Digital TV and Broadband Communication: Containing the Energy "Black Hole" with the Innovative Policy Tool of a Code of Conduct

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ABSTRACT

The European Union is moving fast toward the switch to digital TV and the phase-out of analog broadcasting. This means that the current stock of analog TVs will need converter boxes to be able to function. In early 2004, millions of these boxes will be sold in Italy, the UK and other European countries. At the same time, pay-TV is competing on the market with more sophisticated services and offers. This is resulting in even more complex set-top boxes, which show a worrying rising trend in energy consumption.

In addition to the digital TV services supplied through satellite, terrestrial and cable (fiber or coax), there are new service providers starting to offer digital TV and video-on-demand through the telephone lines with DSL modems or using power line technology. Through broadband, users can download DVD or DVX movies from the web, store them on hard disks, and then play them on TV. These trends will accelerate the convergence between Information Communication Technology equipment and consumer electronics and have a big impact on energy consumption (more than one system always on in each dwelling, and increasing power demand for each device as it gets more powerful).

The European Union has established a successful stakeholder forum through its Code of Conduct on Energy Efficiency of Digital TV Service Systems, which discusses efficiency levels, operating modes, and the necessary power management guidelines to achieve desirable efficiency levels. The paper reports the latest results, advice, and developments from this innovative policy tool.

An Overview of the Drivers for the Code of Conduct

Digital TV Service Systems – The Need for a Code of Conduct.

The television broadcasting sector of consumer electronics is currently undergoing radical changes. The rapid development of a major communication network to support digital television is complemented by continuous developments in the functionality of the reception hardware, giving the consumer:

- Major improvements in the realism of the audiovisual presentation of broadcast services
- For the first time, full interactivity with the content and source of the signals.
- A combined entertainment and communication platform with access to the full Internet or to "walled garden" information services. So digital television is helping to close gap between the "lean forward" solo-working tool of the PC and the "lean back" group

entertainment device of the TV. This convergence may bring significant lifestyle changes in all levels of society, not just to those currently information rich.

The technology supporting these changes is developing at an unprecedented rate. One consequence of this is that the relatively slow and costly manufacturing and marketing cycle of the mass-produced TV cannot viably accommodate the accompanying rapid changes in the technical specification of the hardware. An independent signal interface and data processing platform, the set-top box (STB) has been the preferred manufacturing and market distribution solution. This device readily interfaces with existing and developing TVs and display systems and allows the rapid modification of functionality specifications in high volume production.

The downside of this solution is that the existing voluntary agreement and labeling mechanisms for energy efficient domestic electronic products are too slow to keep up with STB development and could potentially hamper that development. In 1997, a European Commission working group identified the digital service system STB as the domestic electronic device with the largest potential to increase the energy requirement of European households.

Research into proposed development showed that by 2010, the STB could push domestic electronic energy consumption in Europe above that of refrigerators and freezers. With 150 million of these boxes across the EU - equivalent to one per household – the annual electricity requirement for digital service systems with full functionality and poor power management could be around 60TWh (close to the total electricity consumption of Denmark for all sectors). Generation of this electricity would also release 24 $MtCO_2$, which would have a significant impact on the EU's ability to meet its overall Kyoto CO_2 reduction target.

To challenge and resolve this problem, the European Commission set up a working group of the key stakeholders in digital service system development – STB designers, STB manufacturers, component providers (e.g. Silicon[1], LNB, Tuners), service providers – and energy agency specialists.

This activity has become an excellent example of a product policy initiative that united stakeholders early enough to impact the design process *before* the product became ubiquitous.

The Content of the Code of Conduct

The principal aim of the working group is to reduce the energy consumption of the STB through the setting of agreed, practicable power requirement targets in a defined development timescale. To that end, a voluntary agreement or Code of Conduct was devised which Europe's principal STB and TV manufacturers and a major Service Provider, B-Sky-B, currently support.

The Signatories of this Code of Conduct[2] would make all reasonable efforts to:

- Achieve the power consumption targets set for new stand-alone products placed on the market after 1.1.2003, and for digital TVs with built-in Integrated Receiver Decoder placed on the market after 1.1.2005.

