor changes to this structure, i.e. both the current number of *cable connections* (18.1 million) and *satellite systems* (12.2 million), which experienced strong growth in the 90s, will only increase slightly up to 2010. The same is true for the number of *antenna preamplifiers* which are generally necessary for terrestrial TV reception and sometimes required for cable TV (if the signal strength is insufficient).

The number of *set-top boxes* needed to receive digital TV will increase, but probably not to the extent which was rather optimistically assumed in the recent past. According to information of the ARD (2001), only approx. 6 % of households currently use digital television. This means that about 2.3 million corresponding receivers are installed. According to experts' appraisal (among others DocuWatch Digitales Fernsehen 2001), there are hardly any indications at present of a marked acceleration in the spread of these devices. It is therefore assumed that, up to 2005, just over 4 million and, by 2010, approx. 7 million set-top boxes will be installed in German households to use digital television.

The electrical **power consumption** of satellite receiver systems in normal mode is about 20 W and is still around 9 W in standby mode. Since these appliances are not fitted with an off-switch with which they can be completely disconnected from the mains, they thus cause considerable permanent electricity consumption. In addition, another device is necessary for satellite reception, the so-called LNB (Low Blow Converter), with a power consumption of around 4 W in normal and standby mode and which is thus comparable with that of an antenna preamplifier. At 17 W, the power demand of set-top boxes is currently just under that of satellite receivers. However, for the projection to 2010, an increasing power consumption in normal mode is assumed on account of the further development of these devices beyond pure reception and decoding functions towards multi-media platforms. The **operating times** observed today will also increase in the future due to the greater variety of uses which become possible.

Network infrastructure in offices

The main elements of the network infrastructure in offices are

- *servers*, i. e. computers in a network which supply other computers with various services (such as data storage, providing databases or Internet presence or handling e-mail communication) ,
- *hubs and switches*, via which the computer and peripherals are linked in an enterprise network as well as
- *routers*, which connect two spatially separated networks or networks with different protocols.

The data on how German businesses are equipped with these appliances is very poor and the few existing data are usually not freely accessible. The stocks assumed here were therefore extrapolated from existing data and expert estimations, in which, among others, the results of a comprehensive Swiss survey of server distribution (Gubler/Peters 2000; Huser 2002) were transferred to Germany. The results of these estimations are shown in detail in the tables in Appendix A1.4. For the development up to 2010 it is assumed that the current stock of these appliances in enterprises will grow by a good 50 %. The high growth rates of 10-15 % annually experienced in the past are thus not sustained, but the influence on the future power demand is still considerable since the electrical power consumption of routers and especially servers is very high and all appliances are usually operated in normal mode all year round without a break.

To estimate the energy demand, the servers were divided into three classes of size or price (small, medium and very large). The majority of devices fall into the lowest class for which an average power consumption of 150 W was assumed for 2001. The average power consumption of medium-sized appliances was estimated to be

800, that of very large servers 2500 W. In the medium term, it can be assumed that the effective output of servers will continue to grow and thus also the specific energy demand per appliance. This is because optimising energy demand has only played a subordinate role so far among IT infrastructure appliances, the main criteria are primary power, costs and reliability.

The so-called *uninterruptible power supply* (UPS) should not be neglected when regarding the current and future power demand of the network infrastructure in offices. This is used to connect appliances which have to be fail-safe. These usually include servers, routers and switches. The energy demand of these systems can be determined using their operating efficiency which today equals almost 90 % and should improve slightly in the next few years.

Excursus: Data Centres

There is no generally valid definition for the term *data centres*. In a wider sense, it can include all the buildings or parts of buildings which house ICT appliances and which are not directly associated with a specific user. In a more restricted sense, so-called "server farms" are understood to be data centres in which data and services for Internet applications are stored and performed and for which dramatic growth – at least locally –has been forecast in recent years.

Data centres were interpreted in the more restricted sense in this survey and taken as a main example for the increasing significance of the energy demand of the infrastructure for ICT end-use appliances and the possible local concentration of electricity demand which is linked with this development. The appliances situated in data centres were already accounted for under office infrastructure (see Appendix A1.4). When accounting for the energy demand of ICT infrastructure appliances, it is of secondary importance where these appliances are situated - in an office or a server farm.

Apart from that, a separate estimation of the energy demand of data centres is even more difficult, given the current data situation for Germany, than the quantification approach selected for the entire appliance stock in companies (or outsourced in data centres) and their power consumption.

Once the term has been clearly defined, two approaches are widespread to quantify the energy demand of data centres:

- in one approach, the floor space is taken as a base and a specific power consumption for the area (in W/m²) is determined. The electricity demand of data centres (in kWh/m²) is then calculated using the electrical power consumption per unit area and the time of use. This method of calculation has been applied internationally by, e. g. Mitchell-Jackson (2001) and Beck (2001) for the USA and by Hartkamp (2002) for the Netherlands, and usually includes the energy necessary for operating the infrastructure, especially UPS and heat removal.

- Alternatively, the number of ICT appliances used in data centres can be taken as a base and the energy demand calculated using the expected annual electricity demand of the individual types of appliance. In this case, the energy required for operating the infrastructure (power supply, heat removal) has to be additionally taken into account. There are various surveys using this approach (Spreng/ Aebischer 1990, Aebischer et al. 2002 and Huser 2002 for Switzerland, Roth et al. 2002 for the USA and Thomas/Barthel 2001), which are, however, based on data centres in its wider sense and which only include the electricity demand of the appliances themselves and not that required by the infrastructure.

Since, for Germany, there are neither data on the surface areas of data centres, nor on the number of appliances installed there, the energy demand of data centres operated here can only be derived by transferring the data available from the above cited surveys of other countries. The appliance approach for the power demand of data centres in its wider sense yields a typical share of 0.5 % of the total electricity demand of a country. If the power demand to operate the necessary infrastructure is also included, 1 % of the power demand of a country should be a plausible order of magnitude. The approach using the floor space of data centres in its more restricted sense yields values between 15 and 50 kWh/inhabitant. For Germany, applying these figures would mean that between 10 and 25 % of companies' ICT infrastructure appliances are operated in data centres.

Whether this share will increase decisively in future, i. e. whether businesses prefer a continued outsourcing of IT services or their direct control in in-house computer centres or server centres, is very difficult to judge at present. For reasons of efficiency, outsourcing to larger data centres has benefits since computing, communication and storage can be performed by larger appliances with a lower specific energy demand. Furthermore, appliances operated by service companies have a higher utilisation ratio since it is their core business to utilise their systems as efficiently as possible. Recent surveys assume a fairly moderate growth rate. For Switzerland, an annual growth of almost 2 % is anticipated (Aebischer et al. 2002), for the USA, the relevant estimates are between 1.8 and 6.1 %/a (Roth et al. 2002).

2.4 Infrastructure of the telecommunications companies

Fixed network infrastructure

The fixed network infrastructure can be split into the local exchange network and the long-distance network. The local exchange network transports voice or data information from the end-use appliances of the user to the transfer points to the long-distance network. The transmission technology used ranges from analog connections via ISDN to the various broadband connections such as DSL. The long-distance network then takes over the data transmission from the transfer point of the local exchange networks. Connections are bundled and compressed when transmitted over greater distances. In Germany, the main supplier of fixed network connections is the Deutsche Telekom AG, but other network operators such as Arcor AG, Tesion or Netcologne are also represented on the market.

Determining the power demand of the communication and transmission technology of the fixed network operators was based on the same methodological approach as for the other ICT appliances (see Figure 1-1). The number of telephone channels was selected as the stock variable and multiplied by the specific power consumption of the channels. Differentiating the power consumption according to various operating modes is generally not necessary for the telecommunications infrastructure since the systems are in permanent operation (see Appendix A1.5 for the detailed results of the calculations).

Taking into account data from the German Regulatory Authority for Telecommunications and Post (RegTP 1999ff, 2001), around 50.3 million *telephone channels* are assumed for 2001, this number will grow to about 55.5 million by 2010. After 2005, only a greatly flattened growth is anticipated. The *specific power per telephone channel* was approximately 2.4 W in 2001, based on information of the Deutsche Telekom (2001) and the RegTP (1999ff, 2001). In 1997 this figure was around 3 W, however, no further significant decrease is expected in the near future. DSL connections have to be dealt with separately, since additional modems have to be installed for these, which, today, also require a power consumption of 2.4 W per link, although this could drop by about one third in the near future.

Mobile communications infrastructure

Mobile networks, today based on the dominant GSM standard (Global System for Mobile Communications) or the future UMTS standard (Universal Mobile Telecommunications System), are so-called hybrid networks. They consist not only of pure radio links but a considerable part of the communication takes place via grid-based transmission using copper, or optical fibre cables. Two mobile phones do not connect with each other directly, but are linked via stationary transmission/reception installations and switching centres. Here, a distinction was made between *base stations* and *switching centres*. The power demand of the mobile communications infrastructure results from the number of base stations and switching centres and their electrical power consumption. Since the UMTS network represents a completely independent network which has to be constructed from scratch, the two technologies have to regarded separately.

Based on the official data of network operators and the additional interviews conducted for this study, the number of GSM base stations totalled 50 700 in 2001 with an additional 230 GSM switching centres. It is not expected that these will decrease up to 2010 despite the anticipated start of UMTS operation in 2003. Instead a moderate extension of the GSM network is predicted since, according to experts, the existing GSM network will still be needed, i. e. a coexistence of both networks is assumed. Almost 80 000 additional UMTS base stations and about 330 switching centres are reckoned with up to 2010.

The electrical power consumption for UMTS stations according to manufacturer and expert information is more than double that for GMS stations. Since a moderate reduction is expected for both fields in the near future, no major changes will affect this ratio up to 2010. The expected parallel construction of a UMTS network thus has serious consequences for the development of electricity demand in Germany (see Appendix A1.5 for details).

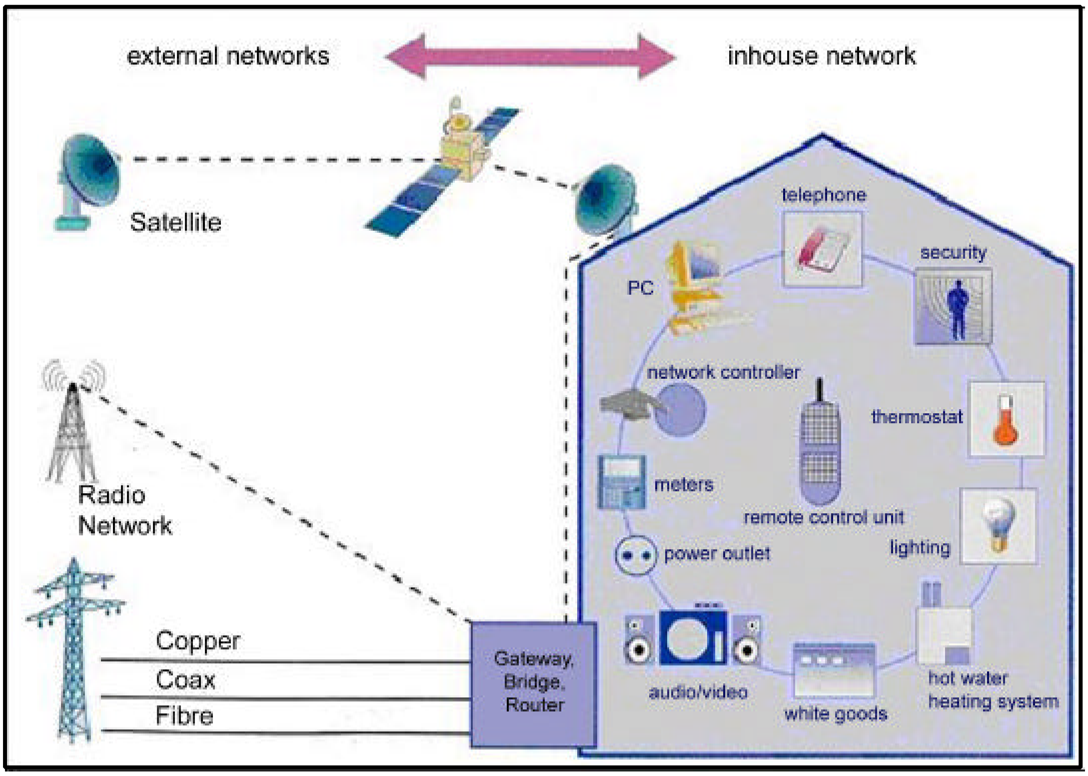
2.5 Intelligent home

Alongside the power demand caused by ICT appliances themselves which was dealt with in the previous sections, there are also advanced or indirect impacts of ICT applications on energy demand. These include both over- and under-consumption occurring in the ICT sector itself and in other fields (e. g. space heating, transport). These effects are described below using the example of the "networked house."[10]

In a networked house, some or all - in principle, already existing - electrical and electronic appliances and energy technology systems are connected with each other via a communication system. Connecting to the external network is done using a centralised gateway which is designed for broadband applications (Figure 2-3).

10 In the full version of this study, other areas examined included "substitution of ICT applications", "telecommuting" and "e-commerce". The biggest effects in the sense of achievable energy savings due to increased ICT applications in other consumption areas resulted for the transport sector.

Figure 2-3: House with external and internal networks



Source: Fraunhofer Gesellschaft (www.inhaus-nrw.de)

On the one hand, networking the house causes an additional energy demand determined by the electrical power consumption of the central gateway, the power supply of the controlling devices for the household technology (heating, hot water, lighting, security) as well as the network technology for the large electrical household appliances for cooking, cooling/freezing and washing/drying (Aebischer/Huser 2000). For an average house, this energy demand depending on the networking technology involved is estimated at approx. 70-115 W.

On the other hand, there are possible energy savings due to networking, mainly effected by improved monitoring and control of the household technology. In Germany, modern, computer-controlled systems for heating have not been installed in many buildings so far. The vast majority are only fitted with a simple control which is basically limited to pre-set temperature reductions, especially overnight. Without house networks, this will probably not change much in the future, so that a large share of the energy savings achievable using optimum control is to be assigned to such household networking. Kleemann et al. (2001) estimate the saving achievable with automated room temperature control at 20 to 30 kWh/m² for individual buildings. This would be equivalent to a saving rate in the order of 15 to 35 % in buildings which comply with the Thermal Insulation Ordinance. The saving effect of a heating control in a networked home is estimated in the order of 20 to 30 % by the Enquête Commission "Sustainable Energy Supply" (2002).

To estimate the net effect of household networking on energy demand, the avoided heating energy demand in residential buildings was compared with the increased power demand due to the networking. Based on the stock numbers for residential buildings and assumed penetration rates of between 2 and 5 % of household networking, an additional demand for electrical power of 700 GWh is set against a reduced demand in heating energy of 1870 GWh. If the effects are compared based on the use of energy source, an additional demand of 1610 GWh results for the electricity supply and a saving of 2390 GWh in energy sources for generating heat. The net effect in the sense of a slight energy saving through household networking is thus not very marked, especially taking into account the large uncertainties attached to this relatively rough estimation.

Overall it can be concluded that, in line with current knowledge, intelligent homes will probably not be a driver for increasing energy efficiency. The possible net energy savings will rather be a positive side effect if optimum control of the heat supply results is effected by the house networking, which would not have taken place without this development.

2.6 Summary of the results

According to the bottom-up analysis of the individual appliances conducted here, the total electricity demand for the use of ICT in households and offices in Germany amounted to around 38 TWh in 2001 (see Table 2-1). This is equivalent to a share of almost 8 % of the overall electricity consumption of final energy sectors in Germany, which totalled 484 TWh in 2001 (AGEB 2002). With reference to the total final energy demand, the 38 TWh denote a share of 1.4 %. A further increase of the power demand for ICT by about 45 % to 55.4 TWh is anticipated up to 2010. This is equivalent to an annual growth of 4.3 %. If the total electricity consumption forecast by Prognos/EWI (1999) of 520 TWh for 2010 is taken as a base, the share of the electricity demand for ICT purposes would already amount to almost 11 % in 2010.

Table 2-1 shows the development of the electricity demand for ICT purposes differentiated according to areas of use and operating mode. This is illustrated below in more detail.

Table 2-1: Overview of the development in electricity demand for ICT appliances and associated infrastructure in households and offices in Germany between 2001 and 2010

2001	Electricity demand (GWh)			
	Normal	**Standby**	**Off-mode**	**Sum**
ICT appliances in households	10279	6987	1849	19115
ICT appliances in offices	4575	2584	628	7787
Household infrastructure	1102	2108	192	3402
Office infrastructure	5153	273	0	5425
Infrastructure telecommunication	2250	0	0	2250
Total	**23359**	**11951**	**2669**	**37979**
2005				
ICT appliances in households	13269	7855	1735	22858
ICT appliances in offices	4330	2759	516	7604
Household infrastructure	2363	2146	186	4695
Office infrastructure	7454	273	0	7726
Infrastructure telecommunication	3560	0	0	3399
Total	**30975**	**13032**	**2436**	**46282**
2010				
ICT appliances in households	15296	7708	1459	24463
ICT appliances in offices	4463	2687	479	7629
Household infrastructure	4060	2212	156	6428
Office infrastructure	10829	273	0	11101
Infrastructure telecommunication	5803	0	0	5803
Total	**40451**	**12880**	**2094**	**55425**

Energy demand according to use

In 2001, the energy demand for ICT is clearly dominated by end-use appliances in households, which account for about half of the total electricity consumption. However, this dominance will weaken in the near future since the largest growth in consumption is not found among ICT end-use appliances - this increases by almost 30 % in households, but decreases slightly in offices - but in the ICT infrastructure. An increase in the power demand of the household infrastructure by 90 % is expected by 2010, it will more than double for the office infrastructure, and the power demand of the infrastructure of telecommunications companies will grow by more than 150 %. This extreme growth can be clearly ascribed to the planned construction of the UMTS mobile communications networks, which have an even higher power demand than the existing GSM networks. The servers have the largest share in the growth in demand of the office infrastructure. Both the stock of servers and the average power consumption per unit will increase strongly[11]. The more moderate increase in the power demand of the household infrastructure can be attributed to both the television infrastructure (especially to the growth in digital set-top boxes) and the internet infrastructure (especially the growth of broadband Internet connections). The slight fall in the power demand of office end-use appliances expected up to 2010 is mainly due to the more energy-efficient LCD monitors being substituted for cathode ray monitors, as well as the substitution of desktop-PCs by the more efficient notebooks. Among household end-use appliances, the electricity demand continues to grow for televisions (mainly caused by longer times of use in normal and standby mode and the trend towards devices with large screens and higher frequencies) and video recorders (caused by the growing diffusion of DVD players which, however, will only slowly substitute conventional video recorders), as well as for personal computers (caused by the use of increasingly powerful appliances with higher power consumption and longer operating times).

Energy demand in the various operating modes

The growth in energy demand is primarily caused by operation in normal mode. This is mainly attributable to the fact that the majority of ICT appliances and systems in the two strongest growing consumption sectors - office infrastructure and the infrastructure of telecommunication appliances - such as servers or mobile communications systems, are operated almost exclusively in normal mode.

In the applications, in which standby mode has a high share in the total electricity demand, namely among ICT end-use appliances and the household infrastructure, a clear increase can be registered at least up to 2005. Overall, the energy demand in this mode rises by 9.0 % from 2001 to 2005. This is followed in the second half of the decade by a marginal drop by 1.2 or 0.2 % per year according to the calculations. This is also a result of the efforts already undertaken to increase energy efficiency which specifically concentrate on this operating mode (see Chapter 6). However, the fact that the decrease is only marginal clearly shows that their effect is not sufficient to really significantly lower the power demand for standby mode.

Only the power demand caused in the off-mode really decreases in the period under review by 21.6 % from 2001 to 2010. The biggest share of this reduction in consumption is not due to an explicit increase in efficiency, but rather that the off-mode

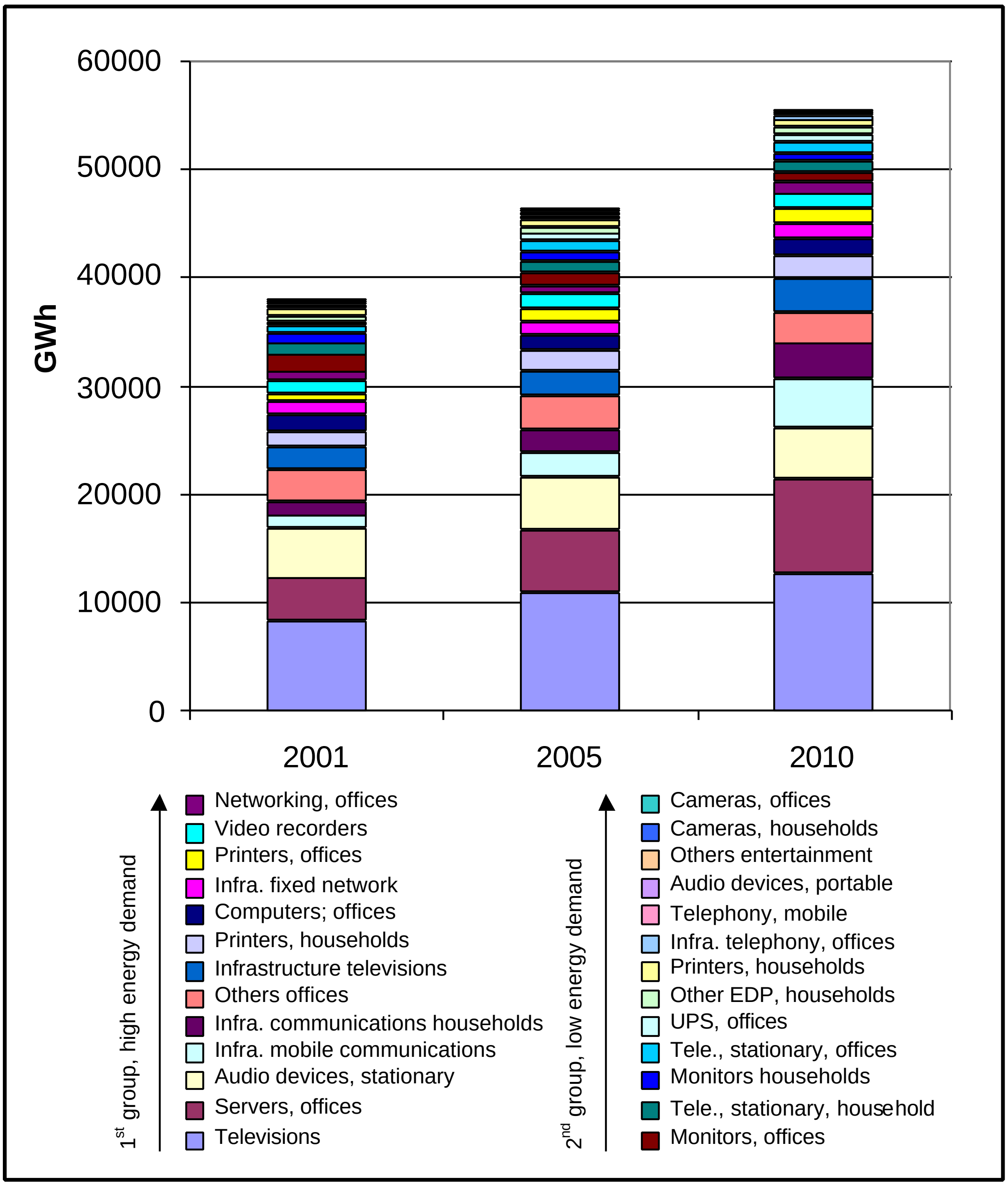
11 The energy demand for the air conditioning of server rooms which is also relevant in this context is not considered in this study since this does not directly involve ICT appliances. A range from 20 to 50 % of the energy demand of the server is cited in the literature as being necessary for air conditioning (Roth et al. 2002; Koomey et al 1999). If a rather cautious value of 25 % of the demand for IT appliances is assumed for Germany, and it is presumed that a small proportion of simple servers are not operated in air-conditioned rooms, then around 930 GWh have to be added to the above cited figures for air conditioning in 2001; in 2005 this increases to 1890 GWh and 3 TWh in 2010.

is replaced by standby mode in several appliances up to 2010, especially televisions. This is an effect of new concepts of use resulting, for example, from digital video broadcasting. Independent of this, an off-mode loss of 2.1 TWh (or almost 0.5 % of the expected total electricity consumption) in 2010 can still be assessed as too high from the viewpoint of energy efficiency and ultimately superfluous.

Energy demand in appliance classes

Examining the energy demand of ICT according to the classes of appliance considered shows that more than half the energy demand from 2005 is distributed over four appliance classes and over 80 % is spread over 10 of 26 classes (see Figure 2-4). The three appliance classes with the greatest energy demand - televisions, servers in offices and audio devices - already held their dominating role in 2001 and retain this throughout the whole period under review. The significance of the infrastructure of the mobile communications companies and the communications infrastructure in households rises steeply in contrast. Among the former, the construction of UMTS networks becomes noticeable, as mentioned above; in the households, the extension of broadband terminals and the appliances used here have the effect of increasing energy demand.

Figure 2-4: Energy demand of ICT according to appliance types



3 Options and potentials for energy conservation of ICT

For the examination of the energy saving options and potentials in the field of ICT it is advisable to differentiate the three operating modes: normal, standby and off-mode. General statements can then be made for the standby and off-mode for a large share of the ICT appliances equipped with these modes, whereas, in normal mode, the technologies vary to such an extent that the analysis has to be performed on an individual appliance level. Alongside technical options and potentials of energy conservation, behavioural changes and modified usage patterns can also play a role in ICT, for example, switching off office equipment regularly after work or switching PCs, monitors, printers and copiers into a power-saving standby mode when not directly in use. Similar options exist for household ICT appliances, e.g. consistent use of the off-switch wherever available or the use of switchable multiple socket outlets. In principle, the technical savings potentials for electrical and electronic appliances are estimated to be much more effective than behavioural driven potentials (Brohmann et al. 2000; Böde et al 2000b), so the analysis undertaken here will concentrate on the technology options.

Options and potentials in the off-mode

As the off-mode has been defined as the mode in which the appliance does not fulfil any function after it has been switched off, but still draws power, there are technical options to completely avoid the power demand occurring when in this mode. Basically, the total savings potential here is as large as the total power demand in off-mode. The projected demand in off-mode decreases slightly from 2.7 TWh in 2001 to 2.1 TWh in 2010 (see Table 2-1), so consequently the savings potentials decrease accordingly. However, even the remaining energy demand is superfluous and should be reduced still further, or completely avoided.

There are several options to do so:

- off-mode losses can be reduced by behavioural measures of the user. Buying and regularly using a switchable multiple socket outlet with which the appliances can be completely turned off is the main measure to be cited.[12] The (one-off) purchase costs for the user are in the order of approx. 5 €, the (annual) savings in electricity costs depend on the type of appliance and lie between 0.25 and almost 4 €. If only one device is connected to the socket outlet, the payback period ranges between 1.5 and 20 years. Much higher electricity cost savings can be achieved by running several appliances on one switchable outlet such as a stereo

[12] Manufacturers occasionally recommend unplugging the appliances from the mains for longer periods of non-use. Admittedly, this option does not generate any costs for the user but it seems rather impractical.

system consisting of several separate devices or a computer system made up of PC, printer and monitor. Audio devices in households and computers with peripherals in households and offices represent the two most important applications for this option.

- Of course, the off-mode loss could also be avoided by the manufacturers equipping their products with switches that disconnect completely from the mains. The main reason for manufacturers preferring to use switches on the low voltage side which do not disconnect the power supply unit from the mains are the lower costs. Although the exact manufacturers' prices could not be determined, the information gathered suggests that the additional costs for switches disconnecting completely from the mains should not be higher than € 2.5 depending on the power to be switched and, in most cases, should be around 1 €. This option would thus be more cost efficient from a macroeconomic viewpoint than users having to purchase the - more expensive - multiple socket outlets.

Options and potentials in standby mode

Switching ICT appliances off completely is linked in many cases with a loss of convenience - e.g. not being able to turn the device on using a remote control - or it is not advisable because appliance settings such as an internal clock or programming would be lost. In the future, a permanent data exchange with the Internet will be possible in digital services that are supplied via multimedia appliances, which also stands in the way of completely disconnecting appliances. For these appliances, the most important savings option is to equip them with energy-efficient circuits for the power supply in standby mode. If equipped with a separate circuit for standby operation, the power consumption of appliances can be reduced to less than 0.5 W, as long as only simple functions like an internal clock or the preservation of an internal memory have to be fulfilled. It is not possible to reduce the energy demand to such low values solely by use of adjusted power supplies if more complex functions have to be performed in standby mode.

The assumptions made about average electrical power consumption in standby mode were modified to estimate the savings potentials here. Depending on the type of appliance, varying achievable figures were assumed for new appliances. For those with simple standby functions, a power consumption of 0.5 W was generally assumed to be attainable, for those with more complex functions, either best practice examples were used or own estimations made. In addition, the replacement rate of the stock with new appliances was also considered. Table 3-1 shows the saving potentials in standby mode calculated up to 2010. Overall, the potential in the year 2010 is estimated to be around 4 TWh which represents almost one third of the total electricity demand in this operating mode. The end-use devices in households account for roughly three quarters of the 4 TWh, the rest is distributed more or less evenly between the end-use devices in offices and the infrastructure in households.

Table 3-1: Savings potentials from increased energy efficiency in standby operation (GWh per year)

	2005	*2010*
ECT end-use appliances in households	**2090**	**3080**
Audio devices	540	860
TV, VCR	960	1250
Telephony	230	320
Computers and peripherals	210	400
Others	150	250
Infrastructure in households	**260**	**490**
TV infrastructure	140	310
Internet/telecommunication-infrastructure	120	180
ICT end-use appliances in offices	**260**	**450**
Telephony	100	190
Computers and peripherals	80	170
Others (mainly copiers)	80	90
Total savings potentials in standby operation	**2610**	**4020**

Source: own calculations

Options and potentials in normal mode

Whereas general statements can be made for a large proportion of ICT appliances in off-mode and standby mode, a detailed analysis of the individual classes of appliances is necessary in normal mode because of the very different technical requirements involved here. Therefore for normal operation, first of all those appliances were examined which account for a prominent share of the total energy demand of ICT appliances in this mode in Germany. A good way to estimate savings potentials is to identify best practice devices. As long as their net power is comparable to that of conventional appliances, the difference in specific power consumption in normal mode per appliance and year can be assessed as the savings potential for the stock resulting from the use of best practice equipment.

This study identified the following relevant savings potentials for the normal mode:

- *televisions*: 1 TWh for the year 2005 and almost 3 TWh for 2010 if there is a quicker substitution of cathode ray tube TVs by LCD TVs, or almost 1 TWh in 2010 if CRT technology continues to dominate but there is a stronger market penetration of best practice CRT TVs.
- *Servers*: between 50 to 60 GWh per year by switching off server-computers overnight in small and medium enterprises.

- *Mobile communications infrastructure*: savings possible by reducing the energy demand for air conditioning and ventilation in the base stations as well as limiting the number of base stations to the greatest extent possible.
- *Personal Computers*: 600 GWh resulting from an energy-efficient design approaching the lower power consumption of notebooks due to the use of mobile processors, which are, however, much more expensive than their stationary counterparts.
- *Internet and telecommunications infrastructure in households:* savings potentials of roughly 80 GWh in 2005 and 220 GWh in 2010 through improved power management in DSL routers.
- *Monitors*: substantial savings potentials from substituting CRT displays with the more energy-efficient LCD displays. This would be as high as 1 TWh per year if complete substitution in households and offices were achieved by 2010. However, this potential can only be fully exploited, if the price for LCD monitors drops considerably in the near future.

4 Development of an early warning system for ICT energy demand

ICT has developed at a tremendous pace over the last twenty years and its development has frequently strayed from its predicted path. For example, for a long time the computer industry believed that there was no market for individual desktop computers. And when digital mobile communication was introduced in 1992 via the so called “D-Netze”, the first two digital networks, hardly anyone reckoned that almost 50 million people would be using mobile communications in Germany in 2001. The innovation rate in the ICT sector continues undiminished, so that greater uncertainties are attached to forecasts for the energy consumption of ICT than is the case in other sectors.

Against this background, a dynamic early warning system was developed within this study as an aid to early recognition of emerging trends in ICT and with which their influence on the energy demand in ICT can be illustrated. To this end, a cross-impact (CI) matrix was constructed which compares the main factors determining energy demand in the ICT groups of appliances or ICT infrastructure systems in households and offices. These demand-determining variables can either affect the stock, the specific power consumption or the intensity of use of the appliances and systems.

The most important factors of influence relevant for stock were identified as:

- *Individualisation*, i. e. a trend towards personal ownership and/or individual usage noticeable for many ICT appliances, which tends to increase the stock and thus also the energy consumption. Current examples for this development are appliances such as mobile phones, notebooks or PDAs with high stock growth rates. In offices, the individualisation of PCs has been more or less complete for some time, here the concept of the "personal computer" has prevailed over the use of large computers in combination with numerous terminals. In contrast, for printers, the opposite trend towards network printers in work groups has become dominant in many offices.
- *Marketing models*, their design can be decisive for how fast new information and communication technologies penetrate the market. Models, in which the appliances are not financed via the purchasing price but via user fees can accelerate the market penetration, since the often frighteningly high acquisition costs of new unknown technologies, which can scare off potential users, cease to apply or are at least clearly reduced. Such marketing models are particularly interesting for suppliers aiming to establish a customer base quickly after high investments in the construction of a new infrastructure, (such as in the case of mobile communications), or if they want to hinder the market entry of competitors offering a rival technology (compare the marketing of ADSL by the Deutsche Telekom).

Marketing models like this also tend to increase the stock. The resulting increase of the energy demand may, however, turn out to be more moderate because of the phenomenon of a "usage gap" observed with very aggressive marketing models in the past. That is, appliances are purchased due to very low investment costs but are only used a little over time so that they are mainly in standby, off-mode or switched off completely. A current example for this development is the mobile phone.

The most important **power-relevant factors of influence** are:

- The *trend towards mobile appliances* tends to reduce electrical power consumption. The energy consumption is an important quality criterion for such devices because it is decisive for the length of time the device can be used independent of the network involved.
- The speed of development of *rechargeable battery technology* for mobile appliances has not been able to keep pace so far with that of the other hard- and software. This has also had the effect of reducing energy demand in that the operating time, which is limited due to the restricted rechargeable battery capacity, gave an incentive to develop and produce power-conserving mobile appliances. A breakthrough in the development of rechargeable batteries with a greatly increased energy density[13] could reverse this trend, i. e. if rechargeable batteries were substantially improved, the electrical power consumption of mobile appliances could increase again.
- The high innovation rate in ICT often results in *technology substitution*, via which the electrical power consumption of appliances is often clearly reduced. One important example are the tube monitors and the much more energy-efficient flat screens. A similar effect can result in the medium to long term from the substitution of conventional electronics by nanotechnology solutions with which switching processes can be achieved with smaller and smaller charges and thus also less waste is produced. The first mature products are expected here between 2005 and 2010 (see Friedewald et al. 2002).
- Increasing the *integration density of the appliances*, i. e. merging functions into one single component (usually a printed circuit board) is also usually associated with lower energy consumption. It is also possible for several functions to be combined in one multi-functional device which brings specific advantages (such as, e. g. the combination of mobile phone and PDA, fax and printer or phone and answering machine).

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[13] This might be achievable using mobile fuel cells. However, at present it is difficult to judge to what extent fuel cells in conjunction with hydrogen storage actually make longer operating times possible.

As an important **influencing factor on use**, new *service variants* should be cited which alter the utilisation structure of ICT appliances, usually in the sense of increasing this. Examples are the "flat rate" for Internet use or UMTS services which continuously supply the user with information about his location (e. g. restaurants or cultural attractions in the vicinity) and which require a permanent data transfer between the end-use device and base station.

The cross-impact matrix illustrated in Tables 4-1 to 4-3 for the end-use appliances in private households and offices as well as the ICT infrastructure compares lines of appliance groups with columns of the influencing factors described above. They are coded in the CI matrix directly using their impact on the energy demand. The values +1 to +3 stand for energy-increasing effects, –1 to –3 for energy-reducing effects, in which 3 represents the strongest effect in each case. 0 denotes no significant impacts on the energy demand.

The values entered in the CI matrix up to now reflect the estimation of the authors and should help to test both the practicability of the methods and the plausibility of the results calculated in Chapter 2 using an alternative methodological approach. The evaluation of the CI matrix is done by summing up the lines and columns. The line totals indicate for which kinds of appliance a significant change in the energy demand can be expected. The column totals give indications of which of the aggregated driving forces should be considered particularly influential.

Among *end-use appliances in households* (Table 4-1), there are clear indications of an increase in energy demand for televisions, cameras, game consoles, PCs and mobile phones in particular. Only the result for mobile phones contradicts the result determined in the model, which predicted electricity demand would fall for mobile communications end-use devices (see Appendix A1.1). Here, it was probably underestimated that the energy demand caused by extending mobile communications will occur predominantly in the infrastructure. The change in effective output and individualisation were assessed as the strongest driving forces behind this development. The effects of technology substitution are ambivalent so that zero results in the CI matrix which does not permit a definite statement. The trend towards greater mobility and the increased integration density of appliances have the effect of reducing the energy demand.

Table 4-1: CI-Matrix to identify and evaluate the main factors of influence on the future energy demand of ICT end-use appliances in households

	Individualisation	Marketing models	Changes in service output	Trend towards mobile devices	Rechargeable battery techn.	Technology substitution	Integration density of devices	Service variants	Line totals
Stationary audio devices	0	0	+1	-	0	0	0	+1	+2
Portable audio devices	0	0	0	0	0	-1	0	0	-1
TVs	+1	0	+3	0	0	-2	0	+1	+3
VCRs	0	0	0	0	0	0	0	0	0
Cameras	+1	0	+1	-	+2	+2	-1	0	+5
Game consoles	0	+1	+3	0	0	0	0	+1	+5
Fixed network telephones	+1	+1	0	-1	0	+1	+1	0	+3
Mobile phones	+1	+3	+2	-	+3	+1	-1	+1	+10
Other communication devices	0	0	0	0	0	-1	-1	-1	-3
Computers	+2	0	+2	-2	+1	0	-1	+2	+4
Monitors	+2	0	+1	-2	0	-1	0	+1	+1
Printers	+1	+1	0	0	0	+1	0	0	+3
Other devices IT	0	0	0	-1	0	0	-1	0	-2
Column total	+9	+6	+13	-6	+6	0	-4	+6	

Table 4-2: CI-Matrix to identify and evaluate the main factors of influence on the future energy demand of ICT end-use appliances in offices

	Individualisation	Marketing models	Changes in service output	Trend towards mobile devices	Rechargeable battery techn.	Technology substitution	Integration density of devices	Service variants	Line totals
Cameras	0	0	+1	-	+2	+2	-1	0	+4
Fixed network phones	0	0	0	0	0	0	0	0	0
Mobile phones	+1	0	+3	-	+3	+2	-2	+1	+8
Computers	+1	0	+1	-3	+2	0	0	+1	+2
Monitors	+1	0	+1	-3	0	-2	0	0	-3
Printers	-1	0	0	0	0	+1	-1	0	-1
Copiers	0	0	0	0	0	-1	-1	0	-2
Column total	+2	0	+6	-6	+7	+2	-5	+2	

Table 4-3: CI-Matrix to identify and evaluate the main factors of influence on the future energy demand of ICT infrastructure

	Individualisation	Marketing models	Changes in service output	Trend towards mobile devices	Rechargeable battery techn.	Technology substitution	Integration density of devices	Service variants	Line totals
Television infrastructure	+1	+1	0	0	0	+2	-1	+1	+4
Internet and telephone infrastructure in households	+2	+2	+1	+1	0	+1	-1	+2	+8
Computer network infrastructure in offices	0	0	+1	+1	0	0	-1	+1	+2
Telephone and other infrastructure in offices	0	0	0	0	0	0	+1	0	+1
Servers	0	0	+3	+1	0	0	-1	+3	+6
Mobile communications infra.	+3	+1	+1	-	0	+3	0	0	+8
Fixed network infrastructure	0	0	+1	-1	0	0	0	0	0
Column total	+6	+4	+7	+2	0	+6	-3	+7	

Among *end-use appliances in offices* (Table 4-2), the effect of the driving forces are estimated as being collectively more moderate than in households and energy-increasing and -reducing factors compensate each other to a greater extent. If the strong growth of mobile phones is assigned to the infrastructure and the very uncertain effect of the rechargeable battery technology is suppressed, the CI matrix total is zero which is equivalent to the results of the projections for the sector of office end-use appliances (see Appendix A1.3).

The results of the CI matrix for the *infrastructure* (Table 4-3) are not directly comparable with the end appliances since several driving forces are not relevant here and the matrix is therefore not as strongly occupied. Nevertheless, clear indications of a strong growth in energy demand can be derived for the sectors Internet infrastructure in households, mobile communication infrastructure, servers and for the television infrastructure in households. Slight or no changes in the energy demand according to the CI matrix result for fixed network infrastructure and the infrastructure in offices (with the exception of servers).

It can be concluded that the early warning system developed here in the form of a cross-impact matrix does mirror the results obtained using the bottom-up analysis in Chapter 2 and can thus be evaluated as an applicable instrument for observing the energy demand of these technologies. However, the CI matrix also shows different tendencies for some aspects than the projections developed on the basis of individual analyses of the appliances. The differences, which can be explained by the fact that the early warning system also includes the impacts of driving forces which are very uncertain (such as substantial improvements in the rechargeable battery technology), substantiate the independent use of the alternative methodological approach. For continued observation of the development it is suggested that this early warning system should be applied by experts at a later point in time in order to capture and assess changes in the very dynamic ICT technology sector.

5 Energy policy measures to promote the energy efficiency of ICT appliances

In principle, energy policy has at its command a range of instruments available at both national and international levels to influence the energy or electricity consumption in the ICT sector, some of which are already being applied today or at least discussed:

- *Regulatory instruments*, i. e. regulations in the form of requirements or prohibitions such as stipulating maximum consumption or minimum efficiency standards or mandatory product labelling.
- The use of *economic instruments* such as taxes/levies (e. g. ecological tax reform), financial incentives (e. g. subsidies for purchasing especially energy-efficient appliances) or tradable emissions permits.
- *Technology and innovation policy* such as promoting the R&D of energy efficiency or procurement activities.
- In addition, there is a wide range of *informational, organisational and voluntary instruments*, including information campaigns, energy consumption labelling on a voluntary basis, consultation and educational/training programmes, voluntary self-commitments or institutional measures such as setting up energy agencies or energy efficiency funds.

Policy instruments to influence the energy consumption of ICT appliances can be applied at various points along the product chain from production through to final use and can vary in their effectiveness with regard to achieving the objective (Table 5-1).

Table 5-1 Possible targets of energy policy when influencing energy consumption in the ICT sector and target effectiveness of energy policy measures

	Regulations (labelling, standards)	Economic incentives	R&D support, procurement	Voluntary measures (labelling, agreements)	Other information, education, training
Stimulation of new energy-efficient technologies	medium	medium	high	medium	low
Promoting the production of energy-efficient products	high	medium	medium	medium	low
Promoting the supply of energy-efficient products	high	medium	medium	medium	medium
Promoting the purchasing of energy-efficient products	high	medium to high	low	medium	medium
Influencing how the appliance is used	low	medium	low	low	medium to high

Sources: based on Wiel/McMahon 2001 and Rath et al. 1999

Regulatory instruments

Legislative measures to influence the energy consumption of ICT appliances primarily involve the mandatory labelling of energy consumption as well as stipulating maximum consumption or minimum efficiency standards. In the majority of countries, however, these regulations do not affect the ICT appliances examined here, but apply to large domestic appliances ("white goods"), light sources, air-conditioning appliances, motors or boilers[14]. One country which has also laid down binding energy consumption target values for individual appliances from the ICT-sector (TVs, VCRs, copiers, computers) is Japan.

For Germany, and also on an EU level[15], there is a growing call to extend the compulsory energy label to ICT appliances (especially TVs, VCRs and office electronics) as well as to introduce minimum efficiency standards as a parallel measure (e. g. Rath et al. 1999; Enquete-Commission Sustainable Energy Supply 2002). The complete avoidance of off-mode losses, which is technically possible, could also be regulated using legislative measures. In its current climate protection programme (EU 2001) the EU has already announced a series of directives to reduce the energy consumption of electrical and electronic appliances, which would provide the legal foundation for such measures[16].

Economic Instruments

A general price policy measure which also promotes the energy efficiency of electrical ICT appliances is increasing the price of electricity by levying an energy, CO_2 or eco tax. This kind of duty has been introduced in a series of EU countries on a national level since the 90s, for example in Austria, Denmark, Belgium, Finland, Germany, the Netherlands, Sweden, the UK and Norway[17].

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14 IEA 2000 and Wiel/McMahon 2001 provide a comprehensive global review of the use of energy efficiency labels and standards.

15 Since the trade with ICT appliances takes place throughout Europe and worldwide, legislative measures at an EU level should be given priority.

16 Both a Framework Directive on Minimum Efficiency Standards for electrical and electronic end-use appliances and the revision of the Framework Directive 92/75/EC on Energy consumption labelling are planned which would allow their extension to other appliances. In Germany, the new energy consumption labelling ordinance of 30 January 2002 (BGBl. I p. 570) has already created an important legal foundation for translating more advanced regulations on an EU level into national law.

17 The MURE database (2002) (http://www.mure2.com) provides an overview and extensive categorisation and description of measures of rational energy use in the end-use sectors of all countries of the European Union and Norway.

Providing financial incentives to purchase energy-efficient appliances in the form of rebates, grants, bonus-malus systems or tax concessions concentrated up to now on large electrical domestic appliances and lighting and not on ICT appliances. An energy efficiency effect can be achieved in principle using financial incentives if these are temporary and strictly tailored for specific target groups (e. g. Brunner et al. 2001, Wiel/McMahon 2001, Schlomann et al. 2001). The main drawbacks of financial incentives are the very high costs of the programmes as well as the free rider effects, which can considerably detract from the cost-benefit ratio of the measures.

The use of tradable emission certificates, which has been increasingly discussed in connection with the so-called Kyoto instruments, will probably not play a direct role in the household and tertiary sectors as things stand at present. These sectors will only be indirectly affected via electricity generation since a direct liability of these sectors seems less practical because of the high transaction costs.

Technology and innovation policy

Within the framework of forcing innovation-oriented technology policy with regard to a sustainable energy system as was recently demanded of Germany by the Enquete Commission Sustainable Energy Supply (2002), the promotion of energy-efficient ICT technologies (including avoiding the unnecessary off-mode consumption) and especially the use of an energy-efficient process technology could represent an important field for R&D promotion in Germany in the future.

Procurement is one instrument which has already been in increasing use in recent years. This can be used to promote energy-efficient appliances from ICT as well. Procurement involves the joint purchasing of energy-efficient appliances by public institutions (public procurement), or by private buyers with large market volumes (co-operative procurement), either with the objective of bringing new efficient appliances onto the market (technology procurement), or the objective of increasing the market share of particularly efficient appliances (market procurement). Sweden pioneered the use of technology procurement to introduce energy-efficient technologies. As a consequence, the instrument was then also applied in other countries such as the Netherlands, Finland and the USA (Wiel/McMahon 2001). The activities of the IEA should also be mentioned here. It has promoted technology procurement projects within the scope of its demand-side-management programme[18] for a series of appliances and components (among others, copiers for offices).

Since the technical possibilities to reduce energy consumption are already known for many ICT appliances and indeed have already been employed for individual

[18] http://dsm.iea.org

appliances, the market procurement, i. e. increasing the market share of these appliances through joint purchasing activities, will probably have greater significance. The biggest potentials for joint purchasing projects are found among office appliances because there is a large demand for such appliances and they are also replaced quite frequently. In the USA, there is a series of guidelines for government agencies purchasing energy-efficient products (Wiel/McMahon 2001). In Denmark (Mure 2002) and Switzerland, there are public procurement activities for office appliances (Aebischer/Huser 2002). In Germany, the Federal Environmental Agency publishes a manual on purchasing environmentally-friendly products (Umweltbundesamt 1999). At the EU level, an initiative on public procurement is also being planned (European Commission 2001).

Voluntary agreements

Voluntary agreements with manufacturers are currently one of the predominant measures to reduce the energy consumption of ICT appliances. Since these usually involve appliances which are traded throughout the EU or worldwide, these agreements are mainly made at the level of the European Union. The existing agreements all apply to reducing the standby losses in consumer electronics:[19]

- a negotiated agreement between the European Commission and individual manufacturers of consumer electronics as well as the European Association of Consumer Electronics Manufacturers (EACEM) to decrease the idling losses of televisions and video recorders of 1997,
- a further negotiated agreement between the EU Commission and EACEM on the standby losses of audio appliances of 2000,
- a code of conduct about the energy efficiency of digital TVs and
- another code of conduct of July 2000 affecting the efficiency of external power supplies for electronic and electrical appliances.

Voluntary agreements as a measure to increase energy efficiency have received controversial evaluations (see, e. g. Rennings et al. 1997; Kübler 1998; Rath et al., 1999). Compared with legislative instruments, such as minimum efficiency standards, they have the advantage of being quicker and more flexible in their implementation and target setting which is significant in the rapidly evolving ICT sector. A further advantage is seen in the lower administrative costs (Thomas 2001). The major drawback is that the targets agreed are frequently too weak in the sense of increasing energy efficiency and instead tend to reflect what has already been achieved, or efficiency improvements which would have been achieved anyway in the foreseeable future even without the agreement. If the agreed targets for standby

[19] For the details of these agreements see http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

are regarded in the voluntary commitments described above, it can be seen that, in many cases, technical solutions to reduce the power demand in standby mode to under 0.5 W already existed in the 90s. In contrast the targets agreed are much higher. Other problems are that self-commitments are not legally binding and it is difficult to monitor compliance with the targets. For the voluntary agreements at EU level mentioned above, only rather weak monitoring is planned in the form of an annual confidential and anonymous report of the manufacturer to the European Commission. Furthermore, for the agreements designed as codes of conduct, there is no guarantee that the leading manufacturers will actually participate.

Labelling

Alongside voluntary agreements, voluntary energy consumption labels or ecolabels including energy or standby consumption also play an important role in increasing the efficiency of electrical and electronic appliances.[20] These labels do not only fulfil an independent information function for the buyers and users of the appliances, but also serve as an important base for the design of further measures such as joint procurement activities, financial incentives, setting up databases for energy-efficient appliances or carrying out information campaigns.

The globally most familiar and widespread of these voluntary energy quality labels is the *Energy Star* from the USA. Appliances with consumption below the fixed minimum efficiency standards, which are updated from time to time, are permitted to carry the Energy Star Label. The Energy Star requirements for ICT appliances do not apply to consumption in normal mode, but only that in standby. The off-mode consumption is not considered either. Furthermore, the Energy Star requirements for many ICT appliances are lower than those of other quality labels (Thomas 2001). The Energy Star's acceptance and diffusion worldwide, especially among office appliances, are points in its favour. Japan already adopted the Energy Star Programme for office appliances in 1995, the EU completed this step in 2001[21].

The energy label of the *Group for Energy Efficient Appliances GEEA* is equally widespread within Europe for appliances of consumer and information electronics. In order to be able to carry the label, the appliances must remain below certain fixed minimum efficiency requirements in idling mode. Unlike the Energy Star, here, there are minimum requirements set for the off-mode as well as the consumption in standby. The limits for the label are redefined each year. The requirements of the GEEA label generally exceed those of the Energy Star.

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[20] IEA (2000) and Wiel/McMahon (2001) offer a more detailed review of the energy efficiency labels which exist worldwide. Rubik/Scholl (2002) makes a detailed examination of the ecolabels existing in the individual EU countries and the EU.

[21] For details, see energyefficiency.jrc.cec.eu.int/energystar/index.htm

International initiatives

The 1 Watt Plan initiated by the Lawrence Berkeley National Laboratory (LBNL) in 1998 is probably the most important initiative worldwide to reduce the standby losses of electrical appliances. This plan demands that standby losses should be strictly limited to 1 Watt (Meier et al. 1998)[22]. The 1 Watt Plan thus far exceeds the requirements of the self-commitments at EU level and of the majority of quality labels, and yet it is still technically and economically feasible. The Standby Power Initiative of the IEA launched in January 1999 adopted the 1 Watt Plan of the LBNL[23].

Information programmes and campaigns

Information programmes and campaigns have an important concomitant function within the scope of measures to promote the energy efficiency of electrical appliances. They can aim at increasing the share of electrical appliances and at influencing user behaviour.

In Germany in 1999, the BUND, supported by the Federal Ministry for the Environment, conducted a nationwide campaign aimed at indicating the electricity saving potentials in the standby mode of electrical appliances (Brohmann et al. 2001). The *Standby-Kampagne of the Energiestiftung Schleswig-Holstein* (Wortmann et al. 2001; Wortmann/Möhring-Hüser 2001; Wortmann et al. 2002)[24] was a very comprehensively designed campaign carried out at regional level in Schleswig-Holstein, which also received a lot of attention abroad. The positive results of this campaign highlight how important such activities can be in contributing to increasing the energy efficiency of ICT appliances. The main problems are the high costs associated with their implementation which tend to be higher, the more targeted and effective such a programme is.

At a national level the *"Initiative EnergieEffizienz"* on efficient electricity use in private households started in Autumn 2002, a joint nationwide information campaign of the Associations of the Electricity Industry (VDEW, VRE, VKU) and the German Energy Agency (dena)[25]. The campaign covers the topics “standby consumption of electrical appliances”, “white goods” and “lighting”. Dena is also planning a campaign in connection with the adoption of the Energy Star by the countries of the European Union.

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22 The LBNL publishes a list of selected appliances with a standby consumption of under one Watt. eetd.lbl.gov/EA/Standby/DATA/1WProducts.html

23 www.iea.org/standby/

24 www.wirklich-aus.de

25 www.initiative-energieeffizienz.de

Education and further training

Educational and vocational training programmes in the field of rational energy use of appliances are mainly aimed at companies, at both the users of the appliances as well as the planners, buyers and vendors. Educational programmes are primarily conducted by the energy agencies of the Federal states, but also by energy utilities.

Further training activities in Germany, especially in the state funded *"Impulse programmes"* of several Federal states (NRW, Hessen, Schleswig-Holstein, Berlin, Bremen) are based on the model of the Swiss RAVEL Programme[26]. In short events and specialist seminars, information about energy consumption issues, technologies and measures of rational energy use is imparted to those practically involved with these issues in their jobs, e. g. contractors/installers and maintenance/service personnel (Böde et al. 2000b). The "E-Fit" weeks which have been conducted since 1999 within the scope of the Impuls Programme RAVEL NRW are particularly interesting for the sector of office appliances. The activities are mainly aimed at office workers and those responsible for IT and focus on behaviour-oriented measures of electricity conservation. The evaluation of this activity revealed a high degree of willingness to use the recommended measures for saving electricity (switching off lights, turning computers off after work, switching monitors off, disconnecting appliances or using switchable multiple outlets) in the longer term as well. The behaviour at home was also able to be influenced (Gruber 2001).

Institutions

Institutions such as national or regional energy agencies are very important in the conception, organisation, coordination and possible implementation of energy policy measures to promote rational energy and electricity use, especially for information, education and further training measures. In Germany, much of this work is carried out by the regional energy agencies which have existed for many years in the majority of federal states, and increasingly by the German Energy Agency which was set up in Autumn 2000. There are other institutions in addition to these[27].

Another institution which does not exist at present in Germany but which could assume important tasks in the field of promoting electricity efficiency is an *Energy Efficiency Fund* modelled on the British Energy Saving Trust[28] or the Danish Elec-

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26 Rational use of electricity

27 For example, the Gemeinschaft Energielabel Deutschland (GED), consumer centres, Landesgewerbeämter, the Bundesdeutsche Arbeitskreis für umweltbewusstes Management (B.A.U.M), the Bürger-Information Neue Energietechnik und Umwelt (BINE), BUND, WWF.

28 www.est.org.uk

tricity Savings Fund[29]. Setting up such an institution in Germany has been suggested on several occasions in the past (Leprich, 1997, 1999; Wortmann et al. 1999; Schlomann et al. 2000; Enquete Commission Sustainable Development 2002). Such a fund could be an important element in a strategy to improve electricity efficiency and could assume important responsibilities in sectors which are usually not covered by the classical energy agencies, such as, for example, developing an autonomous market for efficient products and actors, coordinating joint purchasing activities, compiling efficiency standards and labelling classes for different appliance groups or initiating research and development activities for further improvement of electricity efficiency.

29 www.elsparefonden.dk

6 Conclusions and Recommendations

For 2001, this study ascertained an electricity demand of 38 TWh for ICT end-use appliances in households and offices and their associated infrastructure. This corresponds to a share of almost 8 % of the total electricity consumption of final consumption sectors in Germany (AGEB 2002). About 50 % of the power demand are accounted for by household end-use appliances, a further 20 % by office end-use appliances, the remaining 30 % by the infrastructure required. A clear increase in the power demand by 45 % up to 55.4 TWh is anticipated up to 2010 which is primarily caused by the increasing significance of ICT infrastructure. The stock of appliances and systems of ICT infrastructure will grow noticeably and since these devices, such as servers or mobile communications systems, are continuously operated, the consumption growth in normal mode is the strongest. The consumption in standby mode shows an increasing tendency, most notably up to the middle of the decade, whereas it decreases in off-mode. However, this has less to do with efforts for greater efficiency and more to do with the expected substitution of the off- by the standby mode (especially in televisions).

The most significant appliance classes with regard to power demand are televisions, stationary audio devices and servers, which accounted for almost 45 % of total demand in 2001. The leading role of these three appliance classes will not alter up to 2010. In contrast, the significance of the infrastructure of the mobile communications companies will increase strongly (due to the development of the UMTS networks) as well as that of the communication infrastructure in households (especially due to the expansion of broadband connections), so that these five most significant appliance classes will probably account for around 60 % of the total power demand for ICT applications in 2010.

Against the background of these results, several recommendations are made below for increasing the energy efficiency of ICT appliances in households and offices and the associated infrastructure. To start with, there are recommendations differentiated according to the individual operating modes, these are then followed by several general recommendations.

Recommendations to reduce the energy demand in off-mode

Even if the power demand in the off-mode will decline to around 2.1 TWh in 2010, this figure must still be regarded as too high from the viewpoint of energy efficiency, since, technically, it can be completely avoided without excessive costs for the manufacturer. For new appliances, it is therefore recommended to target complete prevention of power consumption in off-mode. The most effective way to achieve this is probably a minimum efficiency regulation at an EU level which bans off-mode consumption altogether. Should a complete ban not prove enforceable, the off-mode should at least be taken into account in the present voluntary - or where applicable in the new mandatory - eco- or energy consumption labels. A minimum requirement would be that the product description clearly indicates the existence of this state.

For the existing stock, the most effective way to reduce the power demand in off-mode is a greater use of switchable multiple outlets in households and offices. The associated one-off acquisition costs for the user are redeemed in 1-2 years by the electricity savings achieved, at least for some appliances and especially if several appliances can be switched using one outlet. However, a wide diffusion of switchable multiple outlets can only be achieved with supplementary information measures (such as relevant information campaigns or education and training programmes for companies), which, in turn, also entail costs.

Recommendations to reduce the energy demand in standby mode

Energy policy activities on national, EU and international level have, up to now, focused on reducing the energy demand of ICT appliances in standby mode. At least partial success has been achieved here which will help to curb the future growth in power demand as the results of this study also show. Still, the technical possibilities for increasing energy efficiency far exceed the achievements so far and those expected. Additional saving possibilities in standby mode can therefore be seen in a consistent acceleration of the market diffusion of highly efficient information and communication technologies. Further electricity savings can be achieved with measures targeting user behaviour.

A general recommendation to accelerate the market diffusion of appliances with a low energy demand in standby is to support the 1 Watt initiatives of the LBNL and the IEA. This demand is clearly more stringent than the existing EU self-commitments to reduce standby consumption and most of the minimum standards in today's widespread quality labels such as the Energy Star and the GEEA label. For many ICT appliances, a power consumption of max. 1 Watt is technically feasible straight away. However, if appliances have to fulfil more complex functions in standby, the 1 Watt requirement will probably be difficult to achieve technically as things stand today (e. g. for appliances such as PCs which access a harddisk or, such as copiers which require a minimum temperature before they are ready to operate). For these appliances, it makes sense to promote technical solutions to increase the energy efficiency in standby (promoting R&D, technology procurement). A faster market penetration of such highly efficient appliances could be achieved by making the existing voluntary commitments at EU level and the minimum efficiency requirements contained in today's widespread quality labels (Energy Star, GEEA-Label) more stringent. Market procurement is another way to promote the market penetration of efficient ICT appliances. Since such appliances are often selected based on quality labels such as the Energy Star, the success of procurement activities is greater, the stricter the labelling requirements.

Changes in the behaviour of appliance users can play a supplementary role in reducing the power demand in the standby operation of ICT appliances. However, the prerequisite for a stronger exploitation of these saving potentials are concomitant information and educational activities at national, regional or municipal level.

Recommendations to reduce the energy demand in normal mode

The recommendations to reduce the energy demand in normal mode concentrate on those appliance classes which have a high power consumption in normal mode and a significant share in the energy demand of the ICT sector. According to the results of this survey, these are first and foremost televisions, then audio devices, monitors and personal computers among end-use appliances. Where infrastructure is concerned, this is particularly valid for servers.

It is recommended that the mandatory EU energy consumption labels are extended to include *televisions* because of their high significance for the energy demand in normal mode which will grow by almost 60% up to 2010. In addition, a minimum efficiency ordinance for televisions should be considered. These measures could be used to promote the use of energy-efficient "market best" cathode ray televisions as well as the greater diffusion of the more energy-efficient LCD sets and also possibly cap the trend towards bigger and bigger screens. Similar considerations also apply to *monitors* and *personal computers*. If the route of mandatory energy labels and minimum efficiency standards is not taken here, since the Energy Star has recently been introduced at EU level, it would at least be sensible to include the energy demand of normal mode in the Energy Star and other quality labels. The existing quality labels, which only include standby and to some extent the off-mode, offer neither an incentive for a faster dominancy of LCD technology, nor do they promote the use of energy efficient processors in mobile computers such as notebooks.

For infrastructure devices such as *servers* it is more difficult to make recommendations. Unlike desktop PCs, there are no mobile counterparts for servers for which the best possible energy-efficient solutions have to be developed and which could be promoted using policy measures. Nevertheless, there are still some reasonable actions which could be taken. Since there are hardly any explicit energy-efficient solutions available, their development could be promoted. It would be equally sensible to examine the feasibility and the pros and cons of combining servers (server consolidation). Introducing energy labels for servers is probably not possible because the products differ too greatly and no standardised measurements of the effective output have been able to be made. In contrast, it would be sensible to have a label for the efficiency of the power supplies used, since there is presently no information available on this and it involves clearly measurable features which have not yet been considered in investment decisions.

General recommendations

Several references have already been made to the importance of *energy labels* for increasing the market transparency and accelerating the market diffusion of efficient ICT appliances. Alongside a ratchetting of the efficiency requirements and general consideration of the off-mode and - at least for some appliances - the normal mode as well, it would be sensible to standardise the requirements in the numerous existing labels at national and international level. The variety of labels is also probably confusing for consumers. An important supportive function at the national level when conducting many of the already mentioned measures to increase the electricity efficiency of ICT appliances could be fulfilled by an *Energy Efficiency Fund*, which would have to be set up in Germany, perhaps modelled on the British Energy Saving Trust or the Danish Electricity Saving Fund. Another general measure to promote the development of highly-efficient electrical appliances is a stronger orientation of *R&D promotion* on the criterion of energy efficiency.

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Appendix 1: Results of the computational model

A1.1 Household end-use appliances (for 2001, 2005 and 2010)

Year: 2001		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	**Total**
Appl. Group	**Appliance type**	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Time used [h/a]	consump. [kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Audio devices														**2326,7**	**2107,4**	**232,1**	**4666,2**
(stationary)	Compact system	22	1250	27,5	10	3755	37,6	1,5	3004	4,5	751	69,6	19882	546,8	746,6	89,6	1382,9
	Stereo system1	50	1250	62,5	10	3755	37,6	4	1255	5,0	2500	105,1	28382	1774,5	1066,1	142,6	2983,1
	Clock radio	3	90	0,3	1,7	8670	14,7			0,0		15,0	19997	5,4	294,7	0,0	300,1
Audio devices														**18,3**	**85,4**	**47,5**	**151,2**
(portable)	Radio-tape deck	6	220	1,3	1,8	3416	6,1	1	3416	3,4	1708	10,9	13891	18,3	85,4	47,5	151,2
Televisions														**6771,5**	**1268,1**	**209,4**	**8249,0**
	TV Cathode ray[2]	75	1646	123,5	7	3306	23,1	2	1905	3,8	1904	150,4	54417	6717,8	1258,9	207,3	8184,0
	TV LCD	40	1646	65,8	6	3306	16,5	2	1905	3,8	1904	86,2	485	31,9	8,0	1,8	41,8
	TV Plasma	350	1646	576,1	7	3306	23,1	2	1905	3,8	1904	603,0	25	14,4	0,6	0,1	15,1
	TV projector	180	1646	296,3	7	3306	23,1	2	1905	3,8	1904	323,2	25	7,4	0,6	0,1	8,1
Video recorder														**189,3**	**913,6**	**76,1**	**1179,0**
	Video recorder	17	440	7,5	6	5547	33,3	2	1387	2,8	1387	43,5	24627	184,2	819,6	68,3	1072,1
	Video-DVD-player/recorder	17	110	1,9	6	5767	34,6	2	1442	2,9	1442	39,4	2717	5,1	94,0	7,8	106,9
Cameras														**5,3**	**6,3**	**31,2**	**42,8**
	Video camera/camcorder	9	60	0,5	6	120	0,7	1,5	2249	3,4	6331	4,6	7556	4,1	5,4	25,5	35,0
	Digital camera	9	60	0,5	6	60	0,4	1,5	1704	2,6	6936	3,5	2252	1,2	0,8	5,8	7,8
Others														**14,7**	**0,0**	**42,7**	**57,4**
	Game console	15	100	1,5	0	0	0,0	1,5	2898	4,3	5762	5,8	9816	14,7	0,0	42,7	57,4
Telephony														**14,5**	**1019,9**	**0,0**	**1034,5**
(Fixed network)	Cordless phone + 1 hand set	3,5	150	0,5	2,5	8610	21,5		0	0,0		22,1	15101	7,9	325,0	0,0	333,0
	Cordless phone >1 handset	4	150	0,6	2,5	8610	21,5		0	0,0		22,1	4011	2,4	86,3	0,0	88,7
	Answering machine	3,5	50	0,2	3	8710	26,1		0	0,0		26,3	16161	2,8	422,8	0,0	425,6
	Fax machine	13	20	0,3	4	8740	35,0		0	0,0		35,2	5312	1,4	185,7	0,0	187,1
Telephony														**33,9**	**278,9**	**0,0**	**312,8**
(mobile)	GSM[3]	11,64	62	0,7	0,36	4318	1,6		0	0,0	4380	2,3	47000	33,9	73,1	0,0	107,0
	UMTS[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Mobile phone charger[4]				2	2190	4,4				6570	4,4	47000	0,0	205,9	0,0	205,9
Computers														**396,7**	**600,8**	**436,5**	**1433,9**
	PC	55	370	20,4	25	1250	31,3	4	4998	20,0	2142	71,6	18624	379,0	582,0	372,3	1333,3
	Notebook	18	370	6,7	6	671	4,0	4	5286	21,1	2433	31,8	2613	17,4	10,5	55,2	83,2
	PDA	1,5	60	0,1	1,2	2436	2,9	1	3132	3,1	3132	6,1	2835	0,3	8,3	8,9	17,4
Monitors														**466,8**	**170,4**	**215,0**	**852,2**
	Cathode ray	70	370	25,9	15	625	9,4	3	3883	11,6	3883	46,9	17782	460,5	166,7	207,1	834,4
	LCD	20	370	7,4	6	675	4,4	2,5	3758	9,4	3758	21,2	842	6,2	3,7	7,9	17,8
Printers														**29,8**	**134,9**	**451,1**	**615,9**
	Inkjet	20	30	0,6	6	698	4,2	4	6480	25,8	1572	30,6	14728	8,8	61,7	380,6	451,1
	Laser	150	30	4,5	20	698	14,0	3	4801	14,4	3231	32,9	4452	20,0	62,1	64,1	146,3
	Matrix	30	30	0,9	16	698	11,2	2	3231	6,6	4801	18,5	995	0,9	11,1	6,4	18,4
Other appliances														**11,7**	**400,9**	**107,4**	**520,0**
	Scanner	18	15	0,3	8	5898	47,2	4	500	2,0	2349	49,4	8131	2,2	383,5	16,3	402,0
	Copier	200	5	1,0	40	25	1,0	2	4365	8,7	4365	10,7	2290	2,3	2,3	20,0	24,6
	Active boxes (PC)	3	185	0,6	1,6	772	1,2	1	5454	5,6	2349	7,2	13036,8	7,2	15,1	71,1	93,4
Total	**Household end-use**													**10279,2**	**6986,7**	**1849,0**	**19114,9**

1 consisting of HiFi amplifier and cassette deck or CD player or audio DVD or minidisc deck; 2 incl. TV/VCR combinations and portable TVs
3 power consumption taking into account the charging efficiency; 4 power demand of charger left in power outlet; 5 standby + off-mode

Year: 2005		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	Appliance type	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Audio														**2446,0**	**2183,9**	**242,0**	**4871,9**
(stationary)	Compact system [1]	22	1250	27,5	10	3755	37,6	1,5	3004	4,6	751	69,6	20012	550,3	751,5	90,2	1392,0
	Stereo system	50	1250	62,5	10	3755	37,6	4	1255	5,0	2500	105,1	30244	1890,3	1135,7	151,9	3177,7
	Clock radio	3	90	0,3	1,7	8670	14,7			0,0		15,0	20138	5,4	296,8	0,0	302,3
Audio														**16,7**	**77,8**	**43,2**	**137,8**
(portable)	Radio-tape deck	6	220	1,3	1,8	3416	6,1	1	3416	3,4	1708	10,9	12660	16,7	77,8	43,2	137,8
Television														**9220,8**	**1504,5**	**112,9**	**10838,2**
	Cathode ray TV[2]	97	1727	167,5	6	4420	26,5	1,5	1307	2,0	1306	196,0	52188	8742,5	1384,0	102,3	10228,8
	LCD TV	45	1727	77,7	5	4420	22,1	1,5	1307	2,0	1306	101,8	5271	409,6	116,5	10,3	536,5
	Plasma TV	350	1727	604,5	6	4420	26,5	1,5	1307	2,0	1306	632,9	75	45,3	2,0	0,1	47,5
	TV projector	180	1727	310,9	6	4420	26,5	1,5	1307	2,0	1306	339,3	75	23,3	2,0	0,1	25,5
Video														**235,5**	**1185,6**	**79,8**	**1500,9**
	Video recorder	17	462	7,9	6	5532	33,2	1,5	1383	2,1	1383	43,1	21942	172,3	728,3	45,5	946,2
	Video-DVD player/recorder	17	231	3,9	5	5686	28,4	1,5	1422	2,1	1422	34,5	16084	63,2	457,3	34,3	554,7
Cameras														**12,4**	**12,3**	**45,2**	**70,0**
	Video camera/Camcorder	9	60	0,5	6	120	0,7	1	2249	2,2	6331	3,5	11405	6,2	8,2	25,6	40,0
	Digital camera	9	60	0,5	6	60	0,4	1	1704	1,7	6936	2,6	11494	6,2	4,1	19,6	29,9
Others														**45,3**	**0,0**	**55,9**	**101,2**
	Video game console	40	105	4,2	0	0	0,0	2	2597	5,2	6059	9,4	10774	45,3	0,0	55,9	101,2
Telephony														**18,1**	**982,0**	**0,0**	**1000,0**
(fixed network)	Cordless phone with 1 hand set	3,5	150	0,5	2	8610	17,2			0,0		17,7	18745	9,8	322,8	0,0	332,6
	cordless phone >1 hand set	4	150	0,6	2	8610	17,2			0,0		17,8	6164	3,7	106,1	0,0	109,8
	Answering machine	3,5	50	0,2	2,5	8710	21,8			0,0		22,0	18574	3,3	404,4	0,0	407,7
	Fax machine	13	20	0,3	3,5	8740	30,6			0,0		30,9	4857	1,3	148,6	0,0	149,8
Telephony[1]														**55,8**	**183,3**	**0,0**	**239,0**
(mobile)	GSM[3]	7,23	88	0,6	0,077	4292	0,3		0	0,0	4380	1,0	57790	36,8	19,1	0,0	55,9
	UMTS[3]	15,77	131	2,1	0,38	4979	1,9		0	0,0	3650	4,0	9210	19,0	17,4	0,0	36,5
	Charger Mobile phones[4]				1	2190	2,2					2,2	67000	0,0	146,7	0,0	146,7
Computer						0	0,0		0	0,0	0	0,0		**570,6**	**768,3**	**476,0**	**1814,9**
	PC	60	425	25,5	25	1417	35,4	4	4843	19,4	2075	80,3	20763	529,5	735,5	402,2	1667,2
	Notebook	21	425	8,9	6	667	4,0	2,5	5251	13,1	2417	26,1	4543	40,5	18,2	59,6	118,4
	PDA	1,5	70	0,1	1	2426	2,4	0,75	3132	2,3	3132	4,9	6030	0,6	14,6	14,2	29,4
Monitor														**588,5**	**206,6**	**153,1**	**948,2**
	Cathode ray2	73	425	31,0	15	708	10,6	2	3813	7,6	3813	49,3	18290	567,4	194,4	139,5	901,3
	LCD	20	425	8,5	5	992	5,0	1,5	3672	5,5	3672	19,0	2473	21,0	12,3	13,6	46,9
Printer														**44,9**	**163,2**	**430,7**	**638,8**
	Inkjet	20	35	0,7	6	698	4,2	3	6457	19,4	1671	24,3	17547	12,3	73,5	339,9	426,6
	Laser	150	35	5,3	20	698	14,0	3	4799	14,4	3228	33,6	6152	32,3	85,9	88,6	206,7
	Matrix	30	35	1,1	16	698	11,2	2	3228	6,6	4799	18,7	342	0,4	3,8	2,2	6,4
Others														**14,1**	**587,5**	**95,9**	**697,5**
	Scanner	16	18	0,3	6	6908	35,4	2	500	1,0	2334	36,7	16068	4,6	569,6	16,1	590,3
	Copier	200	5	1,0	40	25	1,0	2	4365	8,7	4365	10,7	1532	1,5	1,5	13,4	16,4
	Active boxes (PC)	3	212,5	0,6	1,5	879	1,3	1	5334	5,3	2334	7,3	12457,8	7,9	16,4	66,5	90,8
Total	**Household end-use**													**13268,6**	**7855,1**	**1734,8**	**22858,5**

1 consisting of HiFi amplifier and cassette deck or CD player or audio DVD or minidisc deck; 2 incl. TV/VCR combinations and portable TVs
3 power consumption taking into account the charging efficiency; 4 power demand of charger left in power outlet; 5 standby + off-mode

Year: 2010		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	**Appliance type**	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Audio														**2556,6**	**1983,5**	**251,2**	**4791,2**
(stationary)	Compact system[1]	22	1250	27,5	8	3755	30,04	1,5	3004	4,506	751	62,046	20132	553,63	604,76528	90,714792	1249,11007
	Stereo system	50	1250	62,5	9	3755	33,8	4	1255	5,0	2500	101,3	31960	1997,5	1080,1	160,4	3238,0
	Clock radio	3	90	0,3	1,7	8670	14,7			0,0		15,0	20259	5,5	298,6	0,0	304,1
Audio														**14,8**	**69,1**	**38,4**	**122,3**
(portable)	Radio-tape deck	6	220	1,3	1,8	3416	6,1	1	3416	3,4	1708	10,9	11237	14,8	69,1	38,4	122,3
Television														**10847,6**	**1696,7**	**35,7**	**12580,0**
	Cathode ray TV[2]	120	1810	217,2	5	6150	30,8	1,5	400	0,6	400	248,6	36012	7821,8	1107,4	21,6	8950,7
	LCD TV	50	1810	90,5	4	6150	24,6	1,5	400	0,6	400	115,7	21746	1968,0	535,0	13,0	2516,0
	Plasma TV	350	1810	633,5	5	6150	30,8	1,5	400	0,6	400	664,9	1567	992,7	48,2	0,9	1041,8
	TV projector	180	1810	325,8	5	6150	30,8	1,5	400	0,6	400	357,2	200	65,2	6,2	0,1	71,4
Video recorder														**298,5**	**947,9**	**65,1**	**1311,6**
	Video recorder	17	484	8,2	5	5517	27,6	1,5	1379	2,1	1379	37,9	17080	140,5	471,2	35,3	647,1
	Video-DVD player/recorder	17	484	8,2	4	6207	24,8	1,5	1035	1,6	1035	34,6	19201	158,0	476,7	29,8	664,5
Cameras														**19,2**	**18,6**	**34,7**	**72,5**
	Video camera/Camcorder	9	60	0,5	6	120	0,7	0,5	2249	1,1	6331	2,4	18242	8,8	11,7	18,3	38,7
	Digital camera	9	60	0,5	6	60	0,4	0,5	1704	0,9	6936	1,8	19250	10,4	6,9	16,4	33,7
Others														**62,2**	**0,0**	**58,7**	**120,9**
	Video game console	50	110	5,5	0	0	0,0	2	2595	5,2	6055	10,7	11310	62,2	0,0	58,7	120,9
Telephony														**20,9**	**942,4**	**0,0**	**963,2**
(fixed network)	Cordless phone with 1 hand set	3,5	150	0,5	2	8610	17,2		0	0,0		17,7	19702	10,3	339,3	0,0	349,6
	Cordless phone >1 hand set	4	150	0,6	2	8610	17,2		0	0,0		17,8	10547	6,3	181,6	0,0	187,9
	Answering machine	3,5	50	0,2	2	8710	17,4		0	0,0		17,6	19194	3,4	334,4	0,0	337,7
	Fax machine	13	20	0,3	3	8740	26,2		0	0,0		26,5	3322	0,9	87,1	0,0	88,0
Telephony														**69,3**	**107,6**	**0,0**	**176,9**
(mobile)	GSM[3]	5,81	120	0,7	0,0625	4260	0,3		0	0,0	4380	1,0	35360	24,7	9,4	0,0	34,1
	UMTS[3]	7,08	182	1,3	0,125	4928	0,6		0	0,0	3650	1,9	34740	44,6	21,4	0,0	66,0
	Charger mobile phone[4]				0,5	2190	1,1					1,1	70100	0,0	76,8	0,0	76,8
Computer														**747,5**	**930,0**	**459,8**	**2137,4**
	PC	65	480	31,2	25	1656	41,4	4	4637	18,5	1987	91,1	21513	671,2	890,6	399,0	1960,8
	Notebook	25	480	12,0	6	662	4,0	1,5	5216	7,8	2402	23,8	6289	75,5	25,0	49,2	149,7
	PDA	1,5	78	0,1	0,8	2418	1,9	0,5	3132	1,6	3132	3,6	7428	0,9	14,4	11,6	26,9
Monitor														**581,5**	**218,8**	**78,9**	**879,3**
	Cathode ray	75	480	36,0	15	828	12,4	1	3726	3,7	3726	52,1	14205	511,4	176,4	52,9	740,7
	LCD	20	480	9,6	5	1159	5,8	1	3560	3,6	3560	19,0	7308	70,2	42,4	26,0	138,5
Printer														**62,4**	**188,6**	**352,1**	**603,0**
	Inkjet	20	40	0,8	6	698	4,2	2	6452	12,9	1570	17,9	18409	14,7	77,1	237,5	329,4
	Laser	150	40	6,0	20	698	14,0	3	4796	14,4	3226	34,3	7924	47,5	110,6	114,0	272,2
	Matrix	30	40	1,2	16	698	11,2	2	3226	6,5	4796	18,8	79	0,1	0,9	0,5	1,5
Others														**15,8**	**605,4**	**83,9**	**705,1**
	Scanner	14	20	0,3	5	5904	29,5	1	500	0,5	2336	30,3	19782	5,5	594,0	9,9	599,4
	Copier	200	6	1,2	40	25	1,0	2	4364	8,7	4364	11,0	770	0,9	0,8	6,7	8,4
	Active boxes (PC)	3	240	0,7	1,5	1068	1,6	1	5216	5,2	2236	7,5	12908	9,3	20,7	67,3	97,3
Total	**Household end-use**													**15296,4**	**7708,5**	**1458,6**	**24463,4**

1 consisting of HiFi amplifier and cassette deck or CD player or audio DVD or minidisc deck; 2 incl. TV/VCR combinations and portable TVs
3 power consumption taking into account the charging efficiency; 4 power demand of charger left in power outlet; 5 standby + off-mode

A1.2 Household infrastructure (for 2001, 2005 and 2010)

Year: 2001		**Energy consumption per appliance**											**Stock**	**Total consumption**			
		Normal			Standby			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
Appliance group	**Appliance type**	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Time used [h/a]	Consump. [kWh/a]	[in Tsd.]	[GWh]	[GWh]	[GWh]	[GWh]
Televisions														**658.4**	**1369.7**	**0.0**	**2028.1**
	Satellite receiver	20	1873	37.5	9	6687	62.0	0	0	0	0	99.4	12184	456.4	755.2	0.0	1211.6
	Antenna preamplifier	4	1873	7.5	4	6687	27.5	0	0	0	0	35.0	4883	36.6	134.5	0.0	171.1
	Set-top box	17	1873	31.8	9	6687	62.0	0	0	0	0	93.8	2328	74.1	144.3	0.0	218.4
	LNB	4	1873	7.5	4	6687	27.5	0	0	0	0	35.0	12184	91.3	335.6	0.0	426.9
Internet-/Telephone-/Others														**443.6**	**738.6**	**191.8**	**1374.0**
Infrastructure	DSL splitter	4	8760	35.0	0	0	0.0	0	0	0	0	35.0	2200	77.1	0.0	0.0	77.1
	DSL modem	7	389	2.7	4	568	2.3	3	5462	16.4	2341	21.4	2200	6.0	5.0	36.0	47.0
	CATV modem	12	389	4.7	5	568	2.8	3	5462	16.4	2341	23.9	86	0.4	0.2	1.4	2.1
	Satellite modem	24	389	9.3	13	8371	108.8	0	0	0	0	118.2	10	0.1	1.1	0.0	1.2
	PLC adapter	4	389	1.6	0.5	8371	4.2	0	0	0	0	5.7	129	0.2	0.5	0.0	0.7
	PLC house coupler	4	8760	35.0	0	0	0.0	0	0	0	0	35.0	86	3.0	0.0	0.0	3.0
	Router (DSL)	12	8760	105.1	0	0	0.0	0	0	0	0	105.1	220	23.1	0.0	0.0	23.1
	Telephone modem	12	122	1.5	5	835	4.2	3	5462	16.4	2341	22.0	9418	13.8	39.3	154.3	207.4
	ISDN-Box	5.8	8760	50.8	0	0	0.0	0	0	0	0	50.8	6283	319.2	0.0	0.0	319.2
	Intercom	10	4	0.0	4.5	8756	39.4	0	0	0	0	39.4	17573	0.7	692.4	0.0	693.1
Total	**Household infrastructure**													**1102.0**	**2108.3**	**191.8**	**3402.1**

Year: 2005		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	**Total**
Appl. Group	**Appliance type**	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Time used [h/a]	consump. [kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Television														**1049,2**	**1359,9**	**0,0**	**2409,1**
	Satellite receiver	20	2300	46,0	9	6460	58,1	0	0	0	0	104,1	12253	563,6	712,4	0,0	1276,0
	Antenna preamplifier	4	1996	8,0	4	6764	27,1	0	0	0	0	35,0	5023	40,1	135,9	0,0	176,0
	Set-Top box	21	3700	77,7	9	5060	45,5	0	0	0	0	123,2	4282	332,7	195,0	0,0	527,7
	LNB	4	2300	9,2	4	6460	25,8	0	0	0	0	35,0	12253	112,7	316,6	0,0	429,3
Internet-/Telephone-/Others														**1313,6**	**786,0**	**186,0**	**2285,6**
Infrastructure	DSL splitter	4	8760	35,0	0	0	0,0	0	0	0		35,0	10200	357,4	0,0	0,0	357,4
	DSL modem	7	243	1,7	4	849	3,4	3	5368	16,1	2300	21,2	7140	12,1	24,2	115,0	151,4
	CATV modem	12	243	2,9	5	849	4,2	3	5368	16,1	2300	23,3	2800	8,2	11,9	45,1	65,1
	Satelliten modem	24	243	5,8	13	8517	110,7	0	0	0	0	116,6	150	0,9	16,6	0,0	17,5
	PLC adapter	4	243	1,0	0,5	8517	4,3	0	0	0	0	5,2	1067	1,0	4,5	0,0	5,6
	PLC house coupler	4	8760	35,0	0	0	0,0	0	0	0	0	35,0	711	24,9	0,0	0,0	24,9
	Router (DSL)	12	8760	105,1	0	0	0,0	0	0	0	0	105,1	3060	321,7	0,0	0,0	321,7
	Telephone modem	12	91	1,1	5	1001	5,0	3	5368	16,1	2300	22,2	1606	1,8	8,0	25,9	35,7
	ISDN box	5,8	8760	50,8	0	0	0,0	0	0	0	0	50,8	11512	584,9	0,0	0,0	584,9
	Intercom	10	4	0,0	4,5	8756	39,4	0	0	0	0	39,4	18291	0,7	720,7	0,0	721,4
Total	**Household infrastructure**													**2362,8**	**2145,9**	**186,0**	**4694,7**

Year: 2010		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	**Total**
			Time			Time			Time		Time						
		Power	used	Consump.	Power	used	Consump.	Power	used	Consump	used	consump.					
Appl. Group	**Appliance type**	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Television														**1867,6**	**1291,5**	**0,0**	**3159,1**
	Satellite receiver	20	2800	56,0	9	5960	53,6	0	0	0,0	0	109,6	12320	689,9	660,8	0,0	1350,8
	Antenna preamplifier	4	2128	8,5	4	6632	26,5	0	0	0,0	0	35,0	5070	43,2	134,5	0,0	177,7
	Set-top box	25	5600	140,0	9	3160	28,4	0	0	0,0	0	168,4	7118	996,5	202,4	0,0	1199,0
	LNB	4	2800	11,2	4	5960	23,8	0	0	0,0	0	35,0	12320	138,0	293,7	0,0	431,7
Internet-/Telephone-/Others														**2192,0**	**920,3**	**156,5**	**3268,9**
Infrastructure	DSL splitter	4	8760	35,0	0	0	0,0	0	0	0,0		35,0	16000	560,6	0,0	0,0	560,6
	DSL modem	7	210	1,5	3	1098	3,3	2	5216	10,4	2236	15,2	8000	11,8	26,4	83,5	121,6
	CATV modem	12	210	2,5	4	1098	4,4	2	5216	10,4	2236	17,3	7000	17,6	30,7	73,0	121,4
	Satellite modem	24	210	5,0	13	8560	111,2	0	0	0,0	0	116,2	1000	5,0	111,2	0,0	116,2
	PLC adapter	4	210	0,8	0,5	8560	4,3	0	0	0,0	0	5,1	3333	2,8	14,2	0,0	17,0
	PLC house coupler	4	8760	35,0			0,0			0,0		35,0	2222	77,9	0,0	0,0	77,9
	Router (DSL)	12	8760	105,1			0,0			0,0		105,1	8000	841,0	0,0	0,0	841,0
	Telephone modem	12	0	0,0	5	0	0,0	3	0	0,0	0	0,0	0	0,0	0,0	0,0	0,0
	ISDN box	5,8	8760	50,8			0,0			0,0		50,8	13277	674,6	0,0	0,0	674,6
	Intercom	10	4	0,0	4,5	8756	39,4	0	0	0,0	0	39,4	18726	0,7	737,8	0,0	738,6
Total	**Household infrastructure**													**4059,6**	**2211,8**	**156,5**	**6427,9**

A1.3 Office end-use appliances (for 2001, 2005 and 2010)

Year: 2001		**Energy demand per appliance**											**Stock**	**Total consumption**			
			Normal mode			Standby			Off-mode		Off	Total		Normal	Standby	Off-mode	Total
Appl. Group	**Appliance type**	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Time used [h/a]	Consump. [kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Cameras														**0.4**	**0.4**	**3.7**	**4.4**
	Video camera/camcorder	9	15	0.1	6	30	0.2	1.5	871	1.3	7844	1.6	1410	0.2	0.3	1.8	2.3
	Digital camera	9	16	0.1	6	15	0.1	1.5	873	1.3	7857	1.5	1410	0.2	0.1	1.8	2.2
Telephony[1]														**74.4**	**622.5**	**0.0**	**696.9**
(Fixed network)	Cordless phone	3.5	330	1.2	2.5	8430	21.1	0	0	0.0	0	22.2	2351	2.7	49.5	0.0	52.3
	Smart phone	4	330	1.3	2.5	8430	21.1	0	0	0.0	0	22.4	6817	9.0	143.7	0.0	152.7
	Answering machine	3.5	50	0.2	3	8710	26.1	0	0	0.0	0	26.3	3174	0.6	82.9	0.0	83.5
	Fax machine	55	330	18.2	12	8430	101.2	0	0	0.0	0	119.3	3424	62.1	346.4	0.0	408.5
Telephony[1]																	
(mobile)	GSM																
	UMTS																
Computers														**1150.6**	**119.1**	**309.3**	**1579.0**
	PC	50	1870	93.5	25	330	8.3	4	5248	21.0	1312	122.7	10461	978.1	86.3	219.6	1284.0
	Notebook	18	1430	25.7	6	770	4.6	4	3290	13.1	3290	43.5	6700	172.5	31.0	87.9	291.3
	PDA	1.5	66	0.1	1.2	2575	3.1	1	3060	3.1	3060	6.2	588	0.1	1.8	1.8	3.7
Monitors														**1451.5**	**80.6**	**156.5**	**1688.6**
	Cathode ray	80	1870	149.6	15	550	8.3	3	5072	15.2	1268	173.1	9415	1408.6	77.7	143.3	1629.4
	LCD	22	1870	41.1	5	550	2.8	2.5	5072	12.7	1268	56.6	1046	43.0	2.9	13.3	59.2
Printers														**330.4**	**482.2**	**83.8**	**896.3**
	Inkjet	30	110	3.3	6	2200	13.2	4	5160	20.6	1290	37.1	1763	5.8	23.3	36.4	65.5
	Laser	350	220	77.0	50	2090	104.5	2	5160	10.3	1290	191.8	4114	316.8	429.9	42.5	789.1
	Matrix	30	440	13.2	16	3080	49.3	2	4192	8.4	1048	70.9	588	7.8	29.0	4.9	41.7
Others														**1567.8**	**1278.9**	**75.0**	**2921.8**
	Scanner	18	110	2.0	8	6750	46.0	4	1312	5.2	1588	53.2	2351	4.7	108.1	12.3	125.1
	Copier	800	330	264.0	100	1980	198.0	2	5160	10.3	1290	472.3	5877	1551.5	1163.6	60.7	2775.8
	Projector	180	110	19.8	7	1730	12.1	2	1730	3.5	5190	35.4	588	11.6	7.1	2.0	20.8
Total	**Office end-use appliances**													**4575.1**	**2583.6**	**628.3**	**7787.0**

[1] accounted for in households

Year: 2005		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	**Appliance type**	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Cameras														**0,4**	**0,4**	**2,9**	**3,7**
	Video camera/Camcorder	9	15	0,1	6	30	0,2	1	871	0,9	7844	1,2	1462	0,2	0,3	1,3	1,7
	Digital camera	9	15	0,1	6	15	0,1	1	873	0,9	7867	1,1	1827	0,2	0,2	1,6	2,0
Telephony1														**106,3**	**725,6**	**0,0**	**831,9**
(fixed network)	Cordless phone	3,5	330	1,2	2	8430	16,9			0,0		18,0	3655	4,2	61,6	0,0	65,8
	Smart phone	4	330	1,3	2	8430	16,9			0,0		18,2	7309	9,6	123,2	0,0	132,9
	Answering machine	3,5	50	0,2	2,5	8710	21,8			0,0		22,0	3289	0,6	71,6	0,0	72,2
	Fax machine	66	330	18,2	11	8430	92,7			0,0		110,9	5059	91,8	469,1	0,0	560,9
Telephony[1]				0,0			0,0			0,0		0,0					
(mobile)	GSM																
	UMTS																
Computer														**1006,8**	**176,6**	**282,9**	**1466,3**
	PC	50	1540	77,0	20	660	13,2	4	5248	21,0	1312	111,2	10355	797,3	136,7	217,4	1151,4
	Notebook	20	1430	28,6	6	770	4,6	2,5	3280	8,2	3280	41,4	7309	209,0	33,8	59,9	302,7
	PDA	1,5	110	0,2	1	2530	2,5	0,75	3060	2,3	3060	5,0	2436	0,4	6,2	5,6	12,2
Monitor														**998,2**	**109,3**	**89,3**	**1196,8**
	Cathode ray	80	1540	123,2	15	880	13,2	2	5072	10,1	1268	146,6	7248	893,0	95,7	73,6	1062,2
	LCD	22	1540	33,9	5	880	4,4	1	5072	5,1	1268	43,4	3106	105,2	13,7	15,8	134,7
Printer														**568,9**	**506,5**	**69,1**	**1144,5**
	Inkjet	30	110	3,3	6	2200	13,2	2	5160	10,3	1290	26,8	1827	6,0	24,1	18,9	49,0
	Laser	350	330	115,5	50	1980	99,0	2	5160	10,3	1290	224,8	4873	562,8	482,4	50,3	1095,5
	Matrix	30	440	13,2	16	3080	49,3	2	4192	8,4	1048	70,9	0	0,0	0,0	0,0	0,0
Others														**1649,0**	**1240,2**	**71,3**	**2960,6**
	Scanner	18	110	2,0	6	5750	34,5	2	1312	2,6	1588	39,1	2436	4,8	84,0	6,4	95,3
	Copier	800	330	264,0	95	1980	188,1	2	5160	10,3	1290	462,4	6091	1608,0	1145,7	62,9	2816,6
	Projector	180	165	29,7	5	1719	8,6	1	1719	1,7	5157	40,0	1218	36,2	10,5	2,1	48,7
Total	**Office end-use appliances**													**4329,6**	**2758,7**	**515,5**	**7603,8**

1 accounted for in households

Year: 2010		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	Appliance type	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Cameras														**0,5**	**0,4**	**1,5**	**2,4**
	Video camera/camcorder	9	15	0,14	6	30	0,18	0,5	871	0,44	7844	0,7505	1513	0,2	0,3	0,7	1,1
	Digital camera	9	15	0,14	6	15	0,09	0,5	873	0,44	7867	0,6615	1892	0,3	0,2	0,8	1,3
Telephony				0,00			0,00			0,00				**114,6**	**730,6**	**0,0**	**845,2**
(fixed network)	Cordless phone	3,5	330	1,16	2	8430	16,86			0,00		18,015	5045	5,8	85,1	0,0	90,9
	smart phone	4	330	1,32	2	8430	16,86			0,00		18,18	7819	10,3	131,8	0,0	142,1
	Answering machine	3,5	50	0,18	2	8710	17,42			0,00		17,595	3405	0,6	59,3	0,0	59,9
	Fax machine	55	330	18,15	10	8430	84,30			0,00		102,45	5390	97,8	454,4	0,0	552,2
Telephony[1]																	
(mobile)	GSM																
	UMTS																
Computer														**1000,8**	**205,9**	**263,0**	**1469,7**
	PC	50	1430	71,50	20	770	15,40	4	5248	20,99	1312	107,892	10090	721,4	155,4	211,8	1088,6
	Notebook	22	1430	31,46	6	770	4,62	1,5	3280	4,92	3280	41	8828	277,7	40,8	43,4	361,9
	PDA	1,5	220	0,33	0,8	2420	1,94	0,5	3060	1,53	3060	3,796	5045	1,7	9,8	7,7	19,2
Monitor														**819,6**	**109,9**	**61,4**	**990,8**
	Cathode ray	80	1430	114,40	15	990	14,85	1	5072	5,07	1268	134,322	6054	692,6	89,9	30,7	813,2
	LCD	22	1430	31,46	5	990	4,95	1,5	5072	7,61	1268	44,018	4036	127,0	20,0	30,7	177,7
Printer														**783,2**	**496,7**	**81,4**	**1361,2**
	Inkjet	30	110	3,30	6	2200	13,20	3	5160	15,48	1290	31,98	1892	6,2	26,0	29,3	60,5
	Laser	350	440	154,00	50	1870	93,50	2	5160	10,32	1290	257,82	5045	776,9	471,7	52,1	1300,7
	Matrix	30	440	13,20	16	3080	49,28	2	4192	8,38	1048	70,864	0	0,0	0,0	0,0	0,0
Others														**1744,7**	**1143,5**	**71,6**	**2959,8**
	Scanner	18	110	1,98	6	6750	28,75	1	1312	1,31	1588	32,042	2522	5,0	72,5	3,3	80,8
	Copier	800	330	264,00	85	1980	168,30	2	5160	10,32	1290	442,62	6306	1664,9	1061,3	65,1	2791,2
	Projector	180	220	39,60	3	1708	5,12	1	1708	1,71	5124	46,432	1892	74,9	9,7	3,2	87,8
Total	**Office end-use appliances**													**4463,3**	**2687,0**	**478,8**	**7629,1**

1 accounted for in households

A1.4 Office infrastructure (for 2001, 2005 and 2010)

Year: 2001		Energy consumption per appliance											Stock	Total consumption			
		Normal			Standby			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
Appl. group	Appliance type	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Time used [h/a]	Consump. [kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Networking														**664.8**	**0.0**	**0.0**	**664.8**
	Router	40	8760	350.4	0	0	0	0	0	0	0	350.4	1304	456.9	0.0	0.0	456.9
	Hubs/Switches	1.5	8760	13.1	0	0	0	0	0	0	0	13.1	15817	207.8	0.0	0.0	207.8
Telephone/other														**160.8**	**272.5**	**0.0**	**433.3**
Infrastructure	Private branch exchange [W/user]	2	8760	17.5			0			0		17.5	9168	160.6	0.0	0.0	160.6
	Intercom	13	4	0.1	10	8756	87.6	0	0	0	0	87.6	3112	0.2	272.5	0.0	272.7
Server										0				**3945.1**	**0.0**	**0.0**	**3945.1**
	lower price range (< 25kEuro)	150	8760	1314.0	0	0	0	0	0	0	0	1314.0	784	1029.6	0.0	0.0	1029.6
	medium price range (25-100kEuro)	800	8760	7008.0	0	0	0	0	0	0	0	7008.0	107	749.9	0.0	0.0	749.9
	upper price range (>100kEuro)	2500	8760	21900.0	0	0	0	0	0	0	0	21900.0	99	2165.7	0.0	0.0	2165.7
UPS[1]														**382.2**	**0.0**	**0.0**	**382.2**
	for routers	0,88[#]	8760	42.0	0	0	0	0	0	0	0	42.0	913	38.4	0.0	0.0	38.4
	for hubs/switches	0,88[#]	8760	1.6	0	0	0	0	0	0	0	1.6	7909	12.5	0.0	0.0	12.5
	for servers low price range	0,88[#]	8760	157.7	0	0	0	0	0	0	0	157.7	549	86.5	0.0	0.0	86.5
	for servers medium price range	0,88[#]	8760	841.0	0	0	0	0	0	0	0	841.0	75	62.9	0.0	0.0	62.9
	for servers upper price range	0,88[#]	8760	2628.0	0	0	0	0	0	0	0	2628.0	69	182.0	0.0	0.0	182.0
Total	**Office infrastructure**													**5152.9**	**272.5**	**0.0**	**5425.4**

1 Energy demand calculated using efficiency

\# Efficiency

Year: 2005		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	**Total**
Appl. Group	**Appliance type**	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Power [W]	Time used [h/a]	Consump. [kWh/a]	Time used [h/a]	consump. [kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Networking														**808,4**	**0,0**	**0,0**	**808,4**
	Router	40	8760	350,4	0	0	0	0	0	0	0	350,4	1586	555,7	0,0	0,0	555,7
	Hubs/Switches	1,5	8760	13,1	0	0	0	0	0	0	0	13,1	19226	252,6	0,0	0,0	252,6
Telephone/other														**192,3**	**272,5**	**0,0**	**464,8**
Infrastructure	Private branch exchange [W/user]	2	8760	17,5			0			0		17,6	10964	192,1	0,0	0,0	192,1
	Intercom	13	4	0,1	10	8756	87,6	0	0	0	0	87,6	3112	0,2	272,5	0,0	272,7
Server														**5799,9**	**0,0**	**0,0**	**5799,9**
	lower price range (< 25kEuro)	180	8760	1576,8	0	0	0	0	0	0	0	1576,8	952	1501,8	0,0	0,0	1501,8
	medium price range (25-100kEuro)	1000	8760	8760,0	0	0	0	0	0	0	0	8760,0	130	1137,7	0,0	0,0	1137,7
	upper price range (>100kEuro)	3000	8760	26280,0	0	0	0	0	0	0	0	26280,0	120	3160,4	0,0	0,0	3160,4
USV[1]														**653,2**	**0,0**	**0,0**	**653,2**
	for routers	0,9[#]	8760	35,0	0	0	0	0	0	0	0	35,0	1596	55,6	0,0	0,0	55,6
	for Hubs/Switches	0,9[#]	8760	1,3	0	0	0	0	0	0	0	1,3	13458	17,7	0,0	0,0	17,7
	for server lower price range	0,9[#]	8760	157,7	0	0	0	0	0	0	0	157,7	952	150,2	0,0	0,0	150,2
	for server medium price range	0,9[#]	8760	876,0	0	0	0	0	0	0	0	876,0	130	113,8	0,0	0,0	113,8
	for server upper price range	0,9[#]	8760	2628,0	0	0	0	0	0	0	0	2628,0	120	316,0	0,0	0,0	316,0
Total	**Office infrastructure**													**7453,7**	**272,5**	**0,0**	**7726,3**

1 Energy demand calculated using efficiency

\# Efficiency

Year: 2010		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	Appliance type	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Networking														**1031,6**	**0,0**	**0,0**	**1031,6**
	Router	40	8760	350,4	0	0	0	0	0	0	0	350,4	2024	709,2	0,0	0,0	709,2
	Hubs/switches	1,5	8760	13,1	0	0	0	0	0	0	0	13,1	24537	322,4	0,0	0,0	322,4
Telephone/other														**225,5**	**272,5**	**0,0**	**498,1**
Infrastructure	Private branch exchange [Watt/user]	2	8760	17,5			0			0		17,5	12864	225,4	0,0	0,0	225,4
	Intercom	13	4	0,1	10	8755	87,6	0	0	0	0	87,6	3112	0,2	272,5	0,0	272,7
Server				0,0								0,0		**8790,9**	**0,0**	**0,0**	**8790,9**
	lower price range (< 25kEuro)	220	8760	1927,2	0	0	0	0	0	0	0	1927,2	1216	2342,7	0,0	0,0	2342,7
	medium price range (25-100kEuro)	1200	8760	10512,0	0	0	0	0	0	0	0	10512,0	166	1742,5	0,0	0,0	1742,5
	upper price range (>100kEuro)	3500	8760	30660,0	0	0	0	0	0	0	0	30660,0	153	4705,8	0,0	0,0	4705,8
USV[1]														**780,6**	**0,0**	**0,0**	**780,6**
	for routers	0,92[#]	8760	28,0	0	0	0	0	0	0	0	28,0	2024	56,7	0,0	0,0	56,7
	for hubs/switches	0,92[#]	8760	1,1	0	0	0	0	0	0	0	1,1	19630	20,6	0,0	0,0	20,6
	for server lower price range	0,92[#]	8760	154,2	0	0	0	0	0	0	0	154,2	1216	187,4	0,0	0,0	187,4
	for server medium price range	0,92[#]	8760	841,0	0	0	0	0	0	0	0	841,0	166	139,4	0,0	0,0	139,4
	for server upper price range	0,92[#]	8760	2452,8	0	0	0	0	0	0	0	2452,8	153	376,5	0,0	0,0	376,5
Total	**Office infrastructure**													**10828,7**	**272,5**	**0,0**	**11101,2**

1 Energy demand calculated using efficiency

\# Efficiency

A1.5 Infrastructure of telecommunications companies (for 2001, 2005 and 2010)

Year: 2001		Energy consumption per appliance											Stock	Total consumption			
		Normal			Standby			Off-mode			Off	Total		Normal	Standby	Off-mode	Total
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	Consump.					
Appl. group	**Appliance type**	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Fixed network														**1121.0**			**1121.0**
	Telephone channel (Watt per channel)	2.44	8760	21.4								21.4	50280.0	1074.7			1074.7
	DSL connection (Watt per connection)	2.4	8760	21.0								21.0	2200.0	46.3			46.3
Mobile communications														**1128.7**			**1128.7**
	Base stations GSM	1880	8760	16468.8								16468.8	50.7	834.6			834.6
	Base stations UMTS		0	0.0								0.0	0.0	0.0			0.0
	Switching centre GSM	146000	8760	1278960.0								1278960.0	0.2	294.2			294.2
	Switching centre UMTS		0	0.0								0.0	0.0	0.0			0.0
Total	**Infrastructure telecommunications**													**2249.7**			**2249.7**

Year: 2005		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	**Total**
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	**Appliance type**	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Fixed network														**1314,0**			**1153,2**
	Telephone channel (Watt per channel)	2,44	8760	21,4								21,4	53961,0	1153,2			1153,2
	DSL connection (Watt per connection)	1,8	8760	15,8								15,8	10200,0	160,8			
Mobile communications														**2246,0**			**2246,0**
	Base stations GSM	1780	8760	15592,8								15592,8	62,9	981,1			981,1
	Base stations UMTS	3810	8760	33375,6								33375,6	20,6	687,5			687,5
	Switching centre GSM	140050	8760	1226838,0								1226838,0	0,3	350,9			350,9
	Switching centre UMTS	300520	8760	2632555,2								2632555,2	0,1	226,4			226,4
Total	**Infrastructure telecommunications**													**3560,0**			**3399,1**

Year: 2010		Energy demand per appliance											Stock	Total consumption			
		Normal mode			Standby mode			Off-mode			Off	Total		Normal	Standby	Off-mode	**Total**
		Power	Time used	Consump.	Power	Time used	Consump.	Power	Time used	Consump.	Time used	consump.					
Appl. Group	**Appliance type**	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[W]	[h/a]	[kWh/a]	[h/a]	[kWh/a]	[thousands]	[GWh]	[GWh]	[GWh]	[GWh]
Fixed network														**1424,2**			**1424,2**
	Telephone channel (Watt per channel	2,44	8760	21,4								21,4	55493,0	1185,9			1185,9
	DSL connection (Watt per connectio	1,7	8760	14,9								14,9	16000,0	238,3			238,3
Mobile communications														**4379,1**			**4379,1**
	Base stations GSM	1690	8760	14804,4								14804,4	63,0	932,7			932,7
	Base stations UMTS	3400	8760	29784,0								29784,0	79,2	2359,0			2359,0
	Switching centre GSM	134100	8760	1174716,0								1174716,0	0,3	336,0			336,0
	Switching centre UMTS	259980	8760	2277424,8								2277424,8	0,3	751,6			751,6
Total	**Infrastructure telecommunications**													**5803,3**			5803,3