

Design of Energy-Efficient Set-Top Boxes

Coping with the Energy Needs of Digital Television

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, September 2005



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Published in 2005 by IIIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
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ISSN 1401-9191

Acknowledgements

About half a year ago, I didn't have a precise idea about the transition to digital television, the need for set-top boxes, and why one should write a thesis about this. However, Mikael Holst from Konsumentverket gave me the initial hint to take a closer look into "these boxes". Thanks for this, and for the discussions and feedback on the study scope. I also would like to thank Konsumentverket for financially supporting this work.

Thanks of course to my two supervisors here at IIIIEE, Andrius Plepys and Peter Arnfalk for their guidance, their concise feedback and for always asking the right questions.

This work wouldn't have been possible without the participation from a number of people from industry, television service providers and governmental agencies. Thanks for helping me to find out where the "Watts" disappear and what one could do to keep them.

Thanks to Batch 10 and all other staff members at IIIIEE for an unforgettable year! And finally of course, thanks to my Berni for sharing the coffee and always taking me out for a bike ride when it was time to think out of the (set-top) box.

Lund, September 2005

Abstract

The paper investigates opportunities to minimize electricity consumption that will arise from the expected rapid penetration of households with set-top boxes due to the digitisation of television platforms. The study explores opportunities from a perspective of technical and behavioural change and how to promote this change through policy intervention and industry action. To explore the drivers and barriers affecting the design of energy-efficient set-top boxes, data was collected through a series of interviews with representatives from set-top box producers, service providers, research institutions, energy agencies and policy makers, as well as through a review of relevant literature and Internet resources on the field.

Considerable variations in power needs exist between different set-top box models with similar functionalities. This, and a number of scenario calculations indicate a significant potential to reduce electricity consumption of set-top boxes. Drivers and barriers for manufacturers to explore this potential exist at the level of technology, the corporate level, the governmental level, the level of consumer behaviour, the financial level, and also in industry standards. The study discusses different approaches of policy intervention and industry action that could strengthen the drivers and help to overcome the barriers.

Keywords: set-top box, consumer electronics, digital television, energy efficiency, policy instruments

Executive Summary

Problematization

Electronic home entertainment is increasingly becoming digital, the penetration with devices per household is rising, and the sectors of Consumer Electronics (CE) is converging with Information and Communication Technology (ICT). The next generation of digital home entertainment will be capable to be entirely networked. The vision is that a central home media server stores audio and video data, which can be distributed to numerous display panels and sound systems being spread throughout the home. Television broadcasting also rapidly switches to digital platforms, which requires end-users to install new equipment, such as set-top boxes (STBs) or integrated decoder television sets (iD TVs) to be able to receive digital broadcasting signals. The increasing stock of CE and ICT devices, new functionalities, as well as network capabilities are expected increase electricity demand. With terrestrial and cable platforms becoming digitized, set-top boxes will account for a significant share of this growth in electricity use. In the case, that entire national stocks of television-sets are equipped with set-top boxes, STBs can in a worst case scenario account for up to 1 % of final electricity consumption in Sweden, respectively even around 4 % in the UK. In best-practice scenarios, the impact is considerably lower. The level of uncertainty of these future projections is high as the technology is evolving rapidly.

Table: Scenarios on the electricity consumption of present and future set-top box stocks ¹

Country	Year	STB stock	Electricity consumption	
			total	share of total electricity use *
		[1000]	[GWh/yr]	[%]
Germany	2004	22 477	1 909	0.4 %
	2010	50 263	5 779	1.2 %
	2015	62 977	7 528	1.5 %
UK	2004	15 236	2 485 – 2 629	0.7 %
	2010	65 521	3 285 – 10 181	1.0 – 3.3 %
	2020	74 137	4 516 – 14 565	1.4 – 4.4 %
Sweden	2005	1 768	132 - 171	0.1 %
	2008	4 744	236 - 578	0.2 – 0.4 %
	2013	8 525	403 – 1 167	0.3 – 0.9 %

* share of 2002 electricity consumption

Research Path

The objective of the study is to identify mitigation approaches to limit energy needs of future CE products, in particular in standby mode. Set-top boxes were chosen as object of research for three reasons: (1) the phase-out of analogue broadcasting services will stimulate demand for STBs considerably, (2) most STBs have particularly in standby-mode quite high power needs compared to the best practice model on the market, and (3) STBs can due to their

¹ (Schlomann et al., 2005; VDEW, 2005), (MTP, 2005b), own calculations

network functionalities be considered as a forerunner of future networked homes. The research questions addressed are:

1. What are the drivers and barriers for set-top box producers to reduce energy consumption of their products?
2. How can industry act and policy makers intervene to mitigate the impact on energy consumption that arises from the digitization of television broadcasting?

To understand the quantitative dimension of power consumption of STBs, data on the on-mode and standby-mode consumption of numerous models was compiled from different sources. This data was put into a comparative perspective to identify trends over time, variances in power consumption in a category, differences between different categories, and the ratio of energy consumption between standby and on-modes in a duty cycle. To quantify the significance of the problem, two literature projections on the energy needs of set-top boxes on national levels for Germany and the UK were reviewed. Additionally, the author conducted a scenario calculation for Sweden.

To explore the opportunities how energy efficiency can be realized through technical and behavioral change, a review of relevant literature and Internet resources was conducted. To explore the drivers and barriers, that affect the development of energy-efficient STBs, primary data was collected through a series of interviews with representatives from STB producers, service providers, research institutions, energy agencies and policy makers.

Main findings

Some STB manufactures could significantly reduce power needs of their models in recent years. Still, standby power levels are, due to the boxes' network functionalities, significantly higher than for most other modern devices in the sector of consumer electronics. Furthermore, considerable variations in power needs do exist between different models with similar functionalities. This indicates, that there is further potential to raise energy efficiency and to limit the impacts on energy consumption that will arise from the digitization of television broadcasting.

Drivers and barriers that affect STB manufacturers to reduce energy consumption of their models are numerous and manifold. Key factors that drive the development of more energy-efficient STBs were found to be (1) developments in silicon technology, (2) technical co-benefits such as better thermal management and higher reliability, (3) environmental management systems that helped to implement eco-design approaches into the development process, (4) demand from service providers requesting the STB to keep certain power limits, (5) the Code of Conduct on Energy Efficiency of Digital TV Service Systems being the key stakeholder forum between industry and legislators on the European level, and (6) to some extent demand from private consumers for energy efficient STBs, a factor that was partly reported from Germany.

Key barriers, that limited and counteract to the development of more energy-efficient STBs were found to be (1) physical system modularization, meaning that the reception functionalities are not in the same chassis as the television display which lowers the chances that the STB is put into standby, (2) a trend to more features and higher data rates, (3) information and awareness deficits among producers and service providers, (4) a continuous standby-active mode being requested by service providers, (5) information and awareness

deficits among end-consumers, (6) the additional cost for power saving features, which are difficult to accomplish in a very price-competitive market, (7) the lack of power management standards for consumer electronic products, and (8) certain features of the DVB broadcasting standard setting a barrier for more power efficient tuner and demodulator techniques.

Some of the drivers and barriers are mainly driven by technology and market trends, and for this reason only have a low potential to be changed through policy intervention and industry action. These factors include (1) developments in silicon technology, (2) technical co-benefits, (3) physical system modularization, (4) the trend to more features and higher data rates, and to some extent (5) the additional cost for power saving features.

Table: Current drivers and barriers affecting the development of energy-efficient STBs, as well as their operation in an energy efficient way.

Level	Drivers	Barriers
Technical level	<ul style="list-style-type: none"> ➤ Silicon developments ➤ Technical co-benefits 	<ul style="list-style-type: none"> ➤ Physical system modularisation ➤ More features / higher data rates
Corporate level	<ul style="list-style-type: none"> ➤ CSR / EMS ➤ B2B procurement 	<ul style="list-style-type: none"> ➤ Information and awareness deficits ➤ Demand for standby-active modes
Governmental level	<ul style="list-style-type: none"> ➤ Code of Conduct ➤ (Regulation) 	
Consumer level	<ul style="list-style-type: none"> ➤ Consumer information 	<ul style="list-style-type: none"> ➤ Information and awareness deficits
Financial level		<ul style="list-style-type: none"> ➤ Additional cost
Standardization level		<ul style="list-style-type: none"> ➤ DVB-standard ➤ Lacking power management standards

Recommendations for action and further research

A number of policy measures and other mechanisms that address energy efficiency of set-top boxes are already in place, which though in some cases are suggested to be improved and complemented by additional approaches. Suggestions are given on (1) the framework for an energy-labelling scheme, (2) the STB industry's potential to inform and train end-consumers, (3) the power of special-interest and consumer-magazines on raising awareness and informing consumers on the power needs of CE and ICT products, (4) the dissemination of ecodesign and best-practice approaches in the STB industry, (5) the need to much more involve service providers, (6) the need for international corporation in setting standards, and (7) the need for power management standards.

A big potential for further energy savings does exist with low power ready modes, which would allow waking up the STB with an external broadcasting signal and going to a full standby-active mode that would allow data downloads. Further research is suggested to explore the potential and practicability of such techniques. Another field for technical research could be the applicability of more intelligent power management functionalities and their effect on power savings. The environmental implications of two macro trends in the sector of Consumer Electronics, the trend to modularize functions to physically separated chassis' and the increasing role of software solutions over hardware might also deserve further investigations.

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1 Introduction

1.1 The digitization of consumer electronics

Consumer Electronics (CE) has been defined as “electronic equipment intended for use by everyday people”². This definition would cover entertainment, information and communication technologies. Though, most often the term Consumer Electronics describes products for electronic home entertainment, such as televisions, audio systems, and playback and recording devices. On the other hand, Information and Communication Technologies (ICT) apply to electronics computers and computer software to “convert, store, protect, process, transmit, and retrieve information”².

The history of Consumer Electronics can be tracked back to the middle of the 19th century when Frenchman Edouard Léon Scott invented the phonoautograph, the earliest known sound recording device. In 1877, Thomas Alva Edison invented the first phonograph, a device for recording and replaying sound and at the turn of century, the gramophone and the shellac record became the first widely used commercial product in home entertainment³. At that time, the gramophone, respectively its turntable was exclusively driven by a mechanical spring, which had to be wound up by human muscular power. Things in home entertainment have changed since then. The invention of amplifier tubes, transistors and then integrated circuits brought “electrified” home entertainment and Consumer Electronics was born. Radio broadcasting was established, vinyl records and the compact cassette became popular sound storage mediums. Television became a mass medium and probably shaped everyday peoples’ life and their living rooms like few other technologies.

The digital age of Consumer Electronics started with the launch of the Audio Compact Disc in 1983. Since then, almost all analogue CE applications have been substituted by digital technologies. The tape deck and the Walkman have been replaced by CD-recorders, Mini-disc- and MP3-players. The functions of analogue Video Recording Machines (VCRs) have been taken over by DVDs and hard-disc drives. Analogue camcorders became digital, and the launch of digital still cameras has created a completely new market for the CE industry. Currently, sales of analogue CRT–television sets⁴ are dropping rapidly, while flat screens using LCD or plasma technologies gain an increasing share of the visual home entertainment market. The driving forces behind this development are numerous: better sound and visual quality, longer lifetime and less wear-off off the storage media, better interconnectivity between different devices, and digital portable devices that are smaller and more lightweight than their analogue counterparts.

Unsurprisingly, the availability of new products as well as innovative functions continuously being added to existing product groups drives the demand. Consequently, the global market for CE products has been growing faster than most other areas in recent years. By the year 2010, global turnover of the CE industry is expected to reach more than US\$ 200 billion, an increase of 30 % to 2004 figures⁵, a rate over most other consumer markets. The growth is

² (Wikipedia, 2005)

³ (GFU, 2005)

⁴ Cathode Ray Tube

⁵ (Datamonitor, 2005)

not only driven by the high innovation rate but also due to an increasing global market base. A growing share of the population in fast developing regions such as India and China is able to spend some part of their income on CE products.

Recent years' developments in, for the masses affordable, digital CE products had not been possible without the developments in Information and Communication Technology (ICT). Technological advancements, the rise in global hardware production and falling prices were initially driven by the fast evolving ICT industry. The processing and storage of audio and in particular video data in today's digital CE products has only been made possible by the availability of respective hardware (high clock-rate processors, large-volume flash memory and hard disc drives, etc.) and software and compression techniques (MP3, MPEG, etc.). Furthermore, the Internet and the rapid penetration of broadband connections now allows the exchange and download of digital audio and video data of several hundred megabytes in reasonable time spans. Digital audio and video data can be consumed both with ICT and CE devices and the barriers between these two initially divided technologies vanish. The merge of ICT and CE happens on not only the technical side, but also the two previously separate markets merge. Traditional ICT business organizations such as Microsoft, Dell, Intel, and Hewlett Packard create partnerships and own business sections for the digital home entertainment market (Focus, 2004).

The next generation of digital home entertainment will be capable to be entirely networked. A central home media server stores audio and video data, which can be distributed to numerous display panels and sound systems being spread throughout the home. Information and communication devices can be part of the network with access to the Internet. Data transmission can be wireless, via Ethernet or power line communication. Industry has formed alliances to drive the vision of interoperability with networking functionalities and to standardize content formats and communication interfaces (DNLA, 2004). The visions of the networked home goes even further than converging CE with ICT. Future homes are also expected to be equipped with networked white goods, lighting systems, heating and ventilation, as well as security systems.

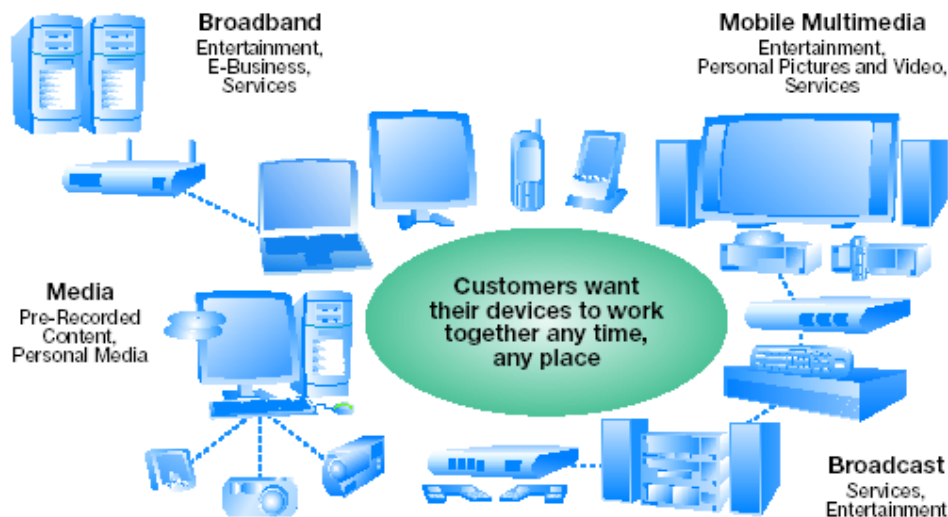


Figure 1.1: Vision of seamless interoperability between CE, ICT, broadcasting and the Internet ⁶

⁶ (DNLA, 2004)

As further outlined in following chapters, the digitalization of television broadcasting started with satellite and cable platforms and will commence with the phase out of analogue terrestrial signals which has already been scheduled in a number of countries for coming years.

To power today's digital home entertainment equipment, turning a crank handle as it was with the first gramophones, is not common practice anymore. Rather, the increasing stock of CE and ICT devices has a growing need for electricity and for many devices, much of this is used in a standby mode.

Table 1.1: Trends in the "electric" home

Digitization of end-consumer CE products	<ul style="list-style-type: none"> ➤ CD-, DVD-players & recorders ➤ MP3-players ➤ Digital still and digital video cameras ➤ Hard-disc drive VCRs
Digitization of television broadcasting platforms	<ul style="list-style-type: none"> ➤ Satellite ➤ Cable ➤ Terrestrial ➤ Internet
Home networks	<ul style="list-style-type: none"> ➤ Home entertainment ("brown goods") ➤ Household appliances ("white goods") ➤ Home automation (heating, climate, etc.)
Convergence of ICT & CE	<ul style="list-style-type: none"> ➤ Online download music stores ➤ IP-telephony ➤ Internet via TV screen

1.2 The growing need for electricity

Similar to the ICT sector, the production, use and end-of life management of digital CE products entails various impacts on the environment. The ecological footprint of the semiconductor industry in terms of energy and water consumption, as well as the use of a high number of chemicals has been discussed in the literature (Plepys, 2004). The high innovation rate of the CE industry encourages consumers to replace their existing, though generally still fully functional CE devices with new products that have some added features. Old products either find some function as a secondary device or are disposed and contribute to the growing rates of electronic waste.

Energy or more explicitly electricity consumption⁷ in the use-phase is a significant aspect of stationary CE-products, which are supplied from the mains. For instance, studies for TV-sets indicate that electricity consumption in the use-phase is in the range of 90 % of total energy of the entire life cycle, including manufacturing and recycling (Wajer & Siderius, 1998). A growing number of devices, more features, bigger television screens, new technologies and network functionalities will increase electricity needs of audio and video home entertainment devices. By 2010, consumption of only television sets and required reception equipment is projected to be around 55-65 TWh in the countries of the EU 15 (Wajer & Siderius, 1998). This is almost a doubling of 1995 figures, and it is equivalent to the output of six large nuclear power stations. For Germany, Schlomann et al. (2005) forecasted that devices for audiovisual home entertainment⁸ will consume around 26.5 TWh by the year 2015. This is

⁷ The terms "energy" and "electricity" are used equivalently throughout the paper to describe final electric work, generally at the point of the end-user's power socket. When generated in thermal power plants, the quantity of required primary energy is generally a factor 2-3 higher than the final electric work supplied.

⁸ Audio systems, television sets, set-top boxes, video & DVD, cameras

an increase of 43 % compared to 2004 estimates, and would account for around 5 % of Germany's final electricity consumption in 2002. Television sets and the required reception infrastructure account with 75 % for the biggest share of this consumption. 5.8 TWh or 22 % are consumed in standby and off-modes⁹.

Standby power has many definitions, two of the most common ones are "the power consumed by an appliance when switched off or not performing its primary functions" or the "minimum power consumption of a device while connected to the mains" (IEA, 2001). The issue of standby power consumption has gained international attention in recent years. Field measures in a number of countries have shown that standby power accounts for around 10 % of residential electricity use. Together in residential and commercial sectors, total standby power use in 29 countries of the OECD is estimated to be 188 TWh per year, or 2.2 % of total OECD electricity consumption (IEA, 2001).

The level of standby power use was found to vary widely between different product groups, as well as between different models in the same product group. Some CE products even consume the majority of their total electricity in a standby-mode, so when the device is not fulfilling its primary function. A well cited example is the VCR where standby power consumption can account for more than 85 % of total electricity consumption in the service-life phase (Mohanty, 2002). TV-sets and VCRs were among the first product groups to be addressed by policies aiming to reduce standby power. In 1997, the European Commission concluded a negotiated agreement with the European Association of Consumer Electronics Manufacturers (EACEM) to reduce standby losses of TVs and VCRs (EACEM, 1997). Since 1999, Japan has addressed the issue with mandatory standards as part of their Top Runner program, an energy efficiency initiative addressing 18 different product groups in total (Murakosh, Nagata, Nakagami, & Noguchi, 1999). In the U.S., the EnergyStar program (EPA, 2002) as well as a Federal Procurement Program based on Executive Order 13221 (Bush, 2001) sought reducing standby power of new ICT and CE products. Standby power use of newly sold TV-sets and VCRs dropped considerably since the mid 1990ies. For instance in Europe, the standby average sales weighted standby consumption of new TV-sets of EICTA members committed to the voluntary agreements dropped from around 7.5 Watts in 1995 to 1.75 Watts in 2003 (Bertoldi, 2005b). Similar trends were observed for VCRs. However the large stock of TVs and VCRs with high standby power needs is only gradually replaced with new and more efficient models. Furthermore, when being substituted with a new model, the old model often finds a second life in some other place of the home, such as the kids' room. Consequently, policy action promoting for energy efficient CE products will reduce overall consumption of the stock only over longer periods

The digitization of television broadcasting faces policy makers and industry with new challenges. Currently, most TV-sets in use only have an analogue tuner. In order to receive and process digital signals that are broadcasted via satellite, cable or air, some additional reception equipment is required. This equipment can theoretically be built into the display device itself, however the majority of digital tuners and digital-to-analogue converters are part of a separate device, a so-called set-top box (STB). The forthcoming phase-out of analogue terrestrial broadcasting, as well as conversion of analogue cable networks to digital services will create a huge market for digital reception equipment. It is expected that within

⁹ Off-mode describes the state when the device is switched off with its main switch but is still connected to the power socket. For those devices, where the main switch is not a "hard switch" on the high voltage side of the power supply unit, standby losses generally occur in the power supply unit itself.

the next decade several 100 millions or even billions of STBs will be sold on a global scale (IEA, 2004).

Most STBs consume electricity for 24 hours per day unless the power supply is physically disconnected from the mains. Depending on the functionality, power needs can range between 6 – 35 Watts in on-mode and from 0.5 Watt up to around 20 Watts in standby-mode. The combination of considerable electricity consumption per device multiplied with the number of devices expected to enter the market in coming years will significantly increase residential electricity needs. For the member states of the European Union, it has been estimated that the reception, decoding and interactive processing of digital TV services might require up to 23 TWh per year in 2006 (EC, 2004a). This equals the annual production of two very large nuclear power stations.

There is a significant potential to limit and minimize the impact on electricity consumption from the expected growing stock of STBs. Measurements conducted by consumer magazines and governmental agencies have shown that power consumption of STBs with similar functions vary widely between different models. Exemplary, Figure 1.2 depicts results from power measurements on 37 digital terrestrial converter models available in the UK.