[1] Throughout the text the authors use the term "Silicon" to describe the electronic components within the set-top box – components, since the principal functional blocks are embedded in LSI silicon chips.

[2] The list of the Signatories and the Code of Conduct can be seen at the website of the EU Stand-by Initiative, the European Actions to Improve Energy Efficiency of Electrical Equipment while either Off or in Standby, at http://energyefficiency.jrc.cec.eu.int/html/standby_initiative.htm

- Support and contribute to the development and acceptance through an ad-hoc Task Force of the Common Power Management Guidelines
- Co-operate with the European Commission and Member State authorities in an annual review of the scope of the Code of Conduct and the power consumption targets for two years ahead.
- Facilitate and encourage consumers to adopt energy efficient practices in connection with the use of digital TV services.
- Co-operate with the European Commission and Member States in monitoring the effectiveness of this Code of Conduct.
- Ensure that procurement specifications for digital TV services, systems, equipment and components are compliant with this Code of Conduct.

The current version of the Code of Conduct sets energy consumption targets lower than average consumption of the STBs currently on the market for the standby passive mode (6W) and the standby active mode (9W) for all STBs, whether cable, terrestrial or satellite, supplied in 2003 to 2005 in the basic configuration. This values will go down to 3W for the standby passive mode and 8W for the standby active mode for satellite STBs (7W for cable and 6W for terrestrial STBs) supplied in 2006 to 2007. The most stringent target for the designer is likely to be the signatory's commitment to a maximum standby active mode of 15W for any future platform, however complex.

In this context, the Code of Conduct identifies a key tool to the achievement of significant energy efficiency targets in digital service system platforms - the development of effective power management in the silicon for the principal functional blocks.

The power management task force, originally formed and supported by the UK Department of Environment Market Transformation Programme, is supporting a silicon development "road map" which will help to qualify future revisions of the power requirement targets in the Code of Conduct.

The task force relies on the cooperation of platform designers and silicon designers in the construction and continuous updating of this roadmap.

Low-cost, simple digital TV converters (defined as 'with no Conditional Access support') for legacy analog TVs and VCRs are a current priority for the task force. To save software development time and cost, OEM products in particular are not making best use of the power management features already embedded in the components used. The current values in the Code of Conduct for simple digital TV converters boxes are 2W for the standby passive mode and 11W for the on-mode (14W for the satellite). This is of particular importance due to the large number of existing analog TVs. By assuming one converter box per household always on at 15 W, current consumption levels would results in additional electricity consumption of 18 TWh per year.

The success to date of this cooperative activity has the potential to contain the electricity requirement of future digital service system products to a level where the benefit to the consumer's lifestyle outweighs, by far, any environmental penalties.

Service Provider Needs and STB Power Architecture

Service Provider Requirements

Effective power management to maximize energy efficiency can only be achieved after consideration of the permitted operating modes. The user may only be aware of the states "ON" and "STANDBY", but the functionality in these states may vary greatly depending on the requirements of the service provider and the delivery medium - cable, satellite, terrestrial transmitters or DSL.

In the "ON" state, digital set-top boxes provide the basic function of decoding of television pictures. Many also have on-screen, interactive information services. Other services such as electronic shopping, e-mail delivery, Internet access, games and software download may also be available. As the digital TV market develops, service providers are keen to offer further premium services, which place additional demands on the hardware and increase power consumption. These services could include TV recording, video-on-demand, telephony, home networking, automation, and wired or wireless interface with peripheral devices. Broadband platforms for new broadcast and communication networks based on wired and/or wireless local area networks (LANs) will add to this energy requirement load. To counteract the resulting increased energy demand and follow the Code of Conduct, close attention needs to be given to efficient power conversion, distribution, and the management of power usage depending on the function required.

When the set-top box is not required for decoding digital television signals, the user is encouraged to select the "STANDBY" mode. Additionally, the set-top box may be able to detect long periods of inactivity and automatically go into "STANDBY" [3]. For many users, this mode could be applied 80% of the time, and it is here that most energy can be saved. However, service provider requirements will determine what is meant by standby. Listed below are three different levels of standby as defined in IEC 62087.

Standby-passive (known as standby passive in the code of conduct). this state, the set-top box will have minimal functionality. Many circuit blocks and the software may be inactive. All that is needed is the ability to receive and recognize a user command to switch into the active state. This standby mode can be used for those services where there is no requirement for continuous or time dependant communication. It offers the greatest opportunity for energy saving but does require time for software initialization when coming out of standby.

Standby-active, low (known as standby passive in the code of conduct). Here the set-top box is not receiving any signal, but some software is running and timed or triggered wake-up is possible as well as rapid response to a user command. The set-top box may periodically wake-up to check the data stream for anything addressed to it. A further possibility to be explored is the

[3] It would be desirable that the STB goes automatically to lower mode consumption. However, it is not totally straight forward to do it as all possible uses of the set-top box shall be considered. For example it is very difficult to detect when the user is expecting to record a programme on an external VCR unless they are using the EPG to select the programme and then drive the VCR into record mode. Many domestic set-ups are not capable of this. This is an important area and much more work shall be done by the Code of Conduct working group.

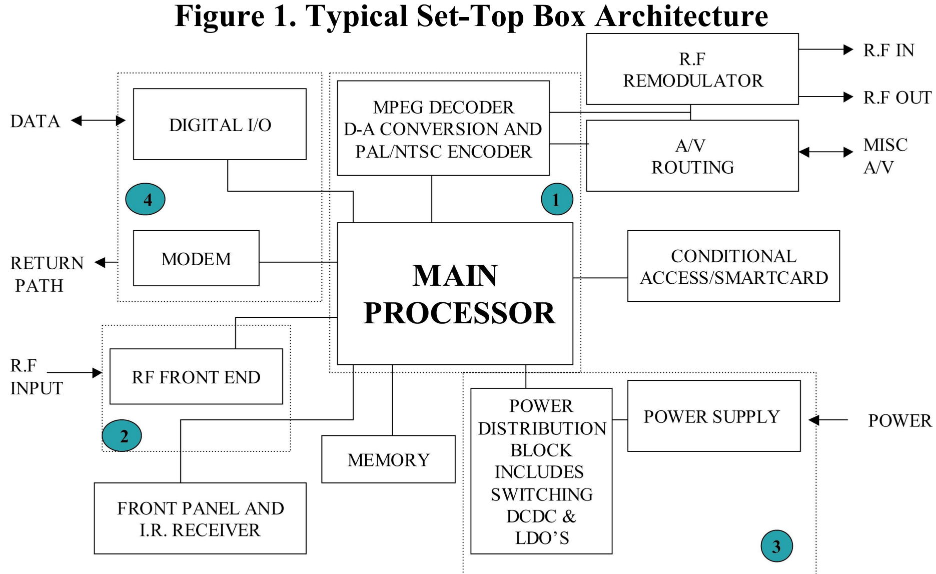
use of a software suspend mode where all processing (except possibly a timer) is halted but memory self-refresh used to enable rapid wake-up.

Standby-active, high (known as standby active in the code of conduct). For operational or security reasons, some service providers require constant communication with the set-top box. Standby Active mode prepares the STB to give speedier network access in the cable and DSL environments or facilitate software download, e-mail delivery and interrogation of a smart card when required. This level of functionality means that the RF front-end and some data processing is always active. This standby mode is often the most appropriate for delivery of additional premium services. The set-top box may appear to be in standby but performing a number of background functions. It could be the link between a home network and the outside world, providing communication even in the standby mode. Effective power management can still reduce energy consumption in this state as described later.

Typical Set-Top Box Architecture

Figure 1 shows a simplified block diagram of a typical set-top box. Some of the opportunities for power management of these circuit blocks in relation to operational and standby states are reviewed below. The blocks consuming the majority of the power are the main processor, MPEG decoder (often part of the main processor), RF front-end, and the power supply / power distribution itself.

Figure 1. Typical Set-Top Box Architecture



Main processor/MPEG decoder, block 1. In standby, no TV picture is required, so the MPEG decoder (along with D-A conversion and composite video encoding) can be disabled to reduce power consumption. Increasingly, this is an integral part of the main processor. The simplest way to reduce power with some software still active is to lower the clock speed consistent with the level of processing needed. Ideally, clock management should be part of the processor design so that this can happen in a controlled manner without interruption of the residual software processes. The choice of software architecture can also have significant impact on energy consumption as discussed later.

RF front-end, block 2. In the Standby-active, low and Standby-passive states, the RF front-end can be disabled or put into sleep mode. In the standby-active, high state it may be possible to reduce clock frequency to save power if processing data with a lower symbol rate.

Power supply and power distribution, block 3. In all standby states the power supply will still be active. For the Standby-passive state, power could be removed from many circuit blocks just leaving a small circuit active to decode user commands from infra-red remote control or the front panel. Power supply conversion efficiency at light load then becomes important.

Digital I/O and modem, block 4. These circuits may be idle for much of the time, even when the rest of the box is fully active. Similar techniques to those used in portable PC design would enable these functions to be normally in a low power state but still looking for any signal which requires them to become fully active.

Optimization of the Power Budget

The European Code of Conduct on Energy Efficiency of Digital TV Service Systems has also focused attention on power reduction in other areas. One example where progress has been made is in the power taken by the low noise block (LNB) used on satellite dishes. Because of historical standards for voltage signaling, these are fed with a supply of 13V or 18V by the set-top box. For a conventional single-output LNB, the DC power consumed can be between 1 and 2 watts. Even higher power is required for dual and quad LNBs. In traditional designs, most of this power is dissipated as heat in a linear regulator having an output of 5V or lower. Recently, some LNB manufacturers have produced more efficient designs using a switching buck converter to derive the low voltage needed. This can reduce the power to the LNB by some 60%.

Recently introduced personal video recorders (PVR) use a hard disc drive (HDD) to store the MPEG data stream for later viewing. The HDD may consume 6 watts of DC power when active. Careful management of the HDD would allow it to go into a sleep mode when not required. However, service providers are keen to access the HDD even when the set-top box is in standby so that movies and targeted advertising can be stored for later retrieval. This extended activity of the HDD can add significantly to energy consumption. Smaller, lower-power hard discs developed for the portable PC market could be used to reduce energy. The main barrier to this at present is the higher cost of these smaller drives.

Future Energy Efficient Platforms and Peripherals

The Code of Conduct working groups will assist and encourage designers and stakeholders to:

- Choose the lowest power standby mode consistent with service provider requirements.
- Decide whether adequate power management of each circuit block can be achieved by control of the silicon/software itself or if switching of power rails is needed.
- Consider power consumption and in-built power management features when choosing silicon for the main processor and RF front-end.
- Involve software designers from the outset so that energy efficient software architecture and power management are incorporated in the early design.

- Check if any third-part software, which may be used for the operating system or conditional access, supports power management.
- The choice of RISC (Reduced Instruction Set Computer) core over a CISC (Complex Instruction Set Computer) CPU can help reduce the overall power consumption. RISC cores are by nature simpler and therefore smaller than CISC CPUs. The smaller number of transistors translates into reduced power consumption. Hard-wired instruction decode logic instead of micro-coded ROMs to decode, fixed 32-bit instruction size instead of variable, as well as a large bank of general purpose registers all contribute to make a RISC CPU simpler and more efficient.
- In the initial design stages, assemble a comprehensive power budget from the voltage and current requirements of each circuit block. Rationalize the voltages delivered by the power supply and design for minimum power loss in any post-regulation circuits.
- Ensure that power to peripheral ports and devices can be turned off when not required.
- Encourage the user to put the set-top box into standby when not required for television viewing. Design in features that make this action easier for the user.
- Design the power supply itself to have high efficiency over all of its required operating range.
- Encourage the rapid standardization of "intelligent" interconnectivity to ensure that any component in the home entertainment and communication network automatically adopts the lowest power requirement for the level of activity required.

The Next Challenge: Broadband Communication Equipment

Overview

Current projections show that the predicted uptake of the two key broadband WANs (wide area *communication* networks), DSL (digital subscriber line) and digital cable, will have a large potential impact on European household energy consumption. Even with the unlikely application of best practice in energy efficiency for all the network and end-user hardware, a simple broadband terminal for, say, 150 million EU households by 2010 would increase annual domestic electricity demand by an estimated 6.6 TWh. This could effectively be doubled by associated LAN equipment.

Broadband wireless networks, including one-way and two-way satellite, are predicted to supply less than 12% of European access requirements by 2010. This relatively low penetration and the formative nature of the technology leaves consideration of the impact of this broadband solution as a low priority. In practice, it is likely that a down path through the digital TV satellite network will provide the broadband solution for those households not passed by digital cable and out of DSL exchange range. The outgoing path is likely to be PSTN modem or, for higher data rates, fixed wireless network.

As a future discussion guide, recent UK tests show that the power requirement taken by a best practice, simple terminal, always on, two-way, broadband satellite link for home installation was 25.6 W, including the dish equipment (LNB) Compare this with the current best practice DSL simple terminal power requirement of 4.0W

Mobile broadband access will develop as a parallel requirement to fixed access in this decade. Energy efficient technology is likely to smooth any step change in the energy consumption of the mobile service provider network infrastructure, in the expansion from 2G, to

UMTS (3G) networks supporting MIDs (mobile information devices) with broadband wireless access. These new networks and associated end-user devices will have household applications and may mitigate the energy requirement impact of fixed broadband hardware or may spawn many new always-on energy-hungry fixed terminal devices.

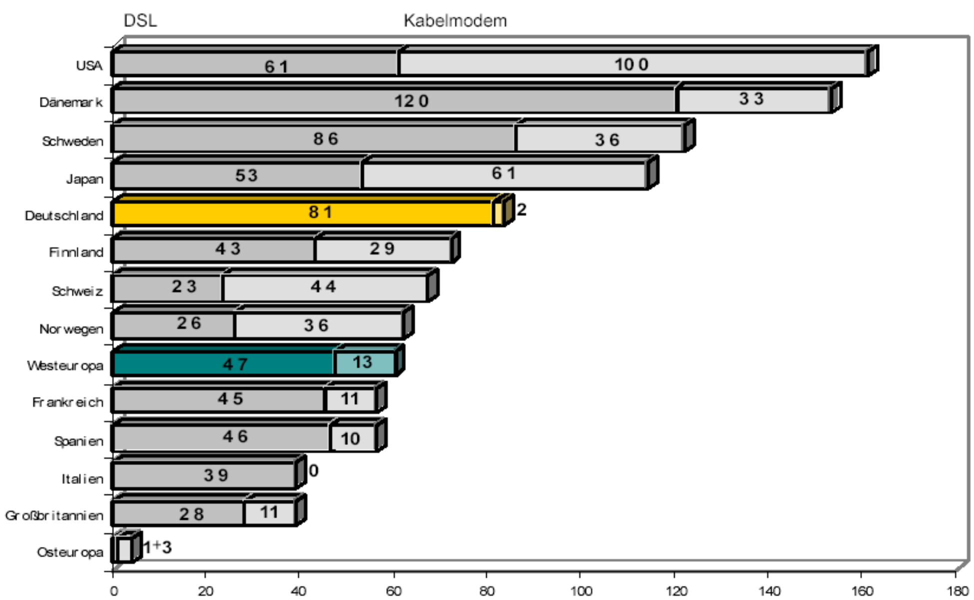
European and World Wide Broadband Usage

Detailed data on DSL usage in Europe is still in compilation but recent German research provides an interesting comparative overview of the world-wide trends in broadband technology.

Broadband Technology	Rate [%]
DSL	56.5 %
Broadband cable systems	38.0%
Gigabit Ethernet	4.7%
Other Techniques	0.8%

BitKom (BitKom 2003) published the following graphics on world wide broadband usage:

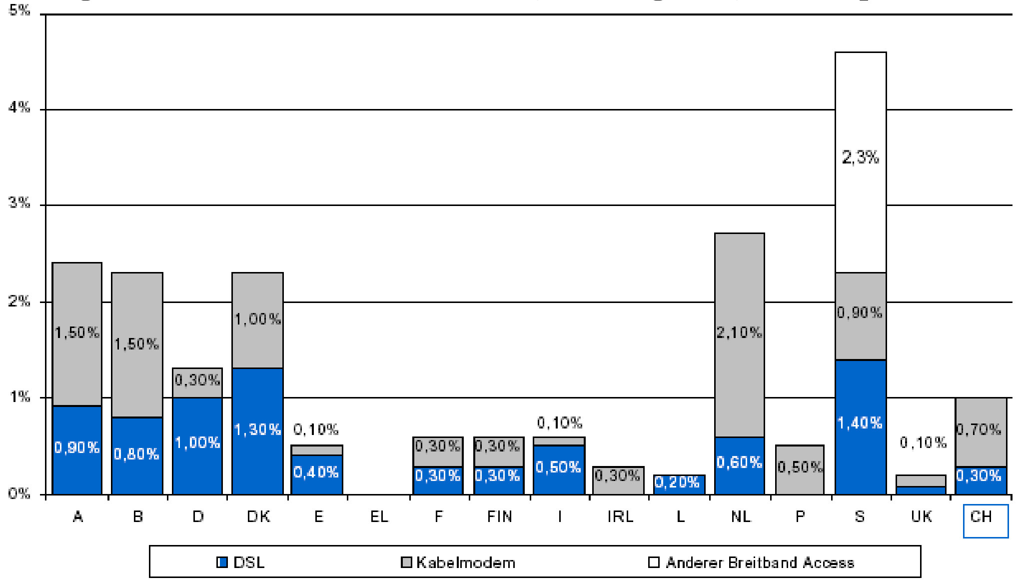
Figure 2. Number of Broadband Connections per 1000 Households in 2002



(Source BitKom)

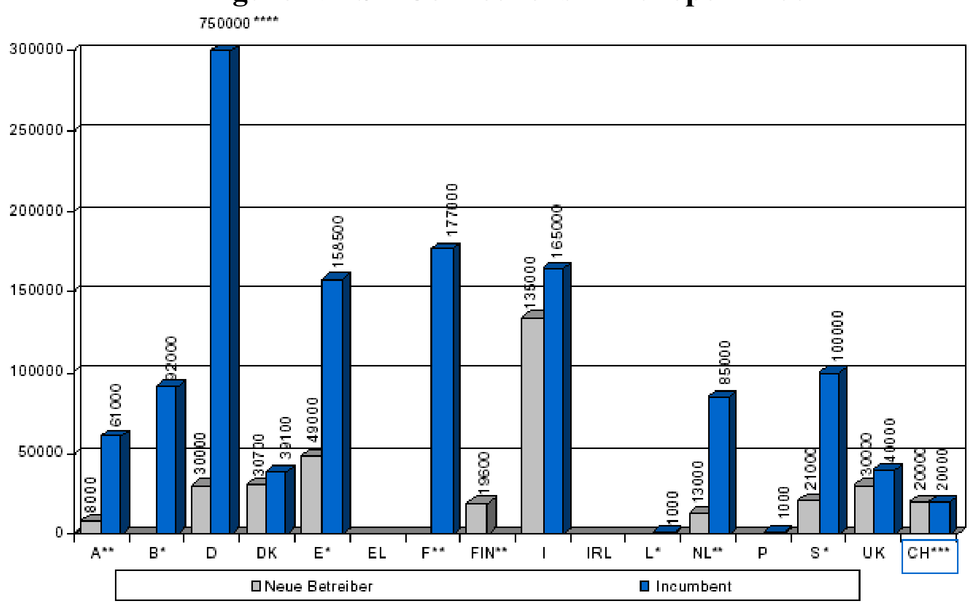
There is also a market analysis from Switzerland (Elixmann 2003) that compares the broadband connections and DSL connections in most European countries. The figures are based on an OECD study from 2001. In this study it is also mentioned that the costs for DSL connections in Germany are quite low, while comparatively expensive in the UK, Sweden and Italy.

Figure 3. Broadband Connections (including DSL) in Europe in 2001



(Source Elixmann)

Figure 4. DSL Connections in Europe in 2001



(Source Elixmann)

Energy Consumption of DSL Modems

Figures on energy consumption for DSL modems vary significantly. In the UK, the largest national telecommunication provider, BT, has, through energy efficient procurement policy, provided basic, self-powered external DSL modems with a 4.0W power requirement. More typical devices in the open market and supplied by some other European telecommunication groups have a power requirement of nearer 10W. With the latter, up to

87kWh per annum could be added to a household's energy overheads, at a cost of approximately 13 Euros because these devices are always on,

DSL connections provided, for example, by German Telekom in broadband package contracts invariably supply external self-powered modem/terminal equipment. This should be questioned, since other providers provide the choice between internal or external modems.

There are some third party products that can be used to replace the contract package external DSL modem – but replacement will be at extra cost to the user. Even if there are some practical benefits in replacement (e.g. using ISDN and DSL services with one device), it is doubtful whether most users would change the package supplied device and near-certain that they would not do so for energy efficiency reasons.

The future isn't all gloomy however. A UK study shows that current and already designed Silicon, for domestic broadband interfaces, soon promises a significant reduction in power requirement if the associated power supplies are efficient.

Table 1. End User Energy Requirement per Household Directly Attributable to Simple-Terminal Broadband Equipment

	CABLE (Average)	DSL (Average)
2003	7.0W (61.3 kWh / annum)	4.0W (35.0 kWh / annum)
2005	3.5W (30.7 kWh / annum)	3.5W (30.7 kWh / annum)
2010	2.0W (17.5 kWh /annum)	2.0W (17.5 kWh / annum)

In studying energy usage (or waste) of DSL modems, user behavior will be critical. An internal DSL modem or a USB connected modem will follow the PC mode. However it is likely that the current flat rate subscription charge for typical DSL broadband packages irrespective of usage may lead to PCs being used for longer periods for audio- or video-on-demand entertainment, massive file exchange, or in a server context and never switched off.

At the moment German Telekom, UK BT, and other providers also offer Wireless LAN routing for DSL connections (router with WLAN functionalities) in addition to the external DSL modem or with a built-in modem. In their current configuration, these routers will also be on all the time. It is expected that WLAN broadband terminal equipment will have a very important impact on the market because it enables the user to connect different devices (mobile PC, second PC, TV) without additional cables. With current best practice, broadband modem platforms supporting wired or wireless network distribution should have a power requirement of 6.6W or less.

Switching Off the Modem?

In user instructions and even direct questioning, European broadband package providers are circumspect about allowing the external DSL modem to be switched off when not required. In practice there can be software updates, mostly done at night, that could be missed if the modem is off. A missed software update may significantly delay the next re-initialisation while new software is downloaded on switch-on. Some telecommunication networks may even require supplier-supervised initialisation if a modem has been switched off for long periods. Others have no problems.

Like the STBs of UK digital satellite TV service provider B-Sky-B, it may be that broadband modem terminal platforms will require an active standby mode to enable software download access at reduced energy levels. As with the TV STBs, this will require the solution to the problem of ensuring that the modem platform runs at the lowest energy level for the usage status without the direct intervention of the user.

All of these factors and others are currently under consideration by the new EC working group for Broadband Service System Code of Conduct.

Conclusions

The EU Code of Conduct has been an important platform for promoting energy efficiency in digital TV services in Europe. The study carried out for the Commission as well as recent market developments have indicated this as one of the fastest growing electricity demand in the residential sector. The Code of Conduct originally designed for STBs has already reduced the energy consumption of STBs, even if these offer many more features and services. Now energy efficiency is among the design priorities of next-generation STBs and in the procurement specification of service providers. The transition to digital TV will add further challenge for energy savings and climate change mitigation in the EU. The revised Code of Conduct covers also the 'simple' STBs used to convert free digital TV signals. It is hoped that the Code of Conduct will make an impact on the power demand of these devices before millions of them are sold. Last but not least, given the success of the Code of Conduct in creating a useful stakeholder forum and in achieving concrete results in a very dynamic technological sector, the Commission and national experts are preparing a new Code of Conduct to reduce energy demand in broadband equipment for the residential sector.

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