Also, the projected future impact of CE products and in particular STBs interferes with the objectives of the European Union of increasing energy efficiency. Energy savings are considered as the most effective and most cost-effective way to contribute to the objectives of reducing overall energy consumption for reasons of climate protection, enhancing security of supply, strengthening competitiveness and providing trade opportunities (EC, 2005b). The European policies on this issue cover a broad range of products, services and infrastructure. Efficiency in energy-using products has been addressed by a mandatory labeling scheme and

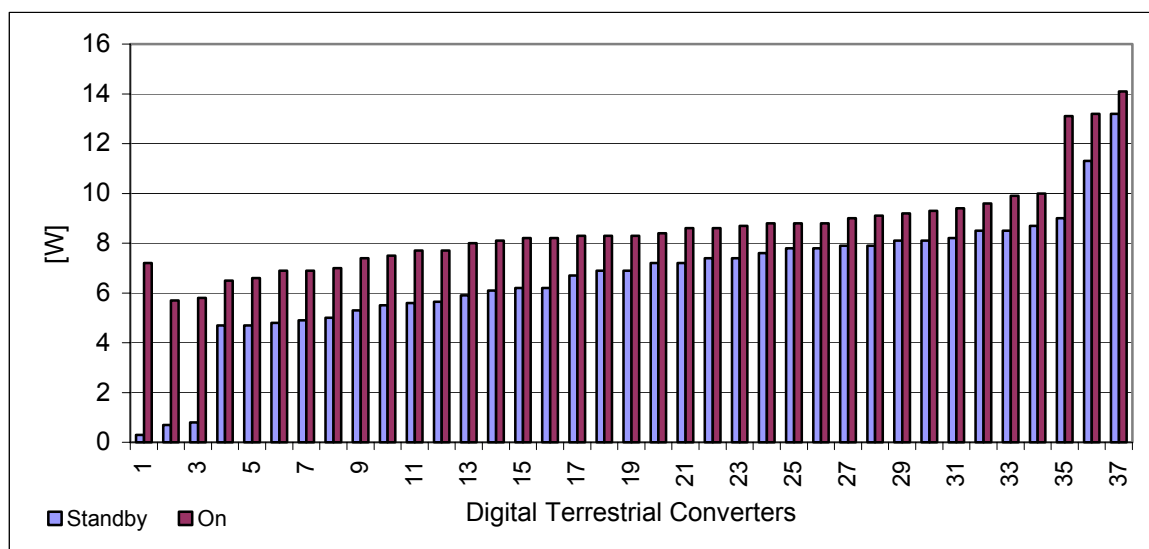


Figure 1.2: Power consumption of 37 digital terrestrial converter models on the UK market in 2004¹⁰

¹⁰ (Armishaw, 2005)

minimum energy requirements for a number of domestic appliances. Office equipment is addressed by the voluntary European EnergyStar programme, and the recently adopted EuP-Directive sets the framework for eco-design requirements for energy-using products (EP, 2005). Another recent initiative is the proposal for a new Directive on energy efficiency and energy services with the objective to annually save at least 1% of previous consumption in the period 2006-2012 (EC, 2003b). The proposal is backed by the parliament but as the bill was submitted for approval to national energy ministers from the EU, binding targets on energy savings have been rejected by the member states.

The experience with TV-sets and VCRs, being devices that are used for many years in the home, illustrates the importance of preventive action. This action should promote the design of energy-efficient STBs before a huge number of households will purchase one or several STBs shortly before the analogue phase-out commences. The expected impact on energy consumption from digital television equipment has internationally been recognized among policy makers. As discussed later in Section 3.2, various measures to tackle the problem have already been implemented, respectively are in preparation. Still, the premise of this thesis is the author's perception that the full potential for energy savings has not been explored.

1.3 Objective and research questions

The future impact of CE products on electricity consumption is likely to conflict with the European objectives on climate protection and security of energy supply. Hence, the objective of the study is to identify mitigation approaches to limit energy needs of future CE products, in particular in standby mode.

Set-top boxes were chosen as object of research for three reasons: (1) the phase-out of analogue broadcasting services will stimulate demand for STBs considerably, (2) most STBs have particularly in standby-mode quite high power needs compared to the best practice model on the market, and (3) STBs can due to their network functionalities be considered as a forerunner of future networked homes. Hence, approaches and experiences for power savings that apply for STBs might also be of use for other networked products.

The research questions addressed are:

1. What are the drivers and barriers for set-top box producers to reduce energy consumption of their products?
2. How can industry act and policy makers intervene to mitigate the impact on energy consumption that arises from the digitization of television broadcasting?

1.4 Research path and methods used

The original starting point of this thesis was a previous course paper exploring policy instruments that address standby power of TV-sets and VCRs in a global context (Strupeit, 2005). Despite the effectiveness of these instruments in reducing standby power of newly delivered products, recently published literature sources projected a further growth in electricity needs of CE and ICT products for different time horizons. The infrastructure for the reception of digital broadcasting services was pointed out as a key source for the growth in electricity needs. Hence, these literature projections helped to define the problem.

A literature review provided a background understanding about the transition path to digital television broadcasting, and in particular about set-top boxes in an organizational and technical perspective. To understand the quantitative dimension of power consumption of STBs, data on the on-mode and standby-mode consumption of numerous models was compiled from different sources. This data was put into a comparative perspective to identify trends over time, variances in power consumption in a category¹¹, differences between different categories, and the ratio of energy consumption between standby and on-modes in an annual perspective. These comparisons were done to explore where energy losses occur, and to investigate whether there is a technical potential for energy savings. To assess the significance of the problem, two literature projections on the energy needs of set-top boxes on national levels for Germany and the UK were reviewed. Additionally, the author conducted a scenario calculation for Sweden.

Table 1.2: Organizations being interviewed

Group	Organizations consulted	Key questions posed
STB-producers	<ul style="list-style-type: none"> ➤ A2B Electronics (S) ➤ Arcon GmbH (D) ➤ Emitor AB (S) ➤ Jacobson's (S) ➤ Kathrein Werke KG (D) ➤ Pace Micro Technology plc (UK) ➤ Philips Consumer Electronics (NL) ➤ SM-Electronic GmbH (D) ➤ Sony Europe (UK) ➤ TechniSat Digital GmbH (D) 	<ul style="list-style-type: none"> ➤ How and to what extent is energy efficiency a design criterion as part of your set-top box development? ➤ What do you consider as the drivers and barriers that affect the design of set-top boxes in terms of energy-efficiency? ➤ What is your perspective on different policy instruments, that promote energy-efficient consumer electronic products?
Broadcasters / Service Providers	<ul style="list-style-type: none"> ➤ British Sky Broadcasting (UK) ➤ Canal Digital (S) ➤ Com Hem (S) ➤ Modern Times Group (S) 	<ul style="list-style-type: none"> ➤ What priority has energy efficiency when you purchase STBs? ➤ What are the reasons for giving it this high/low priority?
Energy / Consumer / Environmental Protection Agencies, etc.	<ul style="list-style-type: none"> ➤ European Commission, Joint Research Center ➤ German Federal Environmental Agency (Umweltbundesamt) ➤ LBNL (B. Nordman) ➤ Senter Novem (H.-P. Siderius) ➤ Swedish Consumer Agency (Konsumentverket) ➤ Swedish Energy Agency (Energimyndigheten) ➤ UK Market Transformation Program 	<ul style="list-style-type: none"> ➤ What is your perspective on the usefulness, efficiency and effectiveness of different policy instrument that promote energy-efficient product? ➤ What is the awareness of consumers in your country on standby power consumption? ➤ Other specific questions.

¹¹ Category is understood as a range of STB models with similar features and functionalities.

To explore the opportunities how energy efficiency can be realized through technical and behavioral change, an extensive review of the literature, Internet resources and through interviews with experts was conducted. So far, relative little standard literature with special focus on set-top boxes could be found. However, materials from conferences, workshops and particularly from the meetings of the working group of the EU Code of Conduct on Energy Efficiency on Digital TV Service Systems were useful sources of information. In addition, present policy instruments promoting energy efficiency for digital reception equipment were reviewed.

Information on the drivers and barriers for set-top box producers to reduce energy consumption of their products was obtained through a series of phone interviews with representatives from STB producers, service providers, research institutions, energy agencies and policy makers. Table 1.2 depicts an overview of contributing organizations and the key questions posed to them. The selection of producers was made with the idea to include both smaller and bigger organizations from a number of countries. Interviewees being accessed were generally employed in the research department, in technical customer support or the environmental department. During a visit to the IFA trade fair in Berlin, sales staff of STB producers was consulted in person.

The findings obtained through the empiric research work were structured according to an approach derived from literature on eco-design, complemented with background information from earlier research stages, and this led to the elaboration of drivers and barriers affecting the design of set-top boxes in terms of energy efficiency. Drivers and barriers were further analyzed on their potential to be changed through technology and market trends, as well as through action by industry or policy makers. The subsequent discussion on different approaches to promote energy efficient STBs is based on the experience of existing approaches, both from the perspective of good examples as well as cases that were less successful.

1.5 Scope and limitations

The study's geographical focus was Sweden, Germany and the UK, although also organizations from other regions were consulted. In all three countries, analogue terrestrial television will be phased out in coming years, though the effect on national electricity use can be rather different due to different structures in broadcasting platforms and different penetration of subscription services. Apart from practical reasons such as language issues and access to information, the key reason for choosing these countries was that they all offer some unique characteristics being of interest for the work.

- The UK is currently the most mature digital TV market in the world due to the widespread use of digital satellite platforms. Furthermore, terrestrial digital reception has been growing very rapidly recently, and with terrestrial broadcasting being the dominating platform the overall market for digital terrestrial reception equipment is big.
- Sweden might be one of the first countries in the world where analogue terrestrial TV signals will be entirely switched off. The phase-out period started in September 2005 and is scheduled to finish off in February 2008.
- The region of Berlin-Brandenburg in Germany was the first region in the world where analogue terrestrial signals were switched off in 2003. By international standards, the problem of standby power consumption is relatively well known among consumers, presumably to different campaigns pointing at this issue.

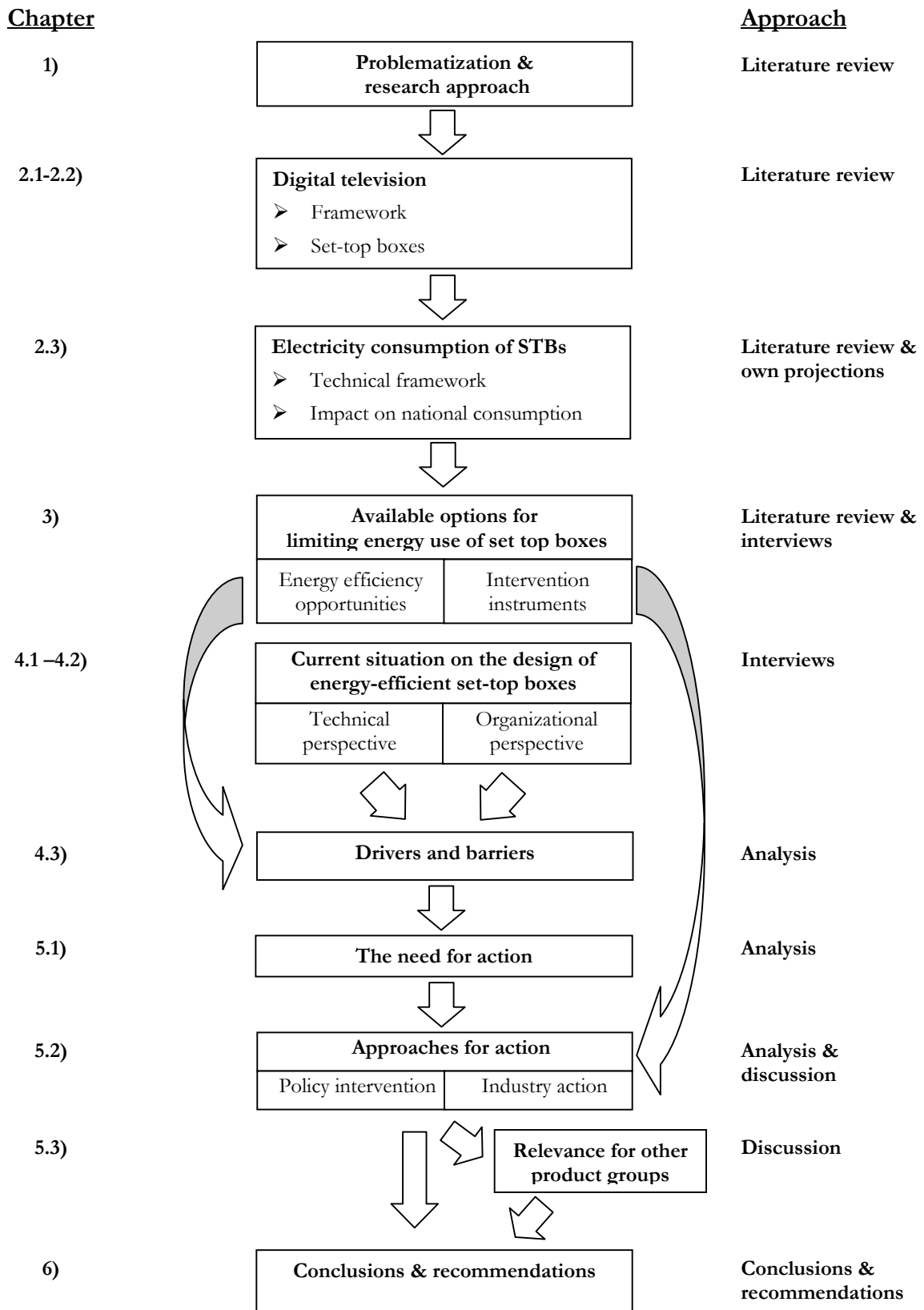


Figure 1.3: Research pathway

The choice of these three countries contributed to a better overall understanding of the research area. It should be noted that comparing the three countries was not an objective of the study.

A limitation of the research was that only a limited number of STB manufacturers and service providers could be interviewed. A larger number of organizations were approached, but the author's perception is, that particularly those organizations where energy-efficiency is not high on the agenda showed little interest to participate. In addition, the nature of phone interviews for information gathering has certainly set up limitations.

Furthermore, the discussion on approaches for industry action and policy intervention in Section 5.2 is only of qualitative nature and hence cannot give a comparative analysis on the effectiveness and cost-effectiveness of different measures.

1.6 Target groups

The intended audience comprises decision makers in business, governments, standardizing bodies, and researchers. In industry, the study is first intended at manufacturers of set-top boxes and related equipment that is used for the reception of digital television broadcasting. Television service providers and broadcasters are important players that can influence the energy efficiency of set-top boxes and hence, these organizations are the second main target group. The study is written from a European perspective and findings on policy approaches, to further explore and utilize the energy savings potential for the growing stock of set-top boxes, can be of interest for policy makers at different levels.

Some of the findings are also relevant for the next generation of consumer electronic systems; hence, the study may be of interest for manufacturers of these products. The study emphasizes the importance of industry standards for power management, for that reason, some results could be of interest for practitioners working in this field. The study concludes with some final reflections on technology change and its environmental implications, which might be of interest for the research community.

1.7 Outline

The thesis is structured into six main chapters. *Chapter 1* introduces the reader into current trends in the sector of Consumer Electronics. The problem, being the stock of consumer electronic products having a growing demand for electricity, is outlined and the research approach is presented.

Chapter 2 starts with a brief outline on legal, organizational and technical aspects of digital television broadcasting. The next section introduces set-top boxes, their involved stakeholders and markets and gives background information on the energy consumption of STBs. Finally, the present and future impact of STBs on electricity consumption at national levels is illustrated with projections for Germany, the UK, and Sweden.

Chapter 3 introduces into the various energy efficiency opportunities for STBs that may be achieved by behavioral and technical change. The second part of the chapter presents the key policy tools, which at present do, respectively in the near future will deal with the issue of energy efficiency for digital television equipment. Additionally, the concept of eco-design standards is introduced.

In *Chapter 4*, the findings of the empiric research work on the current situation of including energy efficiency into the development process of STBs are presented from (1) a technical perspective and (2) an organizational perspective. Supported with background information presented in previous chapters, these findings are analyzed to find explanations for the current situation, which eventually led to answering the first research question.

Chapter 5 starts with an analysis on the need for action, or more explicitly, which drivers and barriers can be changed through policy intervention and industry action, and which factors are more technology and market driven and have a low potential to be changed by action. To answer the second research question, different approaches for industry action and policy intervention are discussed. The chapter concludes with a discussion on the relevance of findings for other products, as well as on the environmental consequences of industry standards and whether preventative action should be taken into this direction.

Chapter 6 summarizes the main findings, provides suggestions for policy makers and industry to act on, and gives recommendations for further research.

2 Set-top boxes and their energy consumption

This Chapter outlines the impact on energy consumption, which arises from the transition to digital television broadcasting at the end-user. The first section illustrates, by the examples of Sweden, Germany and the UK, the transition path to digital television. The next section illustrates the role of set-top boxes as the gateway for digital television services, introduces involved stakeholders, and gives an outlook on the expected growth of the market. Next, background information on the energy consumption of STBs is given. Finally, the present and future impact of STBs on electricity consumption at national levels is illustrated with projections for Germany, the UK, and Sweden.

2.1 The transition to digital television

2.1.1 The legal and organizational framework

In Europe, service providers introduced digital television first via satellite platforms. The driving force behind this development was mainly commercial. Digital platforms could offer more channels, at a lower broadcasting cost per channel, and at much better audiovisual quality for the user. Digital broadcasting also enabled providers of subscription services to use more advanced encryption and conditional access systems. These systems are more difficult to hack and thus help securing intellectual property rights and subscriptions revenues (Slama, 2005).

On the other hand, the introduction of digital terrestrial television is driven by government policy. Reasons for this can vary from country to country. Brown & Picard (2005) claim that governments see the transition to digital as inevitable and consider near-future transition as advantageous for their broadcasting, programme production and manufacturing industries. Another reason, at least for some governments, is to keep better control of television. Since terrestrial broadcasters require licenses allocated by national governments to use the radio spectrum, it is easier to control them than channels distributed by (foreign) satellite broadcasters. The European policy in the audiovisual sector supports this development as digital television benefits overall European objectives such as cultural and linguistic diversity, protection of minors and protection of consumers (RTVV, 2005).

Sweden, Germany and the UK have all introduced digital terrestrial television (DTT), however, the coverage of DVB-T signals as well as the current share of households that have access to digital television (either via satellite, cable or terrestrial) vary to some extent. Sweden commenced digital terrestrial transmissions on 1 April 1999, being the third country worldwide to do so after the U.S. and the UK which both began in November 1998 (Brown & Picard, 2005). Coverage of DVB-T signals is now greater than 98 % and the Swedish government has decided that all analogue terrestrial broadcasting shall be phased out by February 2008. The first region was the island of Gotland, where the epoch of analogue television ended on 19 September 2005. Currently, 35 % of Swedish TV-households use a digital satellite, cable or terrestrial platform. In particular the number of digital terrestrial users is growing rapidly; the service provider Boxer AB had 450 000 subscriptions by the end of June 2005, an increase by 180 000 within 12 months (Boxer, 2005).

In Germany, digital terrestrial broadcasting was launched in November 2002 in the Berlin-Brandenburg region. Only 9 months later, on 4 August 2003, the last analogue terrestrial signals were switched off which made Berlin-Brandenburg the first region in the world where

terrestrial television reception is only possible via DVB-T signals. For the whole of Germany, coverage of DVB-T signals now reaches half of the population and analogue terrestrial signals are scheduled for phase-out by 2010. Due to the high density of broadcasting stations in the country, frequencies for parallel analogue and digital broadcasting are insufficient. Thus, it is planned to keep the transition periods short by switching off analogue signals only shortly after digital signals have been phased in (TV-Plattform, 2005). Similar to Sweden and the UK, cost savings are another reason for keeping the transition period short, as parallel analogue and digital broadcasting entails higher operating costs than only keeping up the digital signal.

The development in digital television in the UK is very dynamic. With more than 3.25 million digital terrestrial boxes and integrated digital TVs being sold in 2004, the UK experiences strong growth in DTT usage. Collectively with digital satellite and cable platforms and a minor contribution from broadband, 62 % of TV households used digital services by March 2005, the highest figure in the world. At present, DVB-T covers around 75 % of the population. The switch-off of the analogue signal is expected to begin in 2008 and to conclude in 2012 (Ofcom, 2005a).

Table 2.1: Key figures of television markets in Sweden, Germany and the UK

	Sweden	Germany	UK
TV-households	4.1 Mill.	33.6 Mill.	25.7 Mill.
TV ownership per TV household	184 % ¹²	154 % ¹³	245 % ¹⁴
Delivery platform (2003)¹⁵			
Terrestrial	35 %	5.4 %	53.2 %
Cable	47 %	56.3 %	15.6 %
Satellite	18 %	38.3 %	31.3 %
Use of digital television via satellite, cable or terrestrial (2005)	35 %	18 % ¹⁶	61.9 % ¹⁷
Coverage of DVB-T signals	> 98 %	52 % ¹⁸	75 % ¹⁹
Phase-out period of terrestrial analogue TV signal	2005 - 2008	2003 – 2010	2008 – 2012 (goal)

¹² 2004 (RTVV, 2005)

¹³ (SBD, 2004)

¹⁴ 2005, Market Transformation Programme

¹⁵ (Adda & Ottaviani, 2005)

¹⁶ June 2005, Arbeitsgemeinschaft Fernsehforschung, (AGF, 2005)

¹⁷ March 2005, (Ofcom, 2005a)

¹⁸ 52 % coverage of TV households, Deutsche-TV Plattform (TV-Plattform, 2005)

¹⁹ 75 % coverage of population (Ofcom, 2005a)

2.1.2 The technology framework

The most widespread technical standard for digital television is Digital Video Broadcasting (DVB). DVB-T²⁰ has been adopted and partly launched throughout Europe, as well as in Russia, the Middle East, India and Australia, among others. Trials are going on in a number of other countries, including China. The organization behind is DVB-Project, an industry-led consortium of broadcasters, manufacturers, network operators, software developers, regulatory bodies and others in over 35 countries (DVB, 2005).

DVB uses MPEG 2 as compression format for visual data and MPEG 1 (Layer II) for audio data. In contrast to analogue broadcasting, digital compression entails that only that information which changes is actually broadcasted. This reduces the required space in the frequency spectrum and allows broadcasting of 4 – 6 digital channels in the same spectrum previously taken up by one analogue channel. Another advantage of digital broadcasting is significant energy saving in the radio transmitter station. For instance, analogue stations in Sweden have an output of up to 1000 kW, whereas a digital radio station only requires up to 50 kW (Rosenkvist, 2004).

Part of the DVB Project is Multimedia Home Platform (MHP), which is a set of specifications for the middleware system that also includes the home terminal (set top box, TV, PC), its peripherals and the in-home digital network. In a specification addressing user and market requirements, it is emphasized that the MHP system shall support power minimization strategies. The specification defines operating states, requires that the platform in on and standby-active mode communicates its state to the user, and recommends that information on power consumption in the on- and standby mode shall be made available to consumers. (DVB, 2001).

2.1.3 Digital television services

The key advantage of digital television is the more effective use of bandwidth, which means that more channels can be broadcasted in the same radio spectrum. Additionally, there is a whole range of new services beyond pure television broadcasting. Interactive broadcasting might include services such as pay-per view and video on demand, home shopping, banking and games and quizzes. Private storage devices allow program recording and time shifting functions. If connected to the Internet, web browsing and e-mail via the TV screen is possible. Furthermore, home entertainment could be bound into a home server and future home networks (Humax, 2005).

2.2 Set-top boxes – The gateway for digital television services

2.2.1 STB characteristics

The vast majority of TV-sets and other devices for the reception and recording of audiovisual data (VCRs, DVD-recorders, etc.) is equipped with an in-built tuner which only can receive and process analogue cable and terrestrial signals. For the reception of any satellite or any digital TV services, additional hardware is required. This hardware can be a stand-alone receiver/decoder (STB) or be integrated into the TV-set (iDTV). Set-top boxes – in combination with a satellite dish for the reception of analogue satellite broadcasting - are used since the 1980ies, the first digital STBs were delivered in the mid 1990s.

²⁰ An additional letter indicates the delivery platform: T (terrestrial), S (satellite), C (cable), or H (handheld applications).

Figure 2.1 depicts the central gateway function of STBs for the reception, processing and interactive capabilities of digital television services. The content and the platform / network provider can either be separate organizations or vertically integrated into one corporation. Subsequently, the term service provider will be used for all organizations dealing with the supply and broadcasting of television services.

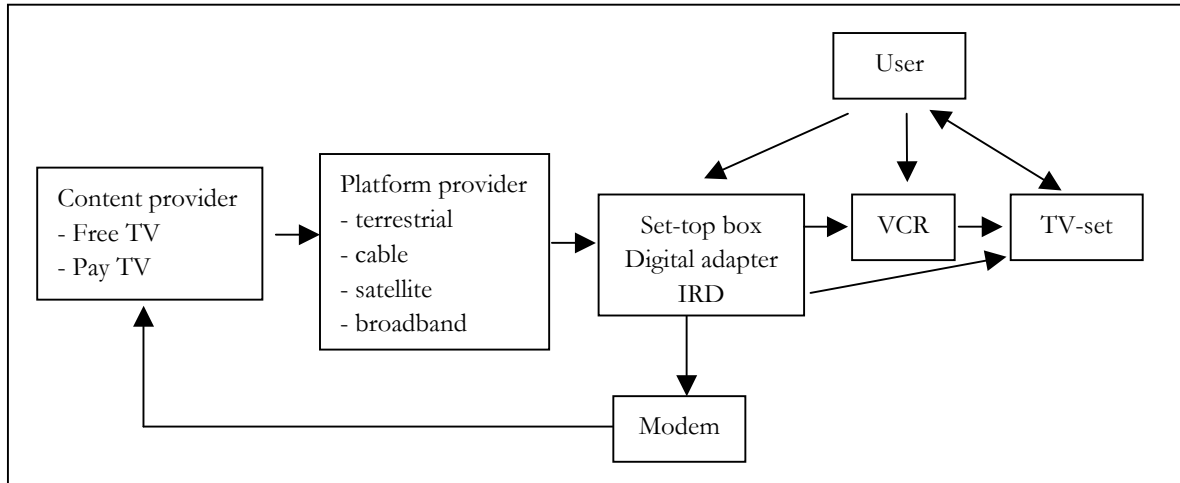


Figure 2.1: The set-top box as the gateway for digital television services

STBs come in a wide range of types. They can be grouped according to their functionalities and the type of broadcasting signal they process. In terms of functionalities, STBs are often categorized into three broad groups:

1. A simple *digital converter* for the reception of digital free-to-air television services and their conversion to analogue RF and / or line signals.
2. STBs for *subscription television services* that contain a conditional access module to ensure that users are subscribers to the service. Some of these STBs also have a return path to allow some interaction by modem uplink to the service provider.
3. STBs with *integrated video recording devices*, in particular hard-disc drives (HDD). In addition to conventional recording functions, HDDs also allow time shift functions, which means that the user watches the beginning of one program while the end is still being broadcasted and recorded. Some recent STB models comprise HDDs of up to 160 Gigabyte capacity, which is sufficient to store up to 80 hours of video.

This categorization is only rough; combinations of the different groups are widely available. Furthermore, STBs can have a number of additional features such as twin tuners, different types of modems (PSTN, ADSL, cable), other I/O interfaces (IEEE1394, ethernet, wireless, USB, home automation interfaces) and additional LNB feeds for satellite receivers. Regarding the delivery or broadcasting platform, distinction is made between (1) terrestrial, (2) cable, (3) satellite, and (4) broadband platforms. Generally, STBs are only designed to work with a single platform. The integration of STB functions into the TV-set itself by means of an integrated decoder (iDTV) is not explicitly addressed in this study. Current sales

figures from the UK indicate that in the short term stand-alone STBs rather than iDTVs will penetrate markets ²¹.

A digital STB is basically a task specific computer. CPU clock rates of modern STBs are similar to the clock rates of Pentium 1 or Pentium 2 processors as they were built into desktop PCs only a few years ago. What STBs distinguish themselves from most other consumer electronic equipment is that they are not stand-alone devices. Their function as an add-on device being placed between the service provider and local peripheral devices such as the TV-set and VCR makes them part of a computer network ²². The exchange and processing of electronic data within this network happens both in standby- and in on-mode. In standby modes, service providers send data for electronic programme guides (EPG), conditional access systems and software updates to the STB. In on-mode, the STB fulfills its primary function and additionally receives, decodes and processes digital video and audio data. Two-way communication between STB and service provider can be realized via a return path, e.g. via a modem. In the networked home of the future, STBs could evolve to a home media server that links all kinds of CE and ICT peripheral devices with external access to some digital television broadcasting platform, as well as to the Internet.

2.2.2 Stakeholders

The stakeholders involved in the development and supply of set-top boxes are similar to those of many other electrical and electronic products. STBs can, especially in their advanced versions, be as complex as personal computers (memory, HDD, CPU, software, graphical user interface). Supply chains both on the hardware and on the software side can be manifold and globally distributed.

However, distribution channels from the producer to the end-user differ to many other CE products. Though STBs for free-to-air services are readily available at retailers, many STBs reach the consumer via service providers as part of a subscription package. Often service providers set hardware and software design specifications to producers, purchase these STBs in huge quantities, and forward them to the final user. Sometimes, when signing a subscription for a television service, consumers themselves are given the choice to purchase the STB via a retailer. But typically the service provider recommends some few models, which have been tested as being technically compatible with their requirements. Thus, also in this case service providers have distinctive influence on the model being chosen by the consumer. Figure 2.2 depicts the principal structure of the supply and distribution chain of STBs; Table 2.2 shows exemplary a selection of different stakeholders in Sweden, Germany and the UK.

²¹ In the UK, total sales for digital terrestrial reception equipment accounted for 2.1 million units in the second half of 2004, of which 87 % were digital adapters and 12 % iDTVs (Ofcom, 2005b)

²² A computer network has been defined as “two or more computers and peripheral equipment that are connected with one another for the purpose of exchanging data electronically”. Source: Encyclopaedia Britannica, (Britannica, 2005)

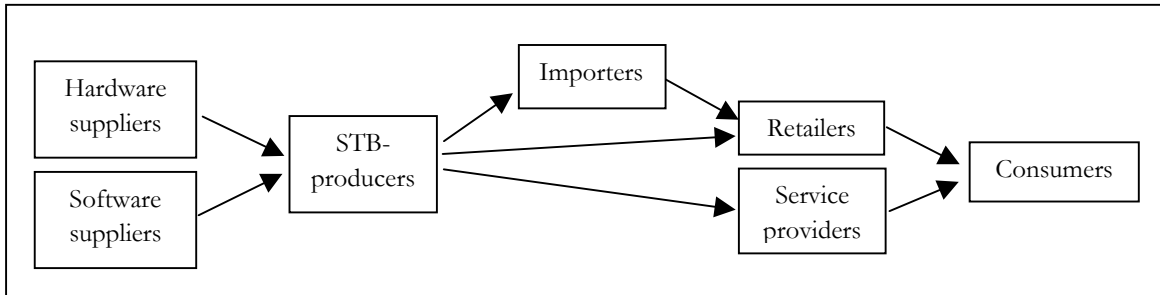


Figure 2.2: The supply and distribution chain of set-top boxes

STB manufacturers can be classified into four broad groups. First, globally operating CE brands such as Sony, Philips, Panasonic and Nokia offering a broad range of CE and ICT equipment have included STBs into their product portfolio. Secondly, some companies such as Pace Micro Technology from the UK and Humax from Korea have specialized themselves in the development of STBs and digital TV equipment. These companies increasingly target international markets and are, in terms of units delivered, among the biggest STB producers in the world²³. Thirdly, there are numerous small manufacturers, often only operating in their national market and possibly neighbouring countries. These companies often have a long tradition in the production of radio and television equipment, STBs are only one of their products. Good knowledge about local and national consumer needs have been described as essential for a successful market performance, as for instance the graphical user interface and other features have to be adapted to local requirements (Löhmann, 2005). A fourth group are low-cost producers, generally from Asia, that particularly use their low product prices as sales argument but do not run a brand strategy.

Table 2.2: Excerpt of stakeholders in Sweden, Germany and the UK

	Sweden	Germany	UK
National STB producers	A2B Electronics, Jacobssons, Emitor	Technisat, Kathrein, Zehnder	Pace Micro Technology
STB importers	Dilog, Tevebox	Radix, Arcon	?
Multinational CE brands	Sony, Philips, Thomson, Panasonic, Pioneer, Nokia, Samsung, Sagem, LG		
Service providers for digital TV services	Canal Digital, Viasat, Comhem, Boxer, UPC	Premiere, Kabel Deutschland	British Sky Broadcasting, ntl, Telewest, Freeview
Consumer / Energy Agencies	Energimyndigheten, Konsumentverket	Stiftung Warentest, Deutsche Energieagentur (DENA)	Market Transformation Programme
Major retail chains for CE	Expert, OnOff, Siba, El-Giganten	Metro (Saturn, Media Markt), EP, Expert, Aldi, Lidl, Plus	Dixon's, Comet
Digital TV associations	Digitalkommisionen Digitalforum	Deutsche TV-Plattform	Digital TV Group
CE retailer & industry associations	Elektronikförbundet	Fachverband Consumer Electronics	?
Standard setting organizations	EICTA - European Information & Communications Technology Industry Association DBV-Project, CENELEC - European Committee for Electrotechnical Standardization International Electrotechnical Commission (IEC), Ecma International		

²³ For instance, Pace claims to be the world's largest dedicated developer of digital TV set-top box technology (2.1 million units delivered in 2004)

2.2.3 A fast growing market

The (global) markets for digital STBs in all variations are expected to grow very rapidly in coming years. Countries with a large share of households still relying on the terrestrial platform will become particular big markets for digital terrestrial reception equipment when analogue terrestrial signals will be phased out one day. Especially, the huge stock of secondary TVs or portable TVs are expected to be equipped with simple (low cost) digital converters for free-to-air services ²⁴.

Even households where the primary TV-set uses a satellite or cable platform are affected by the phase-out of terrestrial analogue signals. For instance, it was reported from Berlin that since the phase-out of the analogue terrestrial signal more than 260 000 DVB-T receivers were sold. This number is much higher than the number of households relying on the analogue terrestrial signal and many of these DVB-T set-top box were used for secondary and tertiary TVs (Focus, 2004). On the other hand, the example of the UK illustrates, that the market for DVB-T receivers already can grow rapidly when digital terrestrial television - compared to the analogue platform - offers significant consumer benefits such as a broader programme offer. Experience from the UK also shows that consumers prefer to buy a STB instead of replacing their existing TV-set with a new model with an integrated digital receiver. This can be explained with the fact that the emerge of digital free-to-air television happened quite rapidly, way ahead of the regular end-of-life of most TV-sets in use. Furthermore, there has been only a limited range of iDTVs on the market, especially in the low-price segment. STBs with additional functions also show a strong growth. Deliveries of personal video recorders using a hard-disc drive as storage medium are reported to increase by 50% annually (Focus, 2004).

With increasing competition from digital satellite and terrestrial platforms, cable operators also accelerate the digitalisation of their networks²⁶ and expect increasing sales of digital subscription packages (Andersson, 2005). In 2005, global set-top box exports are estimated at 59 million units whereof about 29 million units will be shipped from mainland China. Another 6 million STBs will be shipped from Taiwan (GlobalSources, 2005). In a global context, the potential market for STBs is huge. For instance, only China has around 340 million TV households and the Government also plans to switch over to digital terrestrial platforms. By 2008, 200 millions STBs are expected to be in use in China (Zhang, 2004).

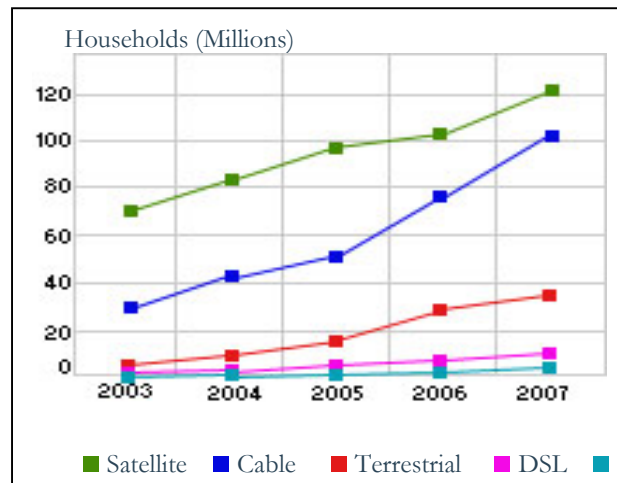


Figure 2.3: Worldwide digital television set-top boxes market forecast ²⁵

²⁴ (Bertoldi, 2004)

²⁵ Strategy Analytics, 12/2003; derived from <http://www.humaxdigital.com/global/abouthumax/industryoutlook.asp>, 24.08.2005

²⁶ (Kabeldeutschland, 2005)

2.3 Electricity consumption of set-top boxes

Energy consumption during the use phase is a significant environmental aspect of the entire life cycle of a set-top box. During the research work detailed studies (LCA or similar) on the service-life electricity consumption as share of the entire life-cycle energy use were not found. There are studies for TV-sets, indicating that the electricity consumption in the use-phase is in the range of 90 % of the total energy of the entire life cycle including manufacturing and recycling (Wajer & Siderius, 1998). Since for TVs the screen has a large impact on the energy bill and for the reason that STB circuit boards are similar to boards in ICT products, PCs have been suggested as a better proxy than TVs (Siderius, 2005b).

2.3.1 Background

Early electric appliances only had two operating modes: on and off. The introduction of TV-sets that could be controlled with an infrared remote control brought the standby mode to peoples' homes. The standby mode has many definitions, two of the most common ones are "the power consumed by an appliance when switched off or not performing its primary functions" or the "minimum power consumption of a device while connected to the mains" (IEA, 2001). Things are more complicated with STBs, which can have several standby modes. Table 2.3 depicts a definition of operating modes as prescribed by EN50301: *Methods of Measuring for the Power Consumption of Audio, Video and Related Equipment* ²⁷.

Table 2.3: Operating modes of STBs in EN 50301 ²⁸

Mode	Set-top box
Disconnected	The appliance is disconnected from all external power sources.
Off	The appliance is connected to a power source, fulfills no function and cannot be switched into any other mode with the remote control unit, an external or internal signal.
Standby-passive	The appliance is connected to a power source, fulfills not the main function but can be switched into another mode with the remote control unit or an internal signal,
Standby-active, low	...and can additionally be switched into another mode with an external signal,
Standby-active, high	...and is exchanging/receiving data with/from an external source.
On	The appliance is connected to a power source and fulfills its main function.

The reason for a further differentiation between standby-passive and -active (high and low) is that STBs are networked devices that even run processes when not fulfilling their main function, which is the receiving and decoding of digital video streams. These processes run in the standby-active mode and comprise the download of electronic programme guides (EPG), software updates and the identification and update of conditional access systems (CAS) that ensure the protection of subscription services and intellectual property rights.

Looking at the circuit board level, Figure 2.5 depicts the breakdown of power consumption of a simple digital converter in on- and standby-passive mode. Total on-mode consumption accounts of this model accounts for 10.6 Watts, with the power supply chain, the central

²⁷ Another widely used standard is IEC 62087: *Methods of measurement for the power consumption of audio, video and related equipment*.

²⁸ (CENELEC, 2001)

microprocessor (CPU), and the tuner being those components where most power is used. Standby power accounts for around 2.2 Watts, which is a rather low value thanks to efficient power management. Still the biggest users are the power supply chain and the CPU-unit, as well as the memory. The high losses in the power supply chain derive both from the power supply unit, which converts 230 Volts AC to low voltage direct current (DC), and from the power architecture with – in this example - six different voltage levels from 1.8 – 32 Volts DC. Voltage regulators supply these voltages, whereas each voltage conversion entails power losses.

The standby mode of the digital converter depicted in Figure 2.4 is a standby-passive mode. More advanced STBs often have a standby-active mode, where the tuner and possibly the CPU are fully on. As a result, power consumption in standby-active mode is a lot higher than in standby-passive and might only be slightly lower than in on-mode, in particular when no or insufficient power management has been implemented.

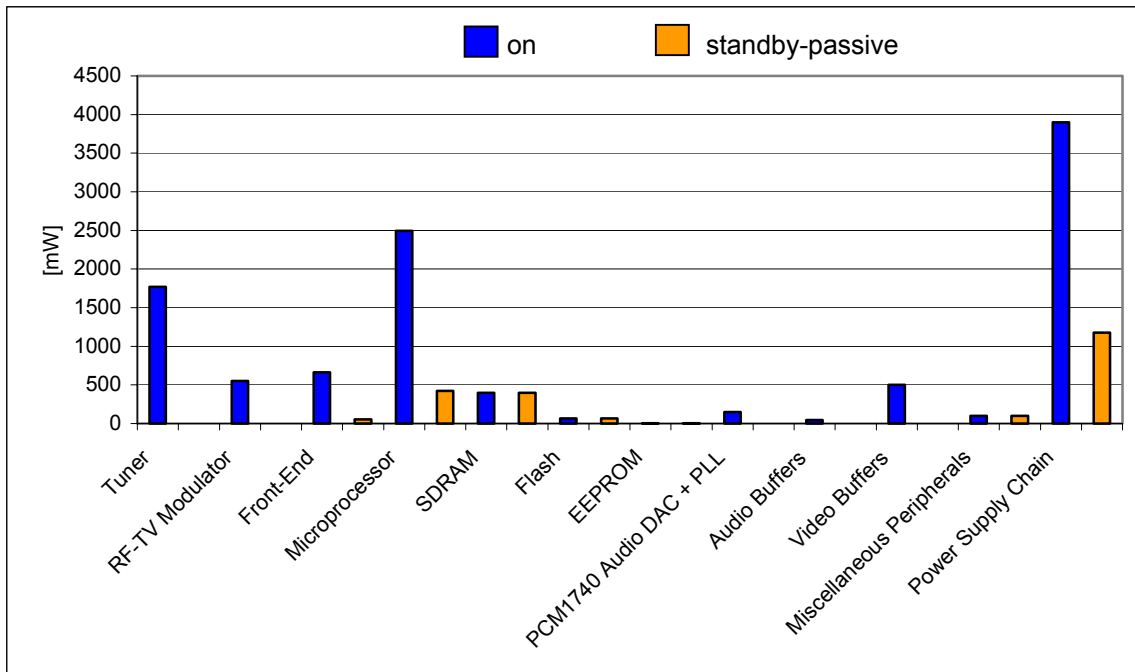


Figure 2.4: Distribution of power consumption of a digital converter ²⁹

²⁹ data derived from (Spini, 2002)

2.3.2 Power consumption of individual set-top box models

Different STB-models fulfilling comparable functions vary widely in their power consumption. Table 2.4 provides an overview of the energy performance of digital terrestrial STBs and satellite receivers. Figures derive from test measures commissioned by consumer magazines and governmental agencies in Germany and the UK.

Table 2.4: Power consumption of set-top boxes for terrestrial and satellite platforms

Source	STB-type	No of models measured	Power consumption			
			mode	average	min	max
				[W]	[W]	[W]
UK EPIC (2002) ³⁰	DVB-S	7	on	18.5	12.5	24.5
			standby	17.8	11.5	23.3
Stiftung Warentest ³¹ 11/2003	DVB-S	9	on	14.0	9.8	20.1
			standby	4.9	2.1	12.0
Audio-Video-Foto Bild 02/2004 – 07/2005 ³²	DVB-S	36	on	10.6	5.6	18.1
			standby	8.5	2.0	18.3
Audio-Video-Foto Bild 02/2004 – 07/2005	DVB-S & analogue sat-receiver with HDD	25	on	18.1	5.6	26.3
			standby	8.7	2.7	18.0
Stiftung Warentest 11/2003	DVB-T	6	on	8.4	6.0	11.1
			standby	6.0	2.4	10.6
Stiftung Warentest 03/2004	DVB-T	6	on	n/a	n/a	n/a
			standby	4.3	0.1	9.0
Market Transformation Programme (2004) ³³	DVB-T (digital adapter)	37	on	8.6	5.7	14.1
			standby	6.6	0.3	13.2
Audio-Video-Foto Bild 02/2004 – 07/2005	DVB-T	29	on	10.0	5.6	20.6
			standby	7.5	1.6	15.5
Audio-Video-Foto Bild 02/2004 – 07/2005	DVB-T with HDD	12	on	17.1	6.3	22.5
			standby	9.2	3.7	16.7
Stiftung Warentest 03/2005	DVB-T	7	on	7.1	5.4	8.7
			standby	4.8	1.7	6.6
Stiftung Warentest 03/2005	DVB-T with HDD	3	on	17.1	14.7	21.5
			standby	7.4	5.8	9.6

Average power consumption figures between these studies vary to some extent due to different STB features (HDD, conditional access, etc.), different sample sizes, and the fact that measurements often were not conducted to any standard. Power consumption between individual STB units of the same model can also vary, as for instance CPUs of the same type can differ in their power needs (Saez, 2005). Despite these uncertainties, the most striking result of these studies is the broad range in power consumption between STBs that fulfill similar functions.

³⁰ (EPIC, 2005)

³¹ According to Jochen Oberst (personal communication, 05.07.2005) power measurements at Stiftung Warentest are done with a high-quality power meter, but not according to any norm.

³² derived from Aktion No-Energy (www.no-e.de, 08.07.2005)

³³ (Armishaw, 2005)

Furthermore, there is evidence that:

- Power consumption of STBs with hard-disc drive is higher than of STBs without, both in on-mode and standby mode;
- Satellite STBs need more power than terrestrial STBs, since they also have to power the low noise block converter (LNB);
- For a number of models, standby power needs are only slightly lower than in on-mode;
- On-mode and standby power consumption of satellite STBs dropped over the years.

Figure 2.5 depicts the projected annual electricity consumption for the most efficient, average, and least efficient model of the respective studies. The projection is based on a duty cycle of 4 hours per day in on-mode and 20 hours in standby-mode, which though does not reflect that many users don't switch their STBs into standby. Annual consumption figures between the different models vary significantly; the least energy-efficient model on the market can consume five or more times as much as the best one. Most digital terrestrial STBs consume between 50 – 90 kWh per year, whereas models equipped with hard-disc drives tend to be in the upper range. The best models only require 20-30 kWh per year. In the context of other household equipment, the annual energy consumption of two average STBs could exceed the consumption of a spacious modern refrigerator ³⁴.

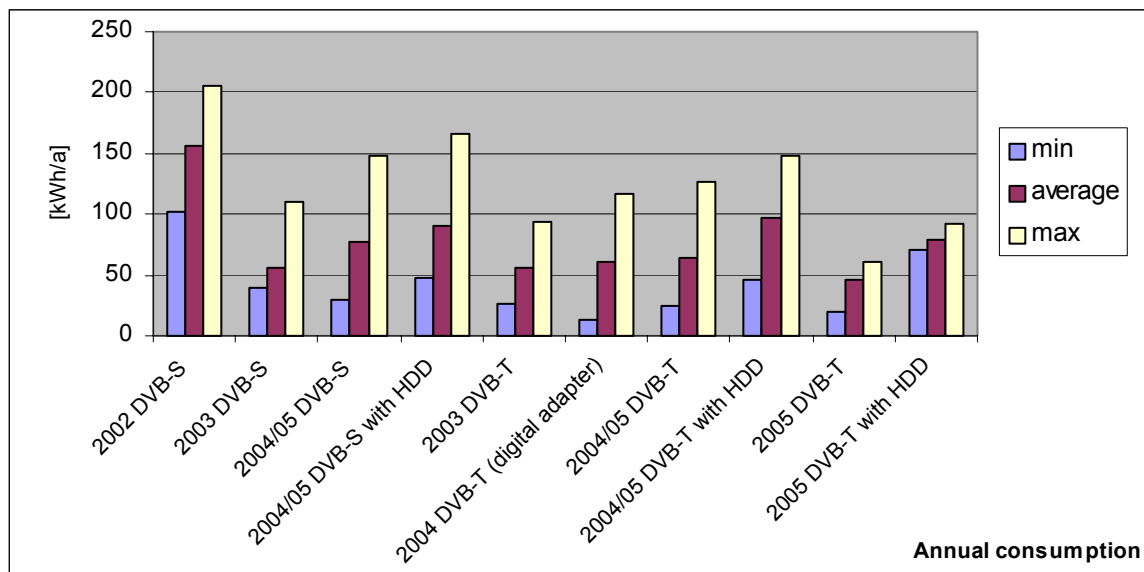


Figure 2.5: Annual electricity consumption in a standard duty cycle ³⁵

³⁴ For instance, the 305 liter model ERC3116 (Energy-class A+) from Electrolux is declared to consume 138 kWh/yr (Electrolux, 2005).

³⁵ 4h/d in on-mode & 20h/d in standby; data derived from Table 2.4

Figure 2.6 is based on the same data as Figure 2.5, but shows a breakdown of annual consumption in standby mode and when fully on. The standby mode accounts for by far the biggest share of total annual electricity consumption and exceeds annual consumption in on-mode by a factor of three to four.

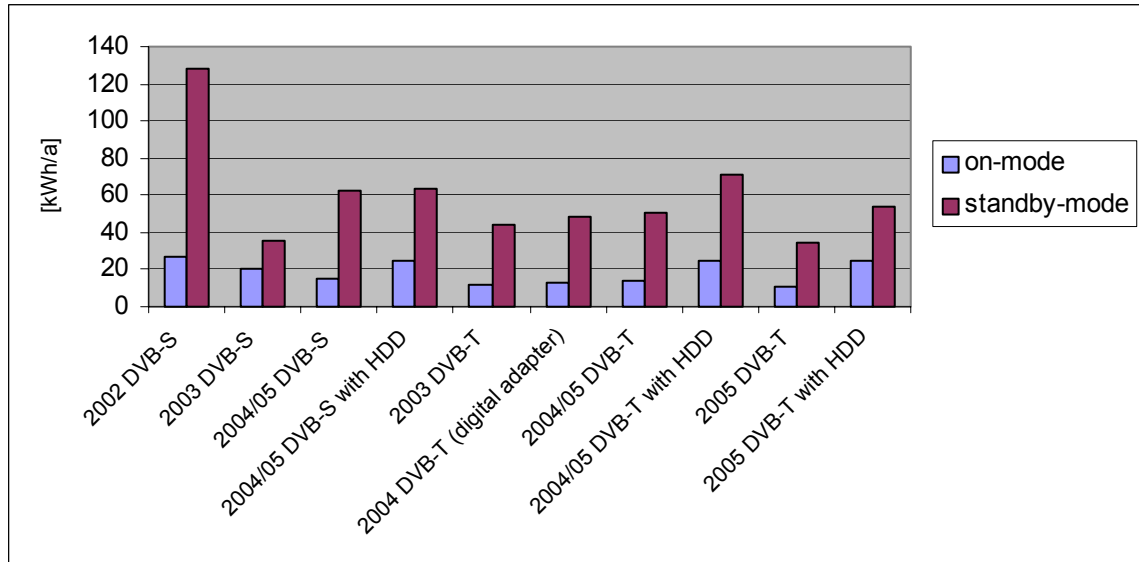


Figure 2.6: Average annual electricity consumption in on- and standby-mode

2.3.3 The impact at national levels

This chapter investigates the current and future stock of STBs and its impact on electricity consumption at a national level. For Germany and the UK, existing studies were reviewed, for Sweden the author conducted own projections. All projections used a bottom-up approach, where a number of input parameters such as the projected STB stock, power consumption for the average STB, as well as usage patterns contributed to the final outcome. Key factors are shown in Figure 2.7.

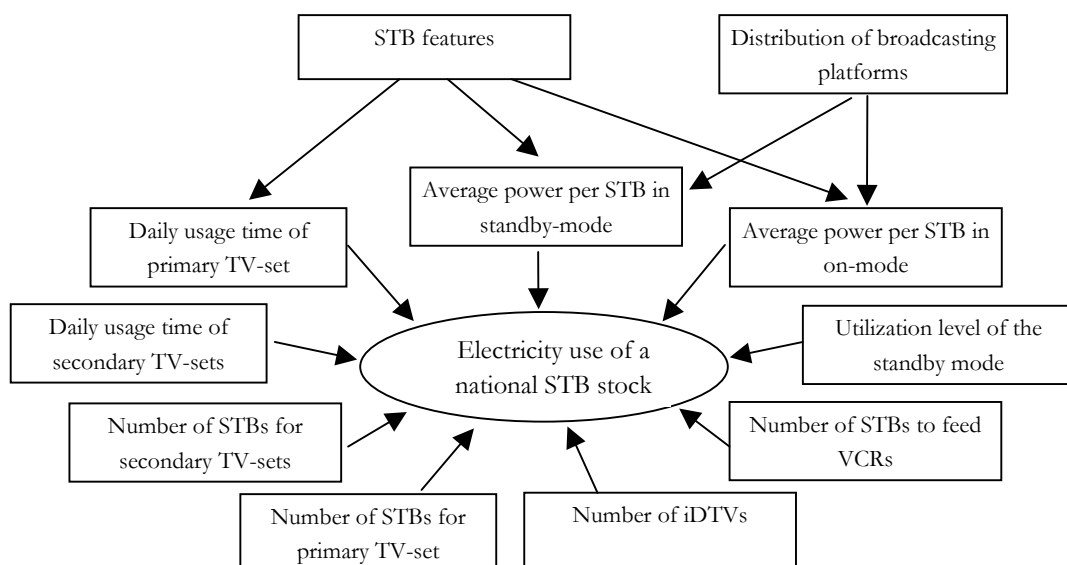


Figure 2.7: Key factors influencing electricity use of a national STB stock

2.3.3.1 Germany

Schlomann et al. (2005) estimated as part of a study on the future impact of ICT technology on electricity consumption, that by 2015 the stock of STBs in Germany is expected to triple, raising from currently 22.5 million units to about 63 million units. The study assumes, that cable networks will entirely be digitized by 2013, analogue terrestrial signals will entirely be phased out by 2015, and terrestrial digital platforms gain market share from currently 12 % to 20 % by 2015. For the 2010/2015 forecasts, greater differentiation (in terms of power consumption per unit) is made between simple converters, STBs with conditional access features, and advanced STBs with recording and other functionalities. Operating times are expected to rise sharply to 5600 hours per year for more advanced models. In relation to Germany's electricity consumption in 2002, the 2015 STB stock is calculated to consume around 1.5 % of total electricity and more than 5 % of household electricity.

Table 2.5: Electricity consumption of the current and future stock of STBs in Germany ³⁶

Year	STB stock				Electricity consumption		
	Satellite	Cable	Terrestrial	Total	Total #	Share of total electricity use *	Share of household electricity use *
	[1000]	[1000]	[1000]	[1000]	[GWh/yr]	[%]	[%]
2004	18 976	1 881	2 320	22 477	1 909	0.4 %	1.4 %
2010	21 264	22 853	6 146	50 263	5 779	1.2 %	4.2 %
2015	22 136	28 807	12 034	62 977	7 528	1.5 %	5.4 %

including consumptions from LNBS
* share of 2002 electricity consumption

2.3.3.2 UK

For the UK, the Market Transformation Programme³⁷ projected the electricity consumption of STBs until the year 2020. The study distinguishes between *Digital Adapters (DA)* for digital terrestrial free-to-air services and *Digital Service System Receiver Platforms (DSSRP)* for subscription services and is based on the assumptions that by 2010 the analogue terrestrial signal will be phased out, which is in accordance with the goals of the Digital Action Plan³⁸. The penetration of subscription services is expected to grow significantly.

Projections were made for three scenarios. In the baseline *Reference Scenario*, average consumption of current STB models remained constant until 2020 and users didn't make use of the standby mode at all. A so-called *Policy Scenario* should demonstrate the effect of a number of different actions and the *Earliest Best Practice* scenario should illustrate the theoretical potential for energy savings if a best practice approach would be taken up as early as possible (MTP, 2005a). Table 2.6 shows the significant savings potential of the *Earliest Best Practice* approach compared to the *Reference Scenario*. In the worst case, equipment for the reception of digital television services will consume around 2.5 % of national electricity, or more than 7 % of household electricity by the year 2020, assuming that total electricity use will not change.

³⁶ (Schlomann et al., 2005; VDEW, 2005), own calculations

³⁷ The Market Transformation Programme is an initiative by the Department for Environmental, Food and Rural Affairs (DEFRA) with the objective to develop policy strategies for improving the resource efficiency of traded goods and services in the UK.

³⁸ <http://www.digitaltelevision.gov.uk/>

Table 2.6: Electricity consumption of the current and future stock of Digital Service System Receiver Platforms and Digital Adapters in the UK ³⁹

Year	Stock		Electricity consumption				
	DAs	DSSRPs	DAs	DSSRPs	Total	Share of total electricity use *	Share of household electricity use *
	[1000]	[1000]	[kWh/yr × unit]	[kWh/yr × unit]	[GWh/yr]	[%]	[%]
Reference Scenario							
2004	5 297	9 939	123	219	2 629	0.3 %	2.3 %
2010	43 251	22 270	123	219	10 181	3.3 %	8.9 %
2020	17 342	56 795	123	219	14 565	4.4 %	12.7 %
Earliest Best Practice Scenario							
2004	5 297	9 939	115	208	2 485	0.7 %	2.2 %
2010	43 251	22 270	25	99	3 285	1.0 %	2.9 %
2020	17 342	56 795	23	72	4 516	1.4 %	3.9 %

* share of 2002 electricity consumption

2.3.3.3 Sweden

For Sweden, estimates on electricity consumption of the digital STB stock are made for three dates: (1) the current situation in 2005, (2) the situation after the phase-out of all analogue terrestrial signals in early 2008, and (3) the point when the entire cable-network is digitized. There is no schedule for this, but following the German study, it is assumed that all cable subscribers use digital television services by 2013.

An increasing number of users have access to digital television in Sweden. In particular subscription numbers to *Boxer*, Sweden's only digital terrestrial television provider, have risen sharply in recent months and accounted to 450 000 by the end of June 2005. No figures on the current use of free-to-air STBs could be found. Digital free-to-air services only offer two additional channels compared to the terrestrial analogue platform and thus, it is assumed that the number of digital free-to-air STBs is still low. However, this will rapidly change with the phase-out of the analogue signal starting on Gotland on 19 September 2005 and to finish off with the last regions in Sweden on 1 February 2008.

Canal Digital and Viasat provide digital television services via a satellite platform and have together about 630 000 subscribers. In other statistics the share of households that use a satellite platform range between 20 % ⁴⁰ and 27 % (RTVV, 2004) implying that around 820 000 to 1.1 million households receive satellite TV. This means that in addition to the 630 000 digital subscribers another 190 000 – 470 000 households receive satellite television via other platforms, e.g. the Astra network. For the estimation of electricity consumption of satellite receivers, the medium figure of 960 000 satellite households is taken. Concerning cable platforms, three service providers currently offer digital services in their networks. The share of digital subscriptions of the total number of households is still low, but it is assumed

³⁹ (MTP, 2005b), In 2002, the UK's 2002 final electricity consumption accounted to 332.7 TWh, whereof 114.5 TWh were used in the residential sector (IEA, 2005).

⁴⁰ (Nordicom, 2005)

Table 2.7: Subscription to television services in Sweden ⁴¹

Platform	Service Provider	Digital	Total
Cable	Com Hem	169 000	1 400 000
	Canal Digital	30 000 #	230 000
	Kabelvision	0	300 000
	UPC Sverige	42.000	294 000
	Sum	241 000	2 224 000
Satellite	Canal Digital	411 000	
	Viasat	240 000	
	Sum	630 000	
Terrestrial	Boxer	450 000	
	Sum	450 000	
Sum all platforms		1 321 000	

estimation based on the digital subscription share of Com Hem & UPC

However, with the analogue terrestrial phase-out in 2008, it is assumed that all secondary TV-sets will convert to the same digital platform as the primary television set in the home. VCRs are not expected to be equipped with an extra STB, but are either assumed to be supplied from a twin tuner or are expected to gradually be substituted with STBs that have inbuilt recording functionalities. Due to their slow advent⁴², iD TVs are not separately displayed in the projection. For the forecast, it will be assumed that the share between the different broadcasting platforms will not change significantly. Furthermore, the number of households and penetration with TV-sets is expected to grow at the same rate as in past years.

Each year has a “low” and a “high” projection, assuming that in the low projection all STBs are switched into standby either by the viewer himself or by some automatic mechanism. In the high projection, only 50 % of users put their STB into standby, the other half of the STB stock always remains on⁴³. In accordance with Schlomann et al. (2005), power consumption in on-mode is expected to increase as STBs will be equipped with more functionalities. On the other hand, Schlomann et al. (2005) expect standby consumption as likely to drop. Power values, as depicted in Table 2.8, are understood as average numbers for the entire stock and figures for individual boxes can vary widely. For instance, a high definition satellite box with recording functionalities might need 40-50 Watts in full operation, while a simple terrestrial converter box could run on 5 Watts. To cope with the high level of uncertainty about future STB design, the “low” projections for 2008 and 2013 use lower power figures than in the “high” scenario. For all projections, a daily duty cycle of four hours in on-mode and 20 hours in standby-mode for the primary TV-set is assumed⁴⁴. Secondary TV-sets are estimated to be on during two hours per day. At the time of writing, the Swedish Energy Agency conducted

⁴¹ (RTVV, 2005), (Boxer, 2005), (Digitalforum, 2005)

⁴² (Widsell, 2005)

⁴³ This assumption is based on the UK experience, that 60 % of users never put their STB into standby.

⁴⁴ The average TV watching time in Sweden is around 2 hours per day (RTVV, 2004), however since TV viewing patterns differ in the family (children generally watch in the afternoon and adults in the evening), an average TV is assumed to be in on-mode for 4 hours per day. Secondary TV sets and VCRs are assumed to be in on-mode for 2 hours per day.

that by 2013, all cable households will be entirely digitalized and all current cable subscribers use a digital cable STB.

Little is known which platform secondary and tertiary TV-sets, as well as VCRs currently use, and whether these devices are already equipped with their own STB. For the 2005 estimate, it will be assumed that 20 % of secondary TV-sets use the same digital platform and the remaining 80 % of secondary devices still use some analogue terrestrial or cable platform.

a field measurement of electric devices among 400 Swedish households (Persson, 2005). Results might be used to improve the data quality of future projections.

Table 2.8: Estimates on power consumption for average STB

Year	Satellite-STB		Cable-STB		Terrestrial-STB		All platforms Level of utilization of standby-mode
	On	Standby	On	Standby	On	Standby	
	[W]	[W]	[W]	[W]	[W]	[W]	[%]
2005 low	17	9	10	6	9	6	100 %
2005 high	17	9	10	6	9	6	50 %
2008 low	11	5	10	5	10	5	100 %
2008 high	17	7	15	6	13	6	50 %
2013 low	15	4	15	4	15	4	100 %
2013 high	20	5	20	5	20	5	50 %

By 2008, more than 4.7 million STBs are predicted to be in use. The entire digitization of cable networks could almost double this quantity to around 8.5 million STBs. Unsurprisingly, electricity use grows with this increase but uncertainty about power needs of the future STB stock is high. In the worst case of the 2013 “high” scenario, all STBs may consume up to 1 % of total electricity in Sweden. The impact on consumers’ power costs will be >900 million SEK per year in the 2013 “high” scenario⁴⁵.

Table 2.9: Electricity consumption of the current and future stock of STBs in Sweden⁴⁶

Year	STB stock				Electricity consumption		
	Satellite	Cable	Terrestrial	Total	Total	Share of total electricity use *	Share of household electricity use *
	[1000]	[1000]	[1000]	[1000]	[GWh/yr]	[%]	[%]
2005 low	959	282	527	1 768	132	0.1 %	0.3 %
2005 high					171	0.1 %	0.4 %
2008 low	1 822	564	2 358	4 744	236	0.2 %	0.6 %
2008 high					578	0.4 %	1.4 %
2013 low	1 915	4 131	2 479	8 525	403	0.3 %	1.0 %
2013 high					1.167	0.9 %	2.8 %

* share of 2002 electricity consumption⁴⁷

⁴⁵ at 0.8 SEK/kWh

⁴⁶ Detailed calculations are depicted in Table A-6, A-7 and A-8 in the Appendix.

⁴⁷ Sweden’s total electricity consumption accounted for 131.6 TWh in 2002, whereof 41.4 TWh were used in the residential sector (IEA, 2005)

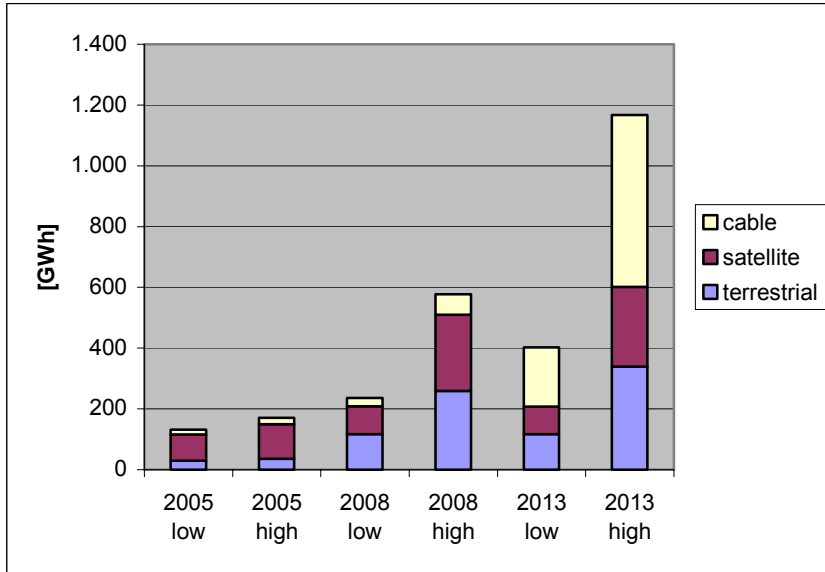


Figure 2.8: Total consumption of digital STBs in Sweden

2.3.3.4 Reflections

The projections differ widely in their approach and for that reason results are not entirely comparable. Furthermore, the level of uncertainty in particular about future usage patterns, the design of future STBs, and hence future power consumption of the average STB is quite high since the technology is developing rapidly.

Despite these uncertainties, it is likely that Digital Television and related services will raise residential electricity needs in the range of a few percent. Impacts vary from country to country for different reasons. The digitization of satellite, cable and terrestrial broadcasting platforms happens at different times, additionally the market share of platforms can differ significantly from country to country. For instance, with more than 50 % of UK households relying on the terrestrial platform, the phase out of analogue signals will have a much higher impact than in Germany where only around 5 % of television households use terrestrial signals. Nonetheless, with the digitization of cable networks, penetration with set-top boxes and the inherent impact on electricity consumption are likely to align between countries.

The relative impact of STBs on national and residential electricity consumption can also vary widely due to the fact that per capita electricity consumption differ widely among countries. For instance, for a number of reasons Sweden has one of the highest per capita electricity consumption in the world, hence the relative impact of STBs is rather moderate here, compared with for example the UK or Germany.

3 Available options for limiting energy use of set-top boxes

This chapter outlines the various energy efficiency options that exist both in the design stage of the STB, as well as in their subsequent use-phase. The section distinguishes between behavioral change⁴⁸ in the use-phase, improved hardware design, power management at different levels, and the opportunities that do exist in other broadcasting standards. The second part of the chapter presents key policy tools, which at present do, respectively in the near future will deal with the issue of energy efficiency for digital television equipment. Additionally the concept of eco-design industry standards is presented.

3.1 Energy efficiency opportunities

3.1.1 Behavioral change

The aggregated electricity consumption of a set-top box stock can significantly depend on the degree users are making use of the standby- and (if applicable) off-mode. Research indicates that, for instance, in the UK up to 60 % of consumers will not switch digital adapters into standby-mode (MTP, 2004). Exemplary, Figure 3.1 shows the implications on annual energy consumption as a function of the share of users that switch their STB into standby. In this example, the STB stock comprises of 10 million units, average on-mode consumption is 11 Watts, standby consumption 2 Watts, and daily television viewing time is assumed to be four hours. Power consumption between the best case (all users make use of standby) and the worst case (no-one ever puts their box into standby) would be 75 MW in installed capacity, a medium sized gas-fired power plant, for instance.

While switching a TV-set into standby gives the immediate “reward” that screen and sound turn off, however, the response from a STB is less perceptible when being switched into standby. A small LED only changing its colour from green to red might be the only indicator. Many manuals don’t explicitly recommend switching the boxes into standby and do not contain information that leaving the box in on-mode will have significant implications on electricity consumption.

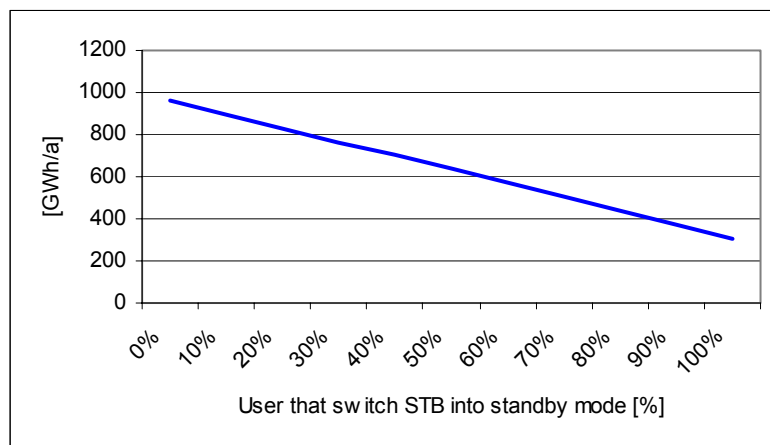


Figure 3.1: Effect of user behaviour on energy consumption of a STB stock

Factors that would increase the likelihood that viewers make use of the standby-mode at a higher rate include that:

- The standby-mode switching function is readily accessible on the remote control (not via a sub menu, etc.)⁴⁹.
- The STB gives a clear response when being switched into standby-mode.
- Recovery time from standby mode is reasonably short⁵⁰.
- Information is provided to the user on the energy consumption in both on-mode and standby mode.
- The user is advised to switch the box into standby if it is not used.

Solutions for automatic switch-off are discussed in Section 3.1.3.2.

3.1.2 Hardware design

A hard-off power switch on the high voltage side of the power supply can disconnect the STB physically from the mains which would eliminate standby consumption but also limit the possibilities for data exchange with the service provider. The switch should be placed on the front end of the STB in order to increase the likelihood that it is really used by the viewer. Currently, only very few STBs are equipped with a hard-off power switch, and if so it is often placed on the backside of the box.

As all electronic products, the STB circuits require low voltage direct current (DC) for operation. These power requirements are provided by internal or external power supplies, which convert and rectify the 220-240 Volts AC of the (European) mains to typically 6 - 12 Volts DC. There are two basic types, linear power supplies and switched mode power supplies (SMPS). Linear power supplies contain a transformer and a rectifier and are most widely used for external supplies of 15 Watts and less. Efficiencies are in the range of 50 – 80 %. Almost all power supplies applied in TV-sets, VCRs and related appliances are switched mode power supplies (SMPS). SMPSs are smaller and more lightweight, have higher efficiencies of up to 90 %, and thus produce less heat than linear power supplies. On the other hand SMPSs generate more RF noise, have a lower power factor and are slightly more expensive (Calwell & Reeder, 2002). External SMPSs in the 10-15 Watts range are reported to cost 2.5 – 3 US\$, which is 20 – 30 % more than for linear power supplies (Huang, 2005).

All power supplies have no-load losses when not being physically disconnected from the mains. In operation, efficiencies can depend very much on the load and are generally lower at part load. To achieve high efficiencies over the duty cycle of a STB, separate power supplies for standby- and for on-mode could be reasonable. The EU Code of Conduct on Energy Efficiency of External Power Supplies contains standards regarding the no-load power consumption and efficiencies under load. For instance, from 2007 the maximum permitted no-load consumption of power supplies with a rated output < 60 Watts has to be under

⁴⁸ Behavioural change in this context only applies to the use phase but not to a change in behaviour when purchasing a STB.

⁴⁹ (Bertoldi, 2005a)

⁵⁰ (Mordziol, 2005; Saez, 2005)

0.3 Watts. The minimum efficiency under load⁵¹ for a 15-Watt power supply – sufficient to power a simple STB – has to be at least 73 % from 2007 onwards (EC, 2004b). Though this Code of Conduct is not applicable to internal power supplies as most often used in STBs, efficiencies can be taken as reference values.

Reducing the number of different voltage levels within the STB and the careful choice of power architecture can result in further power savings. Different components of the STB circuit board may require different supply voltages. For instance, the tuner and RF-modulator might require 5 Volts, the SDRAM and Flash memory 3.3 Volts and the CPU unit 2.5 Volts⁵². Thus, either a power supply providing all the required voltage levels or separate voltage regulators (DC/DC converters) are needed. Since voltage regulators always entail losses of up to 35 - 50 % (Siderius, 1999), the reduction of voltage levels and hence the need for voltage regulation would be beneficial from an energy efficiency perspective.

Power consumption is proportional to the square of the supply voltage and thus reducing IC supply voltages can offer opportunities for power savings (Siderius, 1999). Some drawback of lower chip supply voltages is that efficiency of the power supply chain might suffer to some extent. Another opportunity for power savings is integration. Integrating several functional blocks into one IC will reduce power needs, as fewer chips are needed. Generally, the level of integration increases with products becoming more mature and being produced in larger quantities. Paying attention to external loads, low noise block converters (LNBs) also provide saving opportunities. Power management, as discussed subsequently, offers many opportunities for energy savings. The prerequisite is that the hardware has inbuilt power management functionalities.

3.1.3 Power management

“Power management ensures – without user interference – that the appliance is always in the mode with the lowest power consumption related to the required functionality” (Siderius, 1999). Originally introduced in battery-operated devices such as laptops, power management has become useful also in mains-operated appliances, especially PCs to reduce electricity consumption and minimize heat dissipation. Siderius (1999) distinguished between the following general situations where power management is useful:

- When the function fulfillment of the appliance can end without user interference, e.g. the STB automatically goes into a low power mode when detecting that the TV-set has been switched off.
- When an appliance can carry out several (sub) functions, of which some are not needed at a particular moment or for a particular period. For instance, a STB being in standby mode can switch off those circuits required for the display of video and audio data on the peripheral TV-set.
- When the appliance functions in a network and should be able to receive commands or information from other appliances or from external sources.
- When ambient conditions influence functionality (and power consumption), adapting the functionality to the ambient conditions is also a form of power management. For

⁵¹ Efficiencies in on-mode can be measured at either (a) 100 % rated current output or (b) the simple arithmetic average of efficiencies at 25 %, 50 %, 75 % and 100 % rated current output is taken for compliance checking (EC, 2004b).

⁵² (Spini, 2002)

instance, the brightness of the front-end LED display can be adapted to ambient light conditions.

- When the appliance can detect the need (or absence of need) for the function fulfilment, e.g. when an occupancy detector detects that nobody is watching television.

To gain high acceptance, power management should work with only minimal degradation of user convenience. In particular, start-up and recovery times from low power modes should be as short as possible. The information, respectively the signal to change the power mode can come from different levels. Following, it is distinguished between three levels of power management.

3.1.3.1 On the STB circuit board level

Disabling or powering down circuit blocks or processes when their function is not needed can reduce power consumption. Functional blocks might include the MPEG decoder, the modem and the hard-disc drive, as well as all in- and out-interfaces when not being in use. In lower power modes, the processor can reduce its clock rate to a minimum level. The front end LED display can also be dimmed according to ambient light levels. The EU Code of Conduct has non-binding power management guidelines. For each circuit block maximum functionalities for the standby-active and standby-passive modes are indicated. Generally, common efforts of STB producers, silicon hardware suppliers and software developers are necessary to implement power management on the circuit board level.

3.1.3.2 Between STB and peripheral devices

As discussed in Section 3.1.1, many users do never switch their STB into standby. This problem could be overcome by an automatic power management function that changes the state of the STB according to the peripheral device that it is feeding. The STB should mirror the state of the TV-set and the VCR and follow their on- respectively standby-mode. Table 3.1 depicts an overview over different technical solutions, which can be applied to existing boxes or new models.

One issue with all these solutions is that if the TV-set is displaying data from other than the STB (e.g. a DVD or computer), then the STB is unnecessarily powered up. A drawback of the solution with the additional power saver is that the STB is completely disconnected from the mains and cannot fulfil any legitimate functions (e.g. occasional updates of electronic program guides, etc.) (Nordman, 2005).

Currently, the most common peripheral devices of the STB are the TV-set and a VCR. This might change in the future as on one hand, the function of the STB are likely to be built into an integrated decoder television-set (iDTV). This would facilitate power management, as the integrated decoder will generally have the same operating state as the television display. On the other hand, STBs with inbuilt hard-disc drives and recording functions are becoming increasingly popular.

Multi-room delivery and the networked home are further future trends. Here, STBs or other devices are spread out throughout the home and are less likely to be put into the lowest power standby state from a distant location. Power management becomes also more complex as the STB needs to know which programme streams are required at any particular time and location to power manage the hardware in the best way (Dale, 2005a).

Table 3.1: Potential solutions to automatically put the STB into standby

Solution	Description	Source/ Proposed by
External power saver I	Additional hardware that senses when the TV is powered down and then cuts power to the STB.	(Nordman, 2005) (Bruch, 2005)
External power saver II	Similar hardware but the power is only briefly interrupted to the STB, which triggers the STB to enter its standby mode.	Bob Harrison ⁵³
TV power cord loop-through I	The power cord of the TV is looped through the STB without being electrically connected. Thus, the STB can sense by induction whether the TV-set is on or off.	(Nordman, 2005)
TV power cord loop-through II	Here, the TV is plugged into the STB with the STB then having two power cords - one for the STB and one for the TV. The STB would then have a current transformer to assess the TV's state without having to co-mingle its consumption with that of the TV's.	(Nordman, 2005)
Analogue connection	The STB senses via the analogue connection type (RF, SCART) if the downstream TV is on. There are some doubts whether this is possibly electrically, in particular if the STB signal is routed through another device on its way to the TV.	(Nordman, 2005)
Digital connection and digital networks	When the STB and TV are digitally connected and/or networked, as with IEEE 1394, there would be possibilities to steer the STB from the display or recording device.	(Nordman, 2005)
Remote control with additional functionalities	Additional IR codes of the TV-set are downloaded to the remote control of the STB. Thus, the STB remote control is given additional functionalities to set both the TV-set and the STB into standby.	BSkyB (Holliday, 2005) Sony (Evans, 2005)
Timed standby functio	The STB is set into standby once every 24 hours by a timer, e.g., during the night. Problems can arise when the STB is feeding some recording device.	(Dale, 2005c)

3.1.3.3 Between STB and the service provider

The third level of power management applies to external changes, in particular to the communication protocol between the service provider and the STB. Service providers basically determine in what state (standby-active / standby-passive) the STB will be. Particularly, the STB has to be in standby-active during those times when receiving data from the service provider. This data includes electronic programme guides, software updates, and data related to the conditional access system.

Since this kind of data is not broadcasted continuously, there is no need to keep the STB in standby-active (high) all the time. Rather, after finishing the download, the box could either (1) go into some standby-active (low) mode from where it could be woken up from an external signal or (2) go into standby-passive so that still some internal signal, for instance a timer, could put the box back into standby-active (high). There has been some discussion on the first possibility, to send the STB into such a low power mode where it is still sufficiently awake to detect a signal and switch to a higher mode to receive and process the data (Horowitz, 2005), but it hasn't been implemented in the field yet.

⁵³ reported by (Nordman, 2005)

3.1.4 Broadcasting standards

Opportunities for energy savings do theoretically exist by making use of principles being developed for battery-powered applications where low power consumption is a critical factor. One example is the DVB-H standard, which was exclusively developed for portable, handheld devices. Lower power consumption was the key driver for developing the standard (Steckel, 2005). Much of the power consumption of DVB-T devices derive from the fact, that the whole data of the multiplex stream has to be decoded before any one of the services, e.g. a TV programme can be accessed. In DVB-H, services are therefore not transmitted continuously in a parallel multiplex stream but one after the other in periodical bursts, which are buffered and read out of the buffer at the service data-rate. By making use of this so-called time slicing technique, the receiver can switch to a power-save mode during the intermediate time when other services are being transmitted. Depending on the ratio of on-time to power-save time of the tuner, energy savings of more than 90 % can be achieved (Kornfeld & Reimers, 2005). DVB-H tuners for portable applications might need as little as 20 Milliwatts (Dibcom, 2005). In Germany, the introduction of first commercial DVB-H services in selected regions is expected for 2006 (Steckel, 2005).

3.1.5 Relevant stakeholders to explore the energy savings potential

Figure 3.2 depicts an overview of the various opportunities for energy savings. The different options can be grouped on four different levels: (1) broadcasting standards, (2) the broadcasting platform, (3) the set-top box itself, and (4) local peripheral CE devices, for instance TV-sets and VCRs, to which the STB is connected. The number of stakeholders to be involved into the energy efficiency process can, depending on the intended measures, vary widely. For instance, changes in STB hardware design might only require action of the STB manufacturer and some contribution from the hardware supplier, whereas on the other hand some power management measures will require participation from a higher number of actors.

Level	Energy efficiency opportunities	Actors 1 st tier	Actors 2 nd tier
Broadcasting standard	- Time slicing as in DVB-H	Standardizing bodies	
Broadcasting platform	- Rethinking the need for continuous standby-active - timed wake-ups - low power ready modes	Service providers	Software suppliers Conditional access suppliers
Set-top box	- Optimized hardware, e.g. - Power supply unit - Power architecture - CPU - Front-end tuner - LNBS - Hard-off switch - Power management - Ergonomic user interfaces	Set-top box manufacturers	Hardware suppliers - Silicon suppliers - PSU suppliers - LNB suppliers Software suppliers
Local peripheral devices	- Power management features - to set STB into standby	Other CE manufacturers	Standardizing bodies

Figure 3.2: Energy efficiency opportunities and stakeholder to be involved

3.2 Introduction to relevant policy instruments and industry standards

3.2.1 EU Code of Conduct

The EU Code of Conduct on Energy Efficiency of Digital TV Service Systems is the key policy instrument that addresses energy efficiency of STBs and iDTVs on the EU-level. The European Commission has proposed to all companies dealing with digital television services (service providers, broadcasters, STB manufacturers, silicon manufacturers, etc.) to sign this voluntary agreement and commit themselves to meet the energy performance standards as set in the Code of Conduct (CoC). So far, six STB manufacturers and one major broadcaster have signed the agreement⁵⁴.

Since 2000, an open working group with representatives from industry, governments and independent experts meets about twice a year to consider new power consumption targets and further develop the agreement. The CoC comprises of general guiding principles with the aim to minimize power consumption of digital television services, systems and equipment, as well as of maximum permitted power use levels in different operating modes. Table 3.2 depicts the current and future standards for STBs and simple digital converters. Additional features on top of the basic configuration, for instance hard-disc drives, a modem or other interfaces allow for additional power consumption with a maximum limit of 15 Watts (EC, 2004a).

Table 3.2: Standards of the Code of Conduct on Energy Efficiency of Digital TV Service Systems⁵⁵

Equipment	Mode		Cable	Terrestrial	Satellite
Stand-alone STBs in the basic configuration	standby-passive	01/2003 – 12/2005	6.0 W	6.0 W	6.0 W
		01/2006 – 12/2007	3.0 W	3.0 W	3.0 W
	standby-active	01/2003 – 12/2005	9.0 W	9.0 W	9.0 W
		01/2006 – 12/2007	7.0 W	6.0 W	8.0 W
Simple digital TV converter boxes	standby-passive	01/2005 – 12/2005	2.0 W	2.0 W	2.0 W
		01/2006 – 12/2006	2.0 W	2.0 W	2.0 W
	on	01/2005 – 12/2005	11.0 W	11.0 W	14.0 W
		01/2006 – 12/2006	7.0 W	7.0 W*	10.0 W

* 9 W in case of double RF tuner

3.2.2 Labeling

Some eco- and energy-labels address the power consumption of STBs and iDTVs, though participation from manufacturers has been rather limited so far.

3.2.2.1 U.S. Energy Star

The U.S. Energy Star program has covered a broad range of STBs since January 2001; however, specifications were suspended in the beginning of 2005. Currently, new specifications only for digital terrestrial adapters for free-to air reception are under

⁵⁴ British Sky Broadcasting Ltd, Matsushita Electric (UK) Ltd, Nokia, Pace MicroTechnology PLC, Philips, Pioneer Europe N.V., Sony Europe

⁵⁵ (EC, 2004a)

development. Digital terrestrial adapters are not yet available in the US market, but are expected to experiences high sales after 2007, following the phase out of analog signal broadcasting (Hershberg, 2004). The reason for discontinuing the existing criteria was the lack of participation both in terms of product types qualified and the number of manufacturers with qualified products. Products haven't been designed to enter a low-power mode and for most models power consumption in standby modes was only slightly lower than in on-mode (Fanara, 2004). The EnergyStar programme of the European Community currently only covers office equipment but does not address STBs or other CE product groups (EC, 2005a).

3.2.2.2 EU eco-label

The EU eco-label only has criteria for iDTVs but not for STBs. The criteria addressing energy consumption require a clearly visible off-switch, maximum standby power levels of 1 Watt (passive) respectively 9 Watts (active), and compliance with an on-mode energy efficiency index (EC, 2002). Currently, one single television model is listed to carry the EU-eco label (EUEB, 2005).

3.2.2.3 GEEA energy label

The Group for Energy Efficient Appliances (GEEA) has set criteria that are similar to the EU Code of Conduct but are stricter for standby-passive. Similar to the Code of Conduct, additional features are also given additional power allowances. The GEEA-website currently lists one model (Pace DTVA-UK) with standby-passive consumption of 0.4 Watt that is compliant with the criteria (GEEA, 2005b), however according to the manufacturer the model is not on the market anymore (Dale, 2005c). On the other hand, the GEEA-website lists more than 1000 TV-models from 29 manufacturers that are entitled to carry the GEEA-label.

Table 3.3: Criteria of GEEA-label⁵⁶

STB		2005
Standby-passive (optional)		3 W
Standby-active	➤ terrestrial	7 W
	➤ satellite	6 W
	➤ cable	8 W
Digital to analogue converter ⁵⁷		2005
Standby-passive		2 W
On	➤ terrestrial	11 W
	➤ satellite	14 W
	➤ cable	11 W

3.2.2.4 Mandatory labelling

Within the EU, many household appliances are covered by the mandatory EU energy-labeling scheme. Here, the energy efficiency of the appliance is rated in classes from A to G on the label, A being the most energy efficient, G the least efficient. ICT and CE products are not covered by the scheme. A recent study

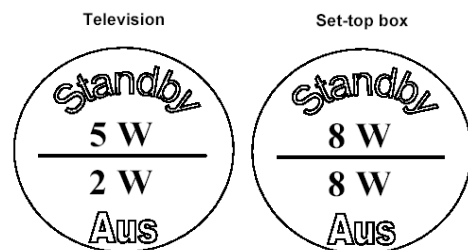


Figure 3.3: Proposed compulsory labels⁵⁸

⁵⁶ (GEEA, 2005a)

⁵⁷ Equipment for the reception of digital broadcast signals by satellite, cable and terrestrial with the main aim to convert these signals to analogue broadcast signals (GEEA, 2005a).

⁵⁸ (Schlomann et al., 2005)

commissioned by the German Federal Ministry of Economics and Labour and conducted by Schlomann et al. (2005) investigated the technical and legal possibilities of a compulsory labeling scheme that addresses standby consumption of electrical household and office appliances in Germany. The study proposes a label for a range of CE and ICT products, including set-top boxes. As depicted by Figure 3.3, the suggested label shall contain the power consumption in Watts in standby mode split into “standby” and “off”.

3.2.3 EuP-Directive

On 11 August 2005, the so-called EuP-Directive went into force; member states have to implement the Directive within 24 months. The Directive establishes a framework for the setting of eco-design requirements for energy-using products with the aim of ensuring the free movement of those products within the internal market. Eco-design is understood as “the integration of environmental aspects into product design with the aim of improving the environmental performance of the EuP throughout its whole life cycle” (EP, 2005).

The EuP-Directive is a framework directive, which will be accompanied by implementing measures that establish eco-design standards for targeted product groups. Implementing measures shall predominantly address those products with equivalent functionality but a wide disparity in the environmental performance available on the market. Products which have been identified as offering a high potential for cost-effective reduction of greenhouse gas emissions comprise heating and water heating equipment, electric motor systems, lighting, domestic appliances, office equipment, consumer electronics and heating ventilating air conditioning systems. In addition, the Directive requests a separate implementing measure that addresses energy consumption in standby or off-mode.

The level of eco-design requirements should be established on the basis of technical, economic and environmental analysis, not necessarily according to the best-performing products or technologies available on the market. The level of energy efficiency or consumption in use shall be set to minimize life-cycle costs to end-users. The Directive specifically encourages the integration of eco-design in small and medium-sized enterprises (SMEs). Such integration should be facilitated by providing relevant information through supporting networks and structures to SMEs (EP, 2005).

3.2.4 Other legislative activities

Outside Europe, California, Australia and China are working on minimum energy performance standards (MEPS). In December 2004, the California Energy Commission approved new appliance standards covering the sale of new products in California in 24 consumer and industrial product categories. From 1 January 2007, mandatory standards for digital adapters will become effective. Standards are 8 Watts in on-mode and 1 Watt in standby-passive (CEC, 2004). Australian regulators are also currently discussing the introduction of minimum energy performance standards for STBs. Power levels for simple digital adapters shall be based on the Californian standards and also include elements of the EU Code of Conduct. Standards shall also cover advanced STBs for subscription services and with recording functionalities, and apply from October 2006 (Ryan, 2005). Also China is preparing some energy labelling scheme and MEPS for a number of appliances, including STBs and digital adapters (Bertoldi, 2005a; Zhang, 2004).

3.2.5 Industry standards on eco-design

3.2.5.1 ECMA-341

In January 2004, Ecma International, the European association for standardizing information and communication systems published the 2nd version of its standard ECMA-314: "Environmental Design Considerations for Electronic Products" (ECMA, 2004). ECMA-341 provides pragmatic guidelines on how to integrate environmental aspects in the product design and development processes. Annex A includes a detailed checklist to be used by product designers to check whether their development process complies with the standard.

ECMA-341 emphasizes life-cycle thinking, addresses energy and resource consumption, material content and selection, chemical and noise emissions, and end-of-life management. Design guidelines on energy efficiency in the product use phase require, among others, the use of low power components and design options, efficient power supplies, power management, short start-up times from low power modes, easily accessible "hard-off" power switches and communication of energy features to the user. The effects of the improved design decisions should be quantified and communicated to the consumer to promote products with reduced life-cycle costs through lower power consumption. Table A-5 of the Appendix depicts energy related design recommendation as given in ECMA-341.

The standard also requires compatibility with applicable voluntary agreements aimed at improving energy efficiency of electrical and electronic equipment, e.g. EICTA's voluntary agreements on energy efficiency and standby power consumption of TV, DVD player, audio and video equipment or the EU Code of Conduct for external power supplies. Products belonging to product categories, which are covered by the international EnergyStar programme, should be compliant to the program requirements. ECMA-341 addresses all kinds of ICT and CE companies. Ecma claims that in particular, small and medium-sized enterprises (SMEs), which do not have their own dedicated environmental engineering expertise, will benefit from this standard (ECMA, 2005).

3.2.5.2 Other standardization work

Other standardizing bodies are also engaged in eco-design standards. In May 2005, the International Electrotechnical Commission (IEC) released the first edition of IEC Guide 114 "Environmentally conscious design - Integrating environmental aspects into design and development of electrotechnical products".

In the beginning of 2004, the European Commission has given a mandate to the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI) to work on a programme on standardization in the field of eco-design of energy-using products. The standards are expected to assist the realisation of the objectives of the EuP-Directive, and should assist manufacturers to comply with the requirements of the future implementing measures (EC, 2004c). In the framework of this mandate, technical committee TC 108 is currently working on an eco-design standard specifically for consumer electronic devices (Schoenmakers, 2005).

4 Drivers and barriers for the design of energy-efficient set-top boxes

This chapter presents the findings, which eventually led to answering the first research question:

What are the drivers and barriers for set-top box producers to reduce energy consumption of their products?

The chapter starts by presenting the findings of the empiric research work on the current situation of including energy efficiency into the development process of STBs from (1) a technical perspective and (2) from an organizational perspective. The section on technology describes the level of power savings achieved in the past, where these savings were realized, and where interviewees see the biggest potential for further savings. The following section presents the findings how energy efficient product design is integrated into the internal and external organizational structures of STB manufacturers.

Supported with information from Chapter 3, these findings are analyzed to find explanations for the current situation. Drivers and barriers for STB producers to reduce energy consumption of their products were found to exist at six different levels.

4.1 Technical perspective

Overall, STBs have become more energy efficient in recent years. Table 4.1 depicts that only a few years ago, power needs of the first digital STBs in standby were almost equal to the consumption when being in full operation. Due to better power management standby power could be reduced, but is still in the range of 60 - 70 % of on-mode levels. Overall, pro-active manufacturers did reduce power consumption in on-mode by 30 – 50 %. Components that contributed to these savings were the power supply and power architecture, the CPU, and LNBs for satellite receivers.

The power supply and subsequent power conversion stages are areas where several interviewed manufacturers paid attention to (Dale, 2005c; Eriksson, 2005; Saez, 2005). Switch mode power supplies were generally preferred to linear power supplies, and high efficient DC/DC regulators were preferred to lossy linear regulators. Some of the savings were achieved by new processor technology. CPU core voltages dropped over time and 1.2 Volts is now a common level (Dale, 2005c). On the other hand, the potential of lower core voltages has not entirely been used for power savings but for improvements in performance instead. For instance, older chip generations for DVB consumed 2.5 Watts at 80 MHz at a core supply voltage of 2.5 Volts. New chip sets were described to work at 1.8 Volts, which theoretically should entail power savings of around 50 %. However, CPU clock rate was more than doubled to 180 MHz and the processor still requires 2 Watts which is only a slight drop from the 2.5 Watts of the older generation (Eriksson, 2005). LNB circuits on satellite boxes were improved significantly, which helped to save 2 - 3 Watts (Dale, 2005c), though at additional material cost (Holliday, 2005).

Power management on the circuit board level was another area being addressed. Some engineers adapted CPU clock rates to levels being really necessary to maintain required functionalities (Eriksson, 2005). Another reason for power reductions in standby mode was to disable the MPEG decoder, some of the digital-analogue conversion on the audio and

video, and things like the modem whenever it is not required (Dale, 2005c). One manufacturer stated that their latest model allows the user to change the default settings in such a way that the 7-segment LED display switches off in standby. Hence, standby power can be brought down from 2.5 Watts to 1 Watt (Hörther, 2005). Thermal management and increased reliability were key motivations for many design engineers to reduce power consumption (Dale, 2005c; Eriksson, 2005; Hörther, 2005; Janson, 2005; Sagebiel, 2005).

Many representatives stated that power efficient STB design can only be realized at a higher cost (Dale, 2005c; Eriksson, 2005; Evans, 2005; Janson, 2005; Schoenmakers, 2005). Power efficient DC/DC regulators, LNBS and other components were described to be more expensive than their more inefficient counterparts. Extra costs can also arise from additional components, for instance, an added microprocessor which is required to support low standby levels (Dale, 2005c).

Table 4.1: Power savings achieved by pro-active organizations

Source	Year	Standby		On-mode
		passive [W]	active [W]	[W]
BSkyB (Satellite-STBs) ⁵⁹	“early” STBs		“almost” 23	23
	2004		8.5	12
Pace Micro Technology (satellite STBs with HDD) ⁶⁰	2002		33	34
	2004		15	23
Pace Micro Technology (satellite STBs)	1999		14	15
	2004		8	10
EU Code of Conduct (cable, satellite & terrestrial STBs) ⁶¹	2001	8	13	19
	2004	3.5	9	10.5
Technisat Digital GmbH (DVB-S receiver) ⁶²	2001/2002	8.3		
	2005	1		

Representatives from STB manufacturers were asked where they see further energy saving opportunities. The fact that many users apparently seldom or never put their STB into standby is well known in the industry. The energy saving potential has been described as significant and different automatic solutions are under discussion. One suggested option was to automatically set the STB into standby with a timer during the night, though, problems might occur when the box is feeding a VCR which is timed to record some program during the night (Dale, 2005c). Another solution under discussion is to put some extra functionality into the STB’s remote control which would enable to control both the TV and the STB and to put both devices into standby at the push of only one button (Evans, 2005; Holliday, 2005). The problem here is the extra costs for the infrared codes for all the different TV products (Dale, 2005c). Some design engineers have considered using the SCART cable to

⁵⁹ (Holliday, 2004)

⁶⁰ (Dale, 2005b)

⁶¹ (Siderius, 2005a)

⁶² (Hörther, 2005)

send a signal from the TV-set to the STB when being put into standby. However, due to the lack of standards in this area, no appropriate solution has been realized yet.

The second big potential for further energy savings being named are low power or sleep modes. Currently, many service providers are reported to require STBs to be continuously in standby-active mode (Dale, 2005c). In standby-active, the STB has to be tuned all the time to look whether there is anything to see to take action on. Timed downloads of EPG data and software updates seem to be less problematic. German manufacturer Technisat applies a technique where the STB is woken up periodically by an internal timer, downloads EPG and other data, and then goes back into the standby-passive mode (Hörther, 2005). German manufacturers Grundig and Kathrein equip many of their advanced STBs with a hard switch-off at the front panel, which enables the user to disconnect the box from the mains.

4.2 Organizational perspective

As illustrated in the previous section, some organizations considerably reduced power consumption of their products. This section presents the findings of the field research work how energy efficient product design is integrated into the internal and external⁶³ organizational structures of STB manufacturers. The intention for this was to organize, but not to test, the findings according to a structure suggested by Johansson (2002), who clustered factors for the successful integration of eco-design in product development around six areas of concern. Not all success factors suggested by Johansson (2002) were covered during the research⁶⁴. Table 4.2 depicts those factors that will be discussed in the following sections.

4.2.1 Management

Commitment and support have been described as crucial factors for the integration of eco-design in product development (Johansson, 2002). One indicator for the existence of management support are guidelines on Corporate Social Responsibility (CSR) and an environmental management system (EMS). Many of the bigger transnational CE manufacturers, such as Philips, Nokia, Sony, Pioneers, Matsushita (Panasonic) and Pioneer have an environmental policy and maintain an EMS. Some service providers such as BSkyB in the UK and Canal Digital in Sweden also follow CSR guidelines, however the overall perception is that service providers are less active in this area than producers. Among smaller manufacturers, the establishment of CSR principles and environmental management systems were found to be less common.

Environmental management systems such as ISO 14001 generally require clear environmental goals, which in terms of the product's power consumption were observed in some cases. For instance, Sony's targets for standby power consumption are less than 1 Watt, as well as a 30 % improvement in overall energy consumption over a 5-year period (Evans, 2005). UK-based STB manufacturer Pace has set the target, that at least 75 % of their boxes developed for supply outside the US market shall be compliant with the EU Code of Conduct (Pace, 2004). Smaller producers generally didn't establish targets and design engineers had more like a "we do what we can" approach (Eriksson, 2005).

⁶³ External structures are, for instance, the relationship to suppliers, customers, and legislators.

⁶⁴ Reasons for this include limitations of the research approach (interviews via phone, sometimes under time constraints), but also that certain factors might not have been relevant for the design of energy-efficient set-top boxes.

Table 4.2: Discussed success factors for integrating energy efficiency in STB product development ⁶⁵

Area of concern	Success factors
Management	<ul style="list-style-type: none"> ➤ Commitment and support are provided. ➤ Clear environmental goals are established. ➤ The environmental considerations are addressed as business issues. ➤ Not only the operational dimension of eco-design should be considered, but also the strategic dimension. ➤ Environmental issues are included when establishing a company's technology strategy.
Customer relationships	<ul style="list-style-type: none"> ➤ A strong customer focus is adopted. ➤ Companies train their customers in environmental issues.
Supplier relationships	<ul style="list-style-type: none"> ➤ Close supplier relationships are established.
Development process	<ul style="list-style-type: none"> ➤ Environmental issues are considered at the very beginning of the product development process and are integrated into the conventional product development process. ➤ Eco-design is performed in cross-functional teams.
Competence	<ul style="list-style-type: none"> ➤ Education and training are provided to the product development personnel. ➤ An environmental specialist supports the development activities. ➤ Examples of good design solutions are utilized.
Motivation	<ul style="list-style-type: none"> ➤ A new mindset emphasizing the importance of the environmental considerations is established.

Business issues were, at least for some manufacturers a key motive to actively work to reduce power consumption of their products. This applied in particular for manufacturers whose business customers (service providers) included energy efficiency into their procurement specifications (Dale, 2005c; Holliday, 2005; Schoenmakers, 2005). Energy efficiency as a business issue in the private consumer market is less relevant. However, some exceptions were observed in Germany, where sales managers stated that power efficiency is a criterion for some end-consumers (Kön, 2005; Löhmann, 2005).

Strategic issues seem to be an important driving force, in particular for larger CE manufacturers, to be engaged in “green” issues. In the case of STBs and iDTVs, the big multinational brands are signatory members to the EU Code of Conduct on Energy Efficiency on Digital TV Service Systems. Being asked for their motives to participate in this voluntary agreement, nearly all stated the importance to be involved in the discussion process with the European Commission. The large manufacturers understood, if no company would sign the agreement, other policy measures with potentially higher compliance costs would be implemented (Bertoldi, 2005a). A green image and being perceived as pro-active in environmental matters were further reasons for CE manufacturers to include environmental aspects in business operations which go further than only compliance with legal regulations (Bertoldi, 2005a; Evans, 2005).

⁶⁵ Selected and adapted from (Johansson, 2002).

Johansson (2002) suggested that environmental issues shall be included when establishing a company's technology strategy. During the research, no information could be attained on this issue, whether energy efficiency was a criterion when establishing the "technology strategy". The general author's perception is, that environmental issues have not significantly changed the technology strategy of STB producers and service providers, but rather existing technologies were improved. It remains to be discussed, what a change in "technology strategy" really means for the STB industry.

4.2.2 Customer relationships

This section presents the findings on whether manufacturers in the private consumer market adopted a strong customer focus in terms of marketing, information, communication, and ergonomic product design that facilitates energy savings.

Generally, energy-efficient STBs - and basically all energy-efficient products - are advantageous from a customer perspective as the operating costs are likely to be lower than for inefficient models. Additionally, there might be co-benefits as an energy-efficient electronic device is likely to be more silent, more reliable and might attain a longer lifetime. However, interviews with producers, service providers and consumer agencies brought the result that the huge majority of consumers are not aware of these benefits.

Moreover, when faced with standby power figures of 5 or 10 Watts, users do generally not perceive these levels as problematic. Power levels of 1500 or 2000 Watts are frequently used in product marketing to emphasize benefits of high wattage electric kettles, microwave ovens and similar equipment where high power requirements are actually transformed into some useful service. In the field of consumer electronics, in particular for audio systems, high wattages can also be attributed with high performance (Schlomann et al., 2005). In the context of 2000 Watts, 5 or 10 Watts seem to be negligible. What is generally overseen is that these standby wattages occur for 20 or more hours every day and that consequently the final energy bill can be a multiple to the 2000 Watts electric kettle, which only might run a few minutes a day. The reality described by representatives of STB manufacturers is that the purchase criteria for CE products are mainly performance, price and style (Evans, 2005). The market, in particular for low-end STBs is very competitive, and users are not willing to pay more for energy efficient boxes, as they are not aware of their benefits.

There are further barriers when it comes to the manageability of low power features. Some STB-models on the market have quite low standby consumption in the range of 1 Watt. However, the standby button on the remote control has two functions, and the box can only be put into standby by pushing the button for several seconds⁶⁶. It has also been reported that for some models the standby mode can only be reached via the menu (Bertoldi, 2005a), which certainly prevents users of making full use of this feature. Other models on the market have a hard-off switch, which enables the user to disconnect the STB entirely from the mains, though in many cases this hard-off switch is placed at the backside of the box.

Johansson (2002) suggested that "companies shall train their customers in environmental issues". The status quo is that the information gap among the majority of consumers is well known among STB manufacturers. Overall very little is done to fill this gap with relevant information. The author scanned a number of instruction manuals⁶⁷ to investigate the status

⁶⁶ Instruction handbook, Nokia Mediamaster 150T

⁶⁷ see Appendix A-3

whether and to what extent issues related to power consumption are communicated to the user. The overall picture is that relatively little priority has been given to this issue. Information on energy consumption is often displayed in small print, dispersed throughout the handbook and at locations most readers never reach. Many, but not all instruction handbooks list on-mode and standby power consumption in the technical datasheet at the end of the handbook. Some handbooks contain in the beginning instructions to physically disconnect the STB during longer periods of non-use. The standby button is generally explained, though handbooks do ignore the fact that a STB gives - in opposition to a TV-set – very little feedback to the user when not being put into standby. Many models only might change the color of a small LED indicator lamp. No handbook could be found, where for instance the negative consequences of not putting the STB into standby are explained in terms of added annual consumption, extra costs and environmental implications.

Those companies that maintain an environmental management system generally also publish some CSR or environmental report on an annual basis. Here, progress in reducing the environmental impact of the organization's products and services is generally displayed in extensive tables and with the example of selected products. Similar corporate information is given on companies' websites. However, these information channels don't reach the broad mass of customers.

4.2.3 Supplier relationships

The importance of close supplier relationships for the energy efficiency process has been described as crucial to support power management features. Support is needed both from hardware and software suppliers, though it has been described as problematic that the different layers of software (drivers, middleware, user interface) come from different third party suppliers which have been described as difficult to involve to put the required power management functionality in. Hardware suppliers are equally important, but they have been described as easier to involve (Dale, 2005c).

4.2.4 Development process

Several of those companies being interviewed included targets on energy, in particular standby consumption into the initial specification list, which then provides the basis for further development stages (Dale, 2005c; Evans, 2005; Hörther, 2005; Schoenmakers, 2005). Allocating power budgets to the individual circuit blocks refines these specifications. Hence, energy consumption is considered at the very beginning of the product development and become an integrated part of the process in those cases observed.

Eco-design literature emphasizes the relevance of cross-functional teams to support the integration of environmental issues into product design. Cross-functional teams comprise of representatives from R&D, marketing, production, and other departments. Only limited information could be collected on this area as part of the research work. A few interviewees indicated that communication between the R&D and the marketing and sales staff is limited. These communication barriers were not only explained with a strict organizational separation into technical and commercial departments (Sagebiel, 2005) but also with spatial distances as, for instance, R&D and production were at a different location than the companies headquarters with the sales department (Hörther, 2005). However, no provable picture could be gained on this issue.

4.2.5 Competence

The level if and to what extent education and training on good design solutions are provided to the product development staff could not be established during the research. It is likely that staff of those organizations that participate in the biannual meetings of the working group of EU Code of Conduct also use this forum for experience and information sharing and, since also hardware suppliers participate in the meetings, gain access to the latest trends in silicon technology.

The existence of an energy specialist who supports the development activities was observed in the case of Pace Micro Technology. Here, a small group with two engineers is involved in every hardware design project to provide the power solution. Further tasks of the group are to promote energy efficiency in the products and to drive software solutions that enable power management (Dale, 2005c). Larger CE manufacturers general have special staff, such as environmental or sustainability managers (Evans, 2005; Schoenmakers, 2005).

Concerning the question whether examples of good design solutions are utilized, most producers agreed upon, that the power supply unit, the power distribution chain and the microprocessor were the components where they first looked into first to achieve power savings. Other measures were more controversial, for instance, whether a hard-switch off is practical for set-top boxes, see Section 4.1.

4.2.6 Motivation

Johansson's (2002) pointed out that a "new mindset emphasizing the importance of environmental considerations" is a success factor for the integration of eco-design into product development. For the purpose of the study, this factor is loosely interpreted to be indicated by the level of awareness and source of motivation for considering energy-efficiency as an important part of the work of individuals. Both, the level of awareness and reasons for being motivated to deal with this issue varied widely between those individuals being interviewed in different organizations. Generally, technicians showed a higher awareness than sales staff. A rather coherent pattern was found on the source of motivation since this seemed to depend very much on the position that interviewees filled. Engineers in research and development considered the design of energy-efficient products to be important from the perspective of technical co-benefits, such as reduced heat dissipation and reliability. Environmental managers seemed to worry more about the companies' green image and potential legislation that might be imposed one day. And sales staff seems to depend on customer requests (or the lack of those) for being or not being interested and informed on power consumption aspects of set-top boxes.

4.3 Drivers and Barriers

Supported with information from Chapter 2 and 3, the finding displayed in 4.1 and 4.2 are analyzed to find explanations for the current situation concerning the activities of STB producers to reduce power consumption of their products. As shown in Table 4.3, drivers and barriers were found to exist at the technical level, the corporate level, the governmental level, the consumer level, the financial level, and at the level of industry standards.

Table 4.3: Current drivers and barriers affecting the development of energy-efficient STBs, as well as their operation in an energy-efficient way.

Level	Drivers	Barriers
Technical level	<ul style="list-style-type: none"> ➤ Silicon developments ➤ Technical co-benefits 	<ul style="list-style-type: none"> ➤ Physical system modularisation ➤ More features / higher data rates
Corporate level	<ul style="list-style-type: none"> ➤ CSR / EMS ➤ B2B procurement 	<ul style="list-style-type: none"> ➤ Information and awareness deficits ➤ Demand for standby-active modes
Governmental level	<ul style="list-style-type: none"> ➤ Code of Conduct ➤ (Regulation) 	
Consumer level	<ul style="list-style-type: none"> ➤ Consumer information 	<ul style="list-style-type: none"> ➤ Information and awareness deficits
Financial level		<ul style="list-style-type: none"> ➤ Additional cost
Standardization level		<ul style="list-style-type: none"> ➤ DVB-Standard (T,C,S) ➤ Lacking power management standards

4.3.1 Technical level

4.3.1.1 Developments in silicon technology

Generally, technology development has been a key driver for more power efficient STB design. As described in Section 3.1.1, more power efficient silicon, switch-mode power supplies and higher integration help to attain power savings. Moore's Law, saying that the complexity of integrated circuits, with respect to minimum component cost doubles every 18 - 24 months, can describe developments in silicon technology. This development entailed that chip densities became higher⁶⁸ and core voltage had dropped which was beneficial from an energy perspective.

4.3.1.2 Technical co-benefits

Energy efficiency of consumer electronics is not only a matter of environmental protection and saving finite resources. Several design engineers highlighted the technical co-benefits of energy efficient product design: thermal management becomes easier, components for active or passive cooling can be omitted, which saves costs and reduces weight. Product reliability and lifetime are likely to increase at temperatures that are more moderate. Actually, many engineers stated that reliability and quality were the initial driving forces to pay attention to

⁶⁸ "As of 2004, current PC processors are fabricated at the 130 and 90 nm levels, with 65 nm chips being announced by the end of 2005. A decade ago, chips were built at a 500 nm level" (Wikipedia, 2005).

power consumption, long before discussions on the environment or security of energy supply came up.

4.3.1.3 Physical system modularization

For decades, the TV tuner was physically integrated into the same chassis that hosted the actual display functions. However, this changed with the upcoming of satellite television where an additional receiver was required. In the past, receiver and STB technology developed a lot faster than display technology, so consumers rather preferred to buy two separate devices. A similar trend is currently observed in the transition period of the digital terrestrial phase-out. Most consumers buy a STB as their existing TV-sets are still fully functional and have not reached their end-of life phase.

This modularization entails two implications on energy consumption. First, instead of one power supply, two separate units with overall higher power losses are required. Secondly, and most likely the much bigger problem is the fact that many users do not put their STB into standby when they put their TV set into standby. Automatic solutions for this have been discussed in Section 2.4.1 and 2.4.3.2, but are rarely used so far due to lacking standards that would enable power management between peripheral CE devices.

However, the fundamental cause of this problem is the physical separation of the receiver function from the display device. The physical integration of two or more function into one device is generally beneficial in terms of energy efficiency. Only one signal from one remote control is required to set both functional groups into standby. IDTVs are examples for this physical integration. So far, the choice of iDTVs is somehow limited and models tend to be in the upper price range. On the other hand, display technologies currently undergo a major technology shift as LCD and plasma-screens are developing rapidly and become more affordable for many consumers.

4.3.1.4 More features & higher data rates

More features generally drive power consumption, both in standby and in operation modes. The EU Code of Conduct contains a mechanism that for extra features – being added on to the STB in the basic configuration – permits additional power allowances that may be added to the maximum standby power consumption targets. Table 4.4 depicts the extra standby power allowances for different types of interfaces and other features.

Further trends that will have implications on future STB designs are (1) *High Definition Television (HDTV)*, (2) *Multi-room Delivery* and (3) *Networked Homes*. High Definition Television (HDTV) is already established in the US and is developing in Europe. Around 4.6 million

Table 4.4: Additional power allowances in the EU Code of Conduct ⁶⁹

Feature	Additional power allowance
Internal HDD	2.2 W
IEEE1394 interface	0.8 W
Ethernet interface 100Mbit	0.4 W
Wireless interface	0.7 W
Each serial USB interface	0.3 W
Home automation interface	0.4 W
ADSL modem	2.0 W
Cable modem	0.7 W
Additional LNB feed	1.3 W
Additional tuner/demodulator	2.0 W
Powered remote IR receiver	0.25 W

⁶⁹ (EC, 2004a)

Europeans are expected to use HDTV by 2008 (Datamonitor, 2004). HDTV will push STB power consumption as, e.g. the new DVB-S2 standard and higher compression techniques such as MPEG4 will require more power as the amounts of digital processing increase (Dale, 2005c). The consequence is that, for instance, BSkyB's new high definition STB will not be able to meet the standards of the Code of Conduct (Holliday, 2005). In addition, HDTV displays consume significantly more energy than the current PAL standard does.

Multi-room delivery entails that one central STB supplies a number of display devices, which are spread throughout the home. A remotely accessed box is less likely to be put into standby manually and thus power management might be required, which however, can be complex. On the other hand, one single STB with several signal outputs is generally more efficient than if every display device was supplied by its own box (Dale, 2005a). Future networked homes might even be more complex and power management standards will be required to operate the network in an energy efficient manner.

4.3.2 Corporate level

4.3.2.1 Corporate Social Responsibility & Environmental Management Systems

Corporate Social Responsibility and / or environmental management systems are parallel drivers to the EU Code of Conduct. Primarily, larger transnational CE manufacturers with well-known brands have implemented CSR principles and maintain an EMS. Public pressure, the desire for a green image, and risk management were key motives to implement CSR policies. In some cases, the EMS was introduced some years later than the signatory to the EU Code of Conduct was. It has also been claimed that CSR helped to get resources for energy efficient product design (Holliday, 2005). Smaller STB manufacturers generally didn't maintain a certified EMS.

4.3.2.2 Business-to-business procurement

Business-to-business procurement where the service provider requires certain energy standards is a potential driver for STB manufacturers to engage themselves in energy efficiency. Signatory membership in the EU Code of Conduct (CoC) commits service providers to request their STB suppliers to comply with the standards set in the CoC. So far, with BSkyB only one service provider has signed the agreement. Suppliers to BSkyB are not required to be a signatory member of the CoC, but the models they deliver have to comply with the standards of the CoC (Holliday, 2005). According to company representatives and experts, a small number of other service providers in Germany, France and Italy apply the procurement principles of the CoC but have not signed the agreement. In Sweden, among the four service providers for digital satellite and digital cable services, Canal Digital (Hultgren, 2005) and Viasat, respectively its mother company Modern Times Group (Wahlberg, 2005) include the standards of the Code of Conduct into their procurement specifications.

It could not be established during the research whether any STB manufacturer really changed their STB design in response to requirements from service providers in terms of power consumption. However, Ken Dale of Pace stated that BSkyB's procurement specifications on power efficiency are advantageous for Pace as all competitors also have to meet the same criteria (Dale, 2005c).

4.3.2.3 Information and awareness deficits

The level of awareness whether power consumption of STBs is perceived as a problem varies widely among manufacturers and service providers being interviewed. Generally speaking, bigger manufacturers are better informed than smaller ones, and with some exceptions European and Japanese-based manufacturers have a higher awareness than organizations based in Korean and China. Knowledge on existing and potential future policy instruments is higher in bigger organizations, which generally employ some environmental expert. Smaller producers sometimes have superficially heard of the EU Code of Conduct, but are not familiar with details. One service provider stated that the problem is already addressed by “some kind of EU regulation” and “we expected that all STB manufacturers comply with this regulation”.

Technical staff is generally better informed than staff working in sales. The latter one often downplay STB power needs by referring to “all these other energy consuming” devices in our households and “10 Watts is not really much”. There are also contradictory opinions on various technical options to save power. For instance, some manufacturers consider a hard-off switch as not feasible for the reason of software updates, whereas others haven’t got a problem with equipping most of their STBs with this feature.

4.3.2.4 Demand for standby-active modes

The demand for standby-active functionalities is a key barrier to further reduce power consumption. STB manufacturers are bound to specifications set up by service providers, with many of them reported to require full standby-active functionalities all the time. Service providers have been described as very reluctant to change these requirements for reasons of intellectual property rights security (Schoenmakers, 2005). Managing broadcasting capacities to reduce bandwidth costs has been described as another reason. If the box was only able to receive external data in a specific time window, service providers couldn’t schedule their broadcasting as efficiently, which would cost bandwidth. Bandwidth, particularly for satellite platforms, has been described as very costly (Siderius, 2005b). On the other hand, other providers of subscription services stated that they don’t require a continuous standby-active mode (Andersson, 2005; Hultgren, 2005).

4.3.3 Governmental level

4.3.3.1 EU Code of Conduct

Though the EU Code of Conduct on Energy Efficiency of Digital TV Service Systems is a mutual agreement between business organizations and the European Commission, it has been placed here under the governmental level as the CoC was initiated by the Commission (Bertoldi, 2005a). For those organizations that had signed to the CoC, this voluntary agreement is considered as a key driver to give higher priority to an energy efficient product design, respectively to include energy efficiency into procurement specifications in the case of service providers.

For 2004, five manufacturers reported 46 models out of which 80 % met the power standards of the CoC (Siderius, 2005a). Little information is available on the market share of participating manufacturers. Coverage of simple digital converters is very low. For set-top boxes, coverage of the CoC is reported to be in the medium to high range, in particular in the backdrop that some other larger producers have adopted the CoC standards, though they did not sign the agreement (Bertoldi, 2005a).

Industry generally expressed satisfaction with the Code of Conduct, as the technical framework is flexible, doesn't preclude additional features, and allows the inclusion of new developments, technologies and functions in a fast developing market. Power standards were described as technical achievable though the additional costs for power efficient components were considered as problematic. In opposition to potential regulatory measures, industry appreciated the Code of Conduct as a stakeholder forum to participate and to share information with the European Commission. The European Commission attempts to further increase participation in the Code of Conduct (Bertoldi, 2005a).

4.3.3.2 Regulation

Regulation or minimum energy performance standards haven't been observed as a driver yet. However, the risk of potential regulation encouraged producers to participate in the Code of Conduct (Bertoldi, 2005a; Schoenmakers, 2005). Some manufacturers expect future legislation from the EuP-Directive that might address STB energy consumption, though at the moment nothing is clear on potential implementing measures that might derive from the Directive one day.

4.3.4 Consumer level

Drivers and barriers at the consumer level are very much linked to information and awareness issues. According to the majority of experts being asked, standby power in general, and STB power in particular are not considered as a problem among the large majority of consumers. For consumers electronics, price, performance and style are the key purchase criteria. In opposition to some white goods such as refrigerators, power consumption of CE-products is not a criterion for end-users.

However, there are some regional differences among the UK, Sweden and Germany. Some companies producing and selling to the German market stated that end-consumers have, by international standards, a relatively high interest in power consumption⁷⁰. The reason for this could lie in a number of information and awareness rising campaigns. Germany's leading independent consumer organization *Stiftung Warentest* has been pointed out by several companies for being the source of information for this (Löhmann, 2005; Saez, 2005). *Stiftung Warentest* regularly conducts product test of digital reception equipment und publishes results in its monthly magazine *test*. In recent years, test reports on STBs usually contained consumption figures of standby-mode and in some issues of the operation mode. A poor performance in power consumption may lead to downgrading. In one issue, the high power consumption was even a headline topic⁷¹. Other popular journals such as *Audio-Video-Foto Bild* and *PC Welt*⁷² have also recently addressed the standby problem in feature articles. *Audio-Video-Foto Bild* even developed in corporation with "Aktion No-Energy"⁷³ its own energy label, which is awarded to products having low consumption in standby, respectively no consumption when entirely switched off. Governmental initiatives include the standby campaign of the Federal German Energy Agency (DENA) which also attempts to involve

⁷⁰ see Section 4.2.2 for reference

⁷¹ (Stiftung-Warentest, 2003)

⁷² (AVFB, 2004; Kniffler, 2005)

⁷³ www.no-e.de

retailers and other multipliers, and the “aus.wirklich aus” (off.really off) campaign of the Schleswig Holstein energy saving trust.

Representatives from Swedish STB manufacturers and Swedish service providers stated that their customers don't have any interest in the power consumption of CE products. A study conducted by Lindén, Carlsson Kanyama, & Eriksson (2003) investigated the awareness and attitudes of Swedish consumers towards energy use of CE and ICT devices. The study included a survey among 600 households, as well as 11 qualitative interviews. One result was for instance that 63 % of households participating in the survey stated that they switch off their TV-set with a hard-switch. The motives for doing so were partly for being used to do it, partly to lower the risk for fire, and partly to save electricity and money. 72 % of households had heard about standby functionalities, though there were uncertainties which devices use standby power and people underestimated the share of standby consumption as part of total household electricity consumption. Generally, households expressed the wish for more information on this issue and the implications of behavioral change on energy consumption and energy costs (Lindén et al., 2003). In another survey, conducted by the Swedish Consumer Agency in 2003, a sample of 1000 people was asked to estimate the annual cost of an average household that arises due to standby power consumption. Half of the sample couldn't give an answer, about 30 % estimated the cost to be between 0 - 500 SEK and 20 % to be more than 500 SEK per year (Holst, 2005). The actual cost is estimated to be around 500 SEK/yr.

4.3.5 Financial level

“The price pressure on consumer electronic products is enormous”⁷⁴

“The market for STBs is very, very competitive.”⁷⁵

These two citations stated by industry representatives describe the situation as many interviewed STB manufacturers declared it. The additional (material) cost is considered to be a key barrier for more power efficient product design and industry representatives emphasized the importance to always balance the achievable savings with the extra cost. In particular, the market for low-end STBs has been described as extremely competitive. In the UK, prices for simple STBs start at around 30 pounds, in Sweden terrestrial STBs are available for around 600 SEK. The additional material cost of 1-2 US\$ for more power efficient STB features⁷⁶ are relative moderate, but they multiply in the distribution chain and are difficult to accomplish in this competitive market.

⁷⁴ (Janson, 2005)

⁷⁵ (Evans, 2005)

⁷⁶ (Dale, 2005c)

4.3.6 Standardization level

4.3.6.1 Lacking power management standards

The lack of standards that would enable power management of physically separated CE devices is a key barrier why no STB manufacturer has come up with a satisfactory solution to automatically put the STB into standby for those periods when the TV-set or any other display device is not in operation. Some design engineers stated that they have thought about different possibilities, but due to the lack of relevant standards, these solutions would have been either too costly or too ineffective as they would not be compliant with the products of other manufacturers.

4.3.6.2 DVB-standards

DVB-T is in the process of becoming a globally used standard for digital terrestrial television broadcasting. As previously introduced in Section 3.1.4, the DVB-T broadcasting standard is power intensive in the tuner and the demodulator circuits of the set-top box. With DVB-T, the entire broadband high data stream has to be decoded, even though only one channel out of four to six is used at a time. Hence, DVB-T sets a lower barrier for power reductions in the front-end part.

4.4 Concluding remarks

In recent years, producers could attain significant power savings and most of the action took place at the level of the STB itself. The level of awareness and action on energy issues was found to differ widely between different manufacturers. Pro-active manufacturers were driven by the EU Code of Conduct and CSR/EMS from the management side, co-benefits from the technology side, as well as B2B procurement and to some extent private requests from the demand side. Trends in silicon development were helpful to achieve the savings. From an organizational point of view, progress on the level of the STB was relatively easy to achieve as, from the perspective of an STB manufacturer relevant stakeholders that had to be involved, were on the supply side. Unsurprisingly, savings were first realized for those measures with the best savings-to-cost ratio. Opportunities for further savings do exist from a technical perspective, but are constrained by the extra costs, which are difficult to justify in this competitive market.

Opportunities on other levels have been rarely realized so far. Though some STB manufacturers consider solutions to automatically put the STB into standby, overall, little has been brought into the market yet. The third level for energy efficiency opportunities covers the broadcasting platform. Here, STB manufacturers have little power to drive better power management by themselves, since they are bound to specifications set by service providers and broadcasters.

Some drivers and barriers to energy efficient STB design only address certain STB categories. For instance, business-to-business procurement only affects STBs with more advanced features such as conditional access capabilities. On the other hand, information deficits and the additional costs are much stronger barriers for cheap low-end boxes.

5 Discussion of approaches for industry action and policy intervention

This chapter presents the findings that led to answering the second research question:

How can industry act and policy makers intervene to mitigate the impact on energy consumption that arises from the digitization of television broadcasting?

The chapter starts by analyzing the drivers and barriers, as presented in the previous chapter, on the need for action to change them. Factors are discussed on the issue how they presumably will develop if no action is taken, and if action is taken, what time horizons are realistic. Subsequently, different approaches for industry action and policy intervention to change drivers and barriers are discussed, mainly based on the experience of existing action. Next, it is discussed to what extent the findings of this study on set-top boxes can be relevant and applicable for other CE and ICT products. The chapter concludes with a brief discussion on the environmental consequences of industry standards and whether preventative action should be taken into this direction.

5.1 The need for action

This section analyses the need and potential for policy makers and industry to act with the objective to positively change the drivers and barriers. Positive change is understood as strengthening the existing drivers and weakening or overcoming the existing barriers. Action is understood as both industry action and policy intervention. Following, drivers and barriers are analysed and discussed on (1) their potential to be changed by action and how some factors are rather driven by technology and market demands, (2) the time horizons other drivers and barriers potentially could be changed through action, and (3) synergy effects between drivers and barriers.

Table 5.1 depicts how drivers and barriers were distinguished in four groups. Some drivers and barriers have a very low potential to be changed by action, whereas others could be changed in a short, medium or long term perspective.

Table 5.1: Time horizons to change drivers and barriers through intervention

Time horizon	Drivers	Barriers
Low potential for change through action	<ul style="list-style-type: none"> ➤ Silicon developments ➤ Technical co-benefits 	<ul style="list-style-type: none"> ➤ Physical system modularisation ➤ More features / higher data rates
Short term	<ul style="list-style-type: none"> ➤ Code of Conduct ➤ B2B procurement ➤ Consumer information 	<ul style="list-style-type: none"> ➤ Information and awareness deficits among producers and service providers
Medium term	<ul style="list-style-type: none"> ➤ Regulation ➤ CSR / EMS 	<ul style="list-style-type: none"> ➤ Information and awareness deficits among end-consumers ➤ Demand for standby-active
Long term		<ul style="list-style-type: none"> ➤ DVB-standard (T,C,S) ➤ Lacking power management standards ➤ Additional cost (?)

5.1.1 Low potential for change through action

Some of the technical drivers and barriers are more structural and for that reason difficult to change through, for instance, policy intervention. This does not mean that these drivers and barriers do not change, quite the contrary, developments in silicon technology as well as more features and higher data rates are factors that change rapidly, driven by technology trends and market demand.

The trend in silicon technology with higher transistor densities and operating voltages being reduced is expected to continue. With every technology generation or also called technology node⁷⁷, line width is reduced. A 1993 Pentium 1 processor still had a 800nm architecture⁷⁸. As of 2004, chips were produced at 90nm and are expected to drop with the next technology nodes to 65nm by 2007, 45nm by 2010 and 32nm by 2013 (ITRS, 2003). The operating voltage decreases 20 % per technology node and consequently power consumption per service unit will continue to drop in the foreseeable future.

On the other hand, the rapid development in the semiconductor industry drove demand and opened up new functionalities to the ICT and CE industry. The functionality per chip historically doubled every 1.5–2 years⁷⁹ and the cost per function was reduced by an average 25–30% each year. There is no indication that “Moore’s Law” will stop for the next few chip generations, and this is likely to drive the demand for more features and higher data rates also in the future. To summarize, on one hand power consumption per service unit dropped significantly in the past, on the other hand more functionality combined with falling prices drastically drove demand for ICT products. From an energy perspective, the growing stock of ICT and CE equipment with more functionality outweighed the savings per service unit by far. In the past ICT and CE energy consumption has been growing, a trend which is expected to continue to some extent⁸⁰.

Technical co-benefits are already a strong driver for engineers to design their products with energy efficiency in mind. The strongest technical co-benefits are thermal management and reliability. These drivers will remain, but might become less important as standby power levels are gradually reduced. For portable devices, the need for mobility can be a very powerful driver for energy efficiency as small battery size, low weight and long usage time are critical design factors. Mobile phones and laptops are typical examples where power consumption could be reduced thanks to these drivers. In the field of personal computers, energy efficiency features originally being developed for laptops are also increasingly used for stationary desktop computers. It is doubtful whether such a transfer of energy efficiency features from portable to stationary devices will also happen for digital television reception equipment. The reason is that portable handheld devices, for reasons of energy efficiency, will use a different broadcasting standard (e.g. DVB-H) than stationary devices. Only if principles of DVB-H are transferred to the DVB-T (and possibly DVB-S and DVB-C) standard, stationary devices are likely to benefit from portable devices in terms of energy savings.

⁷⁷ As defined by the International Technology Roadmap for Semiconductors, the technology node parameter represents the minimum half-pitch of a semiconductor custom-layout. For each Node, this defining metal half-pitch is taken from whatever product has the minimum value with historically DRAMs having the leadership (ITRS, 2003).

⁷⁸ <http://www.icknowledge.com/history/history.html>, 10.09.2005

⁷⁹ This trend has happened since the past 30 years and is probably best known as Moore’s Law.

⁸⁰ See (Baer, Hassell, & Vollaard, 2002) & (Cremer et al., 2003) for figures.

Physical system modularization is another structural barrier that is very much driven by technology trends and market demand, and hence hardly can be overcome by policy intervention. The key reason for the increasing level of physical system modularization is that functionalities that previously were hosted in one chassis now develop at different speeds. Consumers are not willing to exchange the entire chassis but rather buy an additional device that only replaces the outdated function with the latest technology. Presumably, this trend is going to continue in the field of consumer electronics within the next few years. Reasons for this assumption are that technology will continue to develop rapidly until it reaches a higher maturity level, network functionalities of future CE products will facilitate the connection of physically separated devices, and subscription services with the inherent need for some conditional access module become more popular. In the long term, all new TV-sets are likely to be iDTVs with an integrated digital tuner for terrestrial platforms. However, consumers might demand additional functionalities and it is uncertain to what extent these functionalities will be integrated into iDTVs.

5.1.2 Short term

Short-term changes could be initiated immediately and be fully implemented within a year or less. The author assumes that a key prerequisite for short-term changes is that only a limited number of individuals, generally within business organizations, is necessary to kick off actions. Examples for such actions are, from a producers' and service providers' perspective to join the Code of Conduct agreement, which entails the use of procurement guidelines for service providers. The potential to strengthen this driver becomes apparent when considering, that at present only six producers and one service provider are signatory members to the Code of Conduct.

Information and awareness deficits among producers and service providers could also be addressed in a reasonable period by providing information to key employees. The level of information communicated to consumers on energy issues could also be increased in the near-term. For instance, consumer magazines could instantly start to provide more information to their readers about the energy consumption of set-top boxes. Producers should be able to adapt their instruction manuals within a reasonable time span. Executive governmental agencies also instantly could start-up information campaigns directed towards consumers, though the effects might only be realized in the medium term.

5.1.3 Medium term

Other drivers and barriers take more time to be changed by action. The more widespread use of environmental management systems would be desirable for a higher penetration of eco-design into regular product development processes. Implementing a successful EMS initially requires management commitment and then the participation of many employees within the organization. A realistic time from the kick-off until certification is one to two years (Brorson & Larson, 1999).

Regulatory measures in a European context will also only be possible in the medium term, as regulation generally takes time to study, discuss and implement. Bertoldi (1999) describes the process leading to the adoption of minimum energy performance standards in the EU as rather long. The process starts with the Commission making an initial proposal for a Directive which is then followed-up by double readings in the European Parliament and the Council. In the latter one, the proposal has to be agreed by a qualified majority of Member States. Opposition from manufacturers can even further lengthen the process.

As discussed above, information to consumers could be provided at short notice. However, there are millions of consumers to inform and most communication channels will only reach a fraction of this. Additionally, not all people who got the message will transform it into actions. Thus, to reach a critical mass to transform the market will require time and resources. It is difficult to assess whether consumer awareness might rise without action or intervention. A potential driver for this could be a significant increase in electricity prices, however much uncertainty does exist around this issue.

During the research, no information was gathered, how quickly alternatives to continuous standby-active modes could be established in the field. The alternatives mainly require changes on the software side and potentially at the tuner for low power ready modes; hence it is assumed that implementation should be feasible in the medium term.

5.1.4 Long term

The lack of standards was identified as key barrier that complicates power management between the STB and other peripheral devices, such as the TV-set. With regard to broadcasting standards, the DVB-T standard is now established in numerous countries. Hence, it would be a complicated, enduring and probably costly process to adapt this standard with those features that for instance make the DVB-H broadcasting standard so much more power efficient at the receiver unit. Due to a high number of stakeholders involved in the decision making process, standards⁸¹ generally take time to be established and to be changed. Thus, the barriers of missing power management standards as well as the existence of established broadcasting standards could only be overcome in the long term, if action is taken.

Additional cost for a more energy efficient product design can also be a structural barrier that is unlikely to entirely disappear (which does not mean, that it is impossible to overcome this barrier by consumer information or subsidies, for instance). In the long run, power efficient components might become cheaper due to higher demand and higher integration. On the other hand, a more sophisticated design with additional hardware to lower power demand is also in the future likely to be more expensive than a very simple design. Implementing power management will also always be more complex and costly than doing nothing in this regard.

5.1.5 Interactions and synergy effects

Interactions between drivers and barriers mean, for instance, that strengthening one driver can also strengthen other drivers or weaken certain barriers. For example, the more widespread use of environmental management systems and CSR in industry could lead to higher participation in the Code of Conduct and to the more widespread use of power consumption as a procurement criterion in business-to-business transactions. On the other hand, better informed consumers have a higher awareness on life-cycle power costs and this is likely to weaken the barrier of “additional cost”. Furthermore, a higher level of physical system integration entails that the “lack of power management standards” would be less relevant. Consequently, not all factors have to be changed through action to explore the full potential in energy savings.

⁸¹ A *standard* has been defined as “a method, rule, or description subscribed to by the consensus of the appropriate industry and under control of the issuing organization for document revision” (SEMATECH, 2005).

5.2 Policy instruments and industry action

This section discusses on the pros and cons of different approaches for action through policy makers and industry. The discussion is based on the experience of existing, upcoming or suggested approaches, which address set-top boxes or other products. Criteria for discussion are the applicability of the respective approach for set-top boxes, as well as the effectiveness and cost-effectiveness of measures in qualitative terms. It is distinguished between:

- (1) Information to consumers
- (2) Information to industry and service providers
- (3) Voluntary agreements
- (4) Regulation
- (5) Procurement
- (6) Economic instruments
- (7) Power management standards

5.2.1 Information to consumers

In terms of energy issues, the lack of awareness and information deficits among consumers becomes relevant (1) when purchasing a STB and (2) when using it. At the point of sale, packaging of set-top boxes and most CE and ICT products generally doesn't reveal information on the power consumption of the device. Hence, consumers have no choice to compare products on this criterion on the spot. Energy labels and other closely related ratings systems were introduced to alert and inform consumers to the energy use, energy costs and environmental consequences of their purchase decisions (IEA, 2000). There are different types of labels; the subsequent sections discuss the experience and applicability of (1) endorsement labels, (2) comparative labels, and (3) declarative labels for set-top boxes. Furthermore, different options for industry, governmental agencies, and the media to inform consumers are briefly outlined and discussed.

5.2.1.1 Endorsement labels

As previously introduced in Section 3.2.2, the success of the two probably most widespread endorsement⁸² energy labels for set-top boxes has been limited. The criteria for STBs of the U.S. EnergyStar scheme are currently suspended and revised due to lack of participation and the European GEEA-label has almost no participation from STB manufacturers. One explanation for the failure of these energy-labels could have been the ambitious targets. The 2005 criteria of the GEEA-label for STBs already antedate the 2006/2007 standards of the Code of Conduct. As previously discussed, manufacturers consider the standards of the CoC as already challenging to achieve if compliance cost shall be kept at reasonable levels. Hence, the lack of participation in the GEEA-label can be explained with the high targets, which are, though technically achievable, difficult to get paid for on the market. Additionally, recognition of the GEEA-label is limited, for instance in the UK, the label was stated to be completely unknown (Dale, 2005c).

⁸² One type of endorsement labels are ISO Type I labels, which are verified by an independent body, and awarded to products fulfilling criteria corresponding to the best environmental performance within each product group (ISO, 1999).

The lack of participation and inherent suspension of the U.S. EnergyStar criteria for STBs has similar reasons. Taking effect in January 2001, Tier 1 criteria of the scheme were quite generous but were planned to become a lot stricter in Tier 2, which was scheduled to take effect three years later in January 2004. However, set-top box technology and the market had not progressed as quickly as originally envisioned when the specifications were set up and the entry of force of Tier 2 criteria was first postponed and then suspended. Research by the EPA showed that U.S. set-top boxes currently have little variation in power consumption, both between different manufacturers and across operating modes. For future specifications, it was suggested to bring forward a sleep or low power mode that would allow keeping network connectivity, and entailing higher energy savings. This was described to require significant support from all STB manufacturers and service providers (EPA, 2005). The lesson learned is, that participation and success of voluntary labeling schemes for STBs will be higher if industry including service providers are part of the discussion and if standards are not only set to levels that are technically achievable, but also take compliance costs and the market conditions into consideration.

5.2.1.2 Comparative labels

Manufacturers of CE products seem to be rather skeptical about comparative or classification labels such as the EU energy-label. For instance, it has been stated that a classification label could lead to the shift of environmental aspects. For instance, a LCD-screen with a backlight containing mercury will be a more energy efficient product than a product with a mercury-free backlight. From an industry perspective, another drawback of a classification label for CE products is that products with more features and therefore higher energy requirements are likely to receive a poor grade in the classification scheme (Evans, 2005). This is not in the interest of industry, as they prefer to sell high-end products, which generally offer higher profit margins. Schlomann et al. (2005) also emphasised the considerable additional administration of a classifying label compared to a simple label due to the necessary division of the classes and their adjustments over time, which is considered as problematic in the rapidly changing sectors of CE and ICT.

Concerning set-top boxes, some of this criticism towards classification labels could be overcome by the principle of additional power allowances for extra features as it is used in the Code of Conduct. Hence, a box with more features wouldn't be downgraded just for having more features. Updating the energy performance classifications and keeping a coherent scale can be more problematic. The success of the EU energy-label for refrigerators and freezers had the effect that the majority of appliances gained an A, B or C rating over time (Mordziol, 2005). This development led to the introduction of two additional classes, to be designated as A+ and A++ to indicate the top performers (EC, 2003a). Still, the scale of the label ranges down to "G" which could mislead consumers to assume that even a model rated with "C" is not such a bad buy. Updating the classes in the even faster evolving CE and ICT sector can be challenging.

5.2.1.3 Declarative labels

Another option would be to clearly display the power consumption⁸³ of the STB by means of a declarative mandatory label, as suggested by Schlomann et al. (2005)⁸⁴. The study suggested to impose the labeling obligation explicitly on manufacturers and importers not, as is the case with household appliances, on retailers. A compulsory labeling scheme is likely to raise awareness among manufacturers, retailers and consumers on the issue of power consumption in standby and off modes. Even though the label itself doesn't display comparative information, it enables potential buyers in retailer stores to compare different STBs on their power consumption. If, as suggested, the labeling scheme would cover a broad range of CE devices, consumers could also identify STBs as a product that requires significantly more power in standby than most other modern CE devices. The effect could be that some users prioritize STBs when they physically disconnect CE devices from the mains when not in use. However, this might potentially have adverse effects as the box loses network connectivity and misses software updates, which eventually might lead to customer complaints.

Presumably, industry is not particularly fond of this type of mandatory label, as it would particularly reveal high standby power levels of advanced STBs with many features and possibly direct consumers to buy a simpler model. This cannot be in the interest of industry as low-end boxes generally also have lower profit margins. Nevertheless, a mandatory standby power label would do nothing but simply fetch those information, which is generally displayed in small print in the technical datasheet at the end of the instruction handbook, and bring it on the packaging where potential buyers could include it into their decision making process.

5.2.1.4 Reflections on the applicability of energy labels for set-top boxes

Voluntary energy labeling schemes for set-top boxes haven't shown the expected success yet. Presumably, these labels failed due to insufficient corporation and communication between industry and the labeling and criteria setting organization. Compared to the generally more mature and homogeneous sector of household appliances, technology in the consumer electronics sector is developing fast and the range of features within one product group is big. Hence, the classification and updating of an energy label for STBs and other CE products is challenging.

Adopting the principles and standards of the Code of Conduct and including it into an endorsement label could overcome these barriers. The standards of the CoC have already been developed and agreed upon in cooperation with industry. If signatory membership in the CoC agreement was obligatory to carry the label, a successful label could encourage other producers to join the CoC. Those organizations, which are already signatory members for years, would get the chance to display their efforts also to the private consumer market. The label could also be used for other product groups than set-top boxes, which are covered by other Code of Conduct agreements, such as broadband communication equipment.

⁸³ A similar labeling scheme has been implemented in Denmark by a voluntary initiative between the IT industry and the Danish Electricity Saving Trust. The key manufacturers of the IT industry declare consumption of on, sleep and standby of all PCs and monitors with a label and additionally data is provided in Internet databases (DEST, 2005).

⁸⁴ see Section 3.2.2.4.

In order to not further increase the number of different labels on the market and confuse consumers, it should be discussed if a well-known trademark such as EnergyStar could be suitable to label STBs and possibly other CE products in Europe. An internationally harmonized label is also important from the perspective of globally operating manufacturers in order to keep administrative costs low.

Theoretically, such an endorsement label could also be upgraded with some comparative features. For instance, top performers that are for example 20 % or 40 % better than the CoC base standard could be rewarded with an additional note, similar to the efficiency classes A+ and A++ of the EU label for very efficient refrigerators and freezers. The label would allow for additional power allowances for additional features and standards would automatically evolve with the standards of the CoC. The drawback is that possibly a large share of STBs on the European market would be entitled to carry the label. However, a label with reasonable standards and high participation should be preferable to an ambitious label with no participation.

5.2.1.5 Information from industry

As discussed in Section 4.2.2, eco-design literature suggests that companies shall train their customers in environmental issues, as this would help to also gain business benefits from implementing eco-design into the development process. As discussed, most STB instruction manuals only contain little information on energy consumption, and if so, it is often displayed in small print, dispersed throughout the handbook, and communicates technical information in a way that most people cannot grasp. One of the few better examples is shown in Figure 5.1.

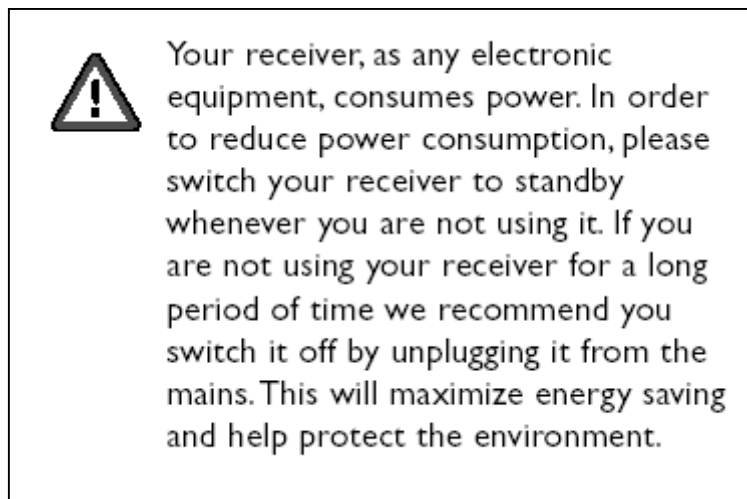


Figure 5.1: Excerpt from an instruction manual⁸⁵

⁸⁵ Source: instruction manual of Philips DTR 320.

A message on the environmental and cost implications of not putting the STB into standby-mode is likely to increase users' awareness on this issue. It is suggested that all information related to energy use is displayed in a clearly visible box and supported by symbols. The textbox could contain information and advice on:

- to make use of the standby mode;
- a calculation on the extra use of energy (and possibly extra cost) per year if the standby mode is not used;
- to physically disconnect the box during longer periods of non-use;
- how to make use of other power saving features, e.g., how to download additional infrared codes of the television set to the STB's remote control, so that both devices can be set into standby at the push of one button;
- power consumption figures in different operating modes;
- the note, that electricity generation and consumption has adverse effects on the environment.

By using the existing communication channel of the instruction manual, compliance costs for manufacturers to communicate this information are negligible.

5.2.1.6 Information from governmental agencies, NGO's and the media

There are some doubts about the efficiency and effectiveness of information campaigns that target the standby issue. They were described as costly and only reach a fraction of the population. From those who are reached not all are motivated and even less do eventually act on the message. Messages have to be simple, straightforward and easily understandable. On the other hand, the broad range of different products requires different actions, which cannot be communicated in a simple message. These simplified messages further hinder the effectiveness of information campaigns (Mordziol, 2005). A possibly more effective way of campaigning could be to address retailers and engage them as multipliers to inform end-consumers. One example for this is a currently running energy-efficiency campaign of the German energy agency DENA, which particularly addresses retailers.

Consumer magazines can be a powerful and - from the perspective of policy makers - cost effective way to address energy issues of STBs and other electronic equipment. In Germany, both the independent Stiftung Warentest and some commercial magazines for CE and ICT products include power figures into their product test reports, and warn of devices with high standby consumption. One magazine also developed its own energy-label (see Figure 5.2) that in words explains what it stands for.



Figure 5.2: Energy label used by a major consumer magazine for CE and ICT products⁸⁶

⁸⁶ Source: Aktion no-energy (No-Energy, 2005); "Power saver! This device can be entirely switched off and doesn't consume power then. In standby it consumes less than 1 Watt!"

Internet databases with power consumption figures of appliances⁸⁷ can – if regularly updated – be a useful source of information for the interested consumers. However, only those consumers who are already interested will actively search for information in such databases.

The phase-out of analogue terrestrial broadcasting will gain much media attention that governmental agencies should use to raise awareness on set-top boxes and their energy consumption. Unfortunately, this can be a tricky and controversial issue, as governments already face some opposition as people complain about being “forced” to purchase STBs for all their TV-sets. A higher awareness on the additional power costs could further increase the unpopularity of the digital switchover. People might perceive the switchover as a hidden raise of television fees (which it actually is, as service providers save on energy costs and end-consumer pay more).

5.2.2 Information to industry and service providers

5.2.2.1 Dissemination of eco-design know-how

As summarized in 4.3.2.3 information deficits among manufacturers and service providers were found to exist particularly among small and medium sized enterprises (SMEs). Hence, the sharing and further dissemination of best practice knowledge could help to lift up consciousness among SMEs. A presently running awareness raising campaign, initiated by the European Commission, specifically addresses electrical and electronics SMEs⁸⁸. The campaign is organized as a series of workshops and attempts to inform SMEs about ecodesign, to identify business success stories and eco-design tools, and to identify required types of assistance for SMEs in helping them to implement eco-design (IZM, 2005).

Similar measures are suggested for the STB industry, and particularly for service providers, which are key actors as they often determine STB specifications and hence have significant influence on the energy performance. Goals of such a campaign should be to:

- inform producers and service providers about current and future policy measures;
- show examples of best practice how to reduce energy consumption of STBs;
- show business success stories to emphasize that energy efficient design can be a success factor both in the business and private consumer market;
- and create information networks to stimulate further discussion.

For Europe, the meetings of the working group of the Code of Conduct can be a useful platform for information exchange, however costs for travels and labour might prevent SMEs to participate in the meetings. It would be desirable to also raise awareness among Asian producers, as alone Chinese manufactures hold around 50% of the global STB market (GlobalSources, 2005).

⁸⁷ Examples are www.topten.ch or databases associated with labelling schemes, such www.efficient-appliances.org.

⁸⁸ EcoDesign: Awareness Raising Campaign for Electrical and Electronics SMEs. (www.ecodesignarc.info)

5.2.2.2 Eco-design standards

Eco-design standards as presented in 3.2.5 can particularly help SMEs to implement eco- and energy-efficiency issues into their development process in a more structured way. Guidelines as, for instance, given by the ECMA-341 standard are rather generic and more detailed advice might be necessary to address individual product groups, such as set-top boxes. These guidelines should further be combined with a best practice handbook on how to optimize set-top boxes from the perspectives of technology, ergonomics and information to the user.

5.2.2.3 Environmental management systems

Environmental management systems, when being in place, were identified as a key driver to include energy efficiency and eco-design into regular product development. They helped to raise the level of awareness and knowledge on the implementation of eco- and energy-efficient design into the product development process. Hence, the further dissemination of environmental management systems should be promoted. CE manufacturers with CSR guidelines and EMS's in place should consider communicating on their environmental performance not only in environmental reports and on the environmental section of their websites, but also using further channels that reach the broad mass of consumers. Instruction manuals or some little extra brochure enclosed in the product packaging would be a cost-effective channel for this. Such action could help to raise consumer awareness, strengthen the brand, and force competitors to follow up.

5.2.3 Voluntary agreements

Voluntary or negotiated agreements between industry and governments, such as the Code of Conduct on Energy Efficiency on Digital TV Service Systems, are in the view of the European Commission the most effective way to reduce standby losses (EC, 1999). Industry also expressed satisfaction with the Code of Conduct (CoC), as the agreement is flexible and allows them to keep in the discussion process with the Commission. A key drawback of the CoC is the low market coverage for simple set-top boxes and digital adapters, as well as low participation from service providers. Particularly, imports from (non-Japanese based) Asian producers are not affected by the agreement. Manufacturers and service providers that didn't sign the CoC, enjoy a free-rider status as they benefit from the CoC since so far no regulation has been imposed on them and they don't have to carry the compliance costs.

As discussed above, the CoC contains many useful technical specifications and standards that could be used for an energy-labelling scheme addressing set-top boxes. An energy label exclusively for signatory CoC members could give qualifying producers some business benefits also in the private consumer market. A successful label might also further drive participation in the agreement.

The question is how to better involve service providers into the dialogue. Generally, the public perceives television service providers as being a business that doesn't cause any environmental pollution. There are no chimneys, no chemicals, no radiation, but entertainment, sports and ideal worlds being broadcasted into the living room. Hence, anything that would disturb this picture and endanger the value of the brand cannot be in the interest of service providers. This value of the brand theoretically makes them vulnerable to public pressure from, for instance, environmental NGOs. On the other hand, the "failure" of not participating in a voluntary agreement most people have never heard off, doesn't make them a very attractive target for NGOs. Nevertheless, the example of BSkyB which decided to adopt CSR guidelines in response to public pressure in the UK (Holliday, 2005) illustrates,

that public pressure can work to make service providers more aware of their environmental footprint.

5.2.4 Regulation

5.2.4.1 Challenges in imposing regulatory measures on set-top boxes

Generally, a regulatory approach with minimum energy performance standards (MEPS) would level the playing field for manufacturers, as all of them have to comply with the standard. Mandatory standards would in particular help to overcome the barrier of additional cost for a more energy efficient product design. So far, there is only little experience with MEPS on consumer electronic products. The Japanese top-runner approach addressed energy consumption of VCRs in standby and TV-sets in standby and on-mode (Murakosh et al., 1999).

STBs might be difficult to address by regulation as this product group (1) comes in a broad range of features and (2) is developing very rapidly. This fast development might be difficult to handle by regulatory measures, which generally take time to study, discuss and implement. Hence, it can happen that when regulatory measures go into force, they might not be in line with the state of technology anymore (Bertoldi, 2005a). The examples of the mandatory standards scheduled in California and Australia indicate that simple STBs or digital adapters might be easier to address by MEPS than advanced models. A 2004 workshop organized by the International Energy Agency on “Saving Energy in Set-Top Boxes” came to similar conclusions. Mandatory regulations were considered as most appropriate for low-functionality boxes, whereas voluntary programs were seen as probably most appropriate for boxes with higher functionality (IEA, 2004).

Difficulties can arise with regulation when defining the product features and delimitating the products to be covered by regulation from products that are exempted from regulation. For instance, if only digital adapters fall under regulatory measures there is some danger that manufacturers might upgrade the model with some little extra feature (additional interface port, etc.). This might let the model fall out off the product group covered by regulation, avoid the extra costs for power efficient features, and still offer some consumer value due to the added feature. Hence, regulation only being imposed on low-end products might drive the market to more advanced models with higher power needs.

If implemented, minimum energy performance standards in some East-Asian countries, such as China, Korea, and Taiwan are likely to also affect the European market. In particular China being a major exporter and having a huge domestic market at the same time plays a key role. The implementation of domestic standards in China, preconditioned they are also enforced, is likely to also benefit export products from an energy efficiency point of view.

5.2.4.2 Will the EuP-Directive drive regulation on set-top boxes in Europe?

The EuP-Directive doesn't explicitly mention set-top boxes to be addressed by implementing measures, but the Directive openly calls for a standard on products with standby power consumption. The expected time schedule for implementing measures is that in 2006 some studies on different product groups will be running, in 2007 draft implementing measures will be developed and discussed in a consultation forum, which might go into force by the end of 2007 or early 2008. Due to transition periods, actual minimum energy performance standards might only be applicable from 2009/2010 on (Schoenmakers, 2005). Hence, mandatory standards will most likely come too late for the first generation of terrestrial STBs that will go into use in those countries and regions where the analogue phase-out is already scheduled for the next years.

The EuP-Directive doesn't exclusively call for regulation, but implementing measures can also be self-regulatory by industry, for instance, through voluntary agreements. The Directive emphasizes the potential benefits of voluntary measures to be more rapid, cost-effective and flexible for technological options and trends. However, the Directive requests legislative measures if self-regulation by industry fails to evolve in the right direction or at an acceptable speed (EP, 2005). Theoretically, the Code of Conduct could become an implementing measure addressing STBs. However, Annex 8 of the Directive sets up an indicative list of criteria for voluntary agreements to be acceptable. The first criteria calls for sufficient representation, which means that a relatively big part of the market should be part of the voluntary agreement. Currently, the Code of Conduct would presumably already fail this criteria as coverage for digital adapters and signatory membership from service providers is very low (Schoenmakers, 2005). Nevertheless, the threat of potential standards under the EuP-Directive could potentially encourage more manufacturers and service providers to become signatory members in the Code of Conduct.

5.2.5 Procurement

As discussed in Section 4.3.2.2, business procurement from service providers with energy performance becoming a procurement criterion drives the awareness and efforts among producers to comply with certain standards. Hence, the more widespread use of business-to-business procurement is desirable. Apart from environmental management systems and the Code of Conduct being key drivers behind procurement standards, it should be discussed whether governmental regulators also could further stimulate this trend when issuing broadcasting licences.

Generally, depending on the broadcasting platform, service providers require a license issued by some governmental agency, such as Radio & Televerket in Sweden. Hence, the governmental agency could stipulate the license-taking service provider to include criteria on power consumption into their purchasing policy. The drawback is, that not all platforms require a license, for instance, in Sweden only frequencies for terrestrial broadcasting are issued by the state.

Public procurement, as shown by the example of the U.S. Federal Public Procurement program on low standby power products (Thomas, Glickman, Harris, & Meier, 2004), can be a powerful driver to promote energy efficient products. However, public agencies generally don't have high demand for STBs, consequently the potential to change the market by means of public procurement is likely to remain very limited.

5.2.6 Economic instruments

It is questionable whether economic instruments such as subsidies or tax breaks for energy efficient STBs are appropriate to overcome the barrier of additional costs for power saving features. In a life-cycle perspective, users of power-efficient STBs already have significant cost savings⁸⁹ that outweigh the extra investment for a more efficient product design. Hence, the use of tax money to support those users who benefit anyway from lower electricity bills is problematic from an equity perspective. Furthermore, administrative costs for allocating tax breaks or subsidies to a mass consumer product are high, not to speak of windfall gains that potentially exist with these types of measures. There are cases where governments directly subsidize STBs, for instance, the Italian government is reported to offer subsidies on the purchase of terrestrial STBs to ease the switchover to digital broadcasting (DTG, 2005). Such kind of subsidies could theoretically be bound to certain energy performance criteria. Energy or environmental taxes being imposed on electricity, as part of a comprehensive energy policy would further increase the life cycle cost savings of power efficient products. However, such taxes are less likely to give the STB market a strong push into the right direction within a foreseeable time horizon.

5.2.7 Power management standards

5.2.7.1 Cutting power needs without compromising network functionalities

One major source of energy consumption for many types of STBs is the networking functionality. The box is always in a standby-active mode ready to receive and process external signals. Introducing a low power ready⁹⁰ or sleep mode without compromising functionality could lead to substantial energy savings. This would require the commitment of manufacturers, hardware and software suppliers, and most importantly service providers to establish new technologies, communications protocols and power management standards. Because service providers set the specifications for STBs, they have controlling influence that is necessary to implement more power-efficient standby modes.

To start with the process, the savings potential of low power modes in a European context should be studied more in detail. Additionally, the technical options for low power modes must be explored. It is essential to get a better understanding of the services and functionalities (security, software and EPG updates) that currently motivate service providers to request STBs to be in standby-active. The next step would be to develop a pilot project that shows the technical feasibility of low power modes. Demonstrating the practicability is important to engage service providers into the dialogue. Ultimately, low power ready modes should become part of an international industry standard.

5.2.7.2 Power managing products in the home

No standards do exist so far that would facilitate power management between the television-set, the set-top box, the VCR, and potentially further peripheral devices. Current analogue interfaces such as SCART and RF were not designed to support power management

⁸⁹ Over the use phase of 7 years, the savings in electricity costs of a power efficient STB (1W in standby) mode compared to an inefficient model (6W in standby) can be in the range of € 30 in net present value (STB is in standby mode 20 hours per day, power costs are 0.15 €/kWh, and the savings are discounted to net present value at 6% interest rate).

⁹⁰ A “low power ready mode” in this context is a mode where the box still could be woken up by an external broadcasting signal and go to a full standby-active mode where data downloads and processing could take place.

functionalities. However, with the industry's efforts to connect and network digital audio and video devices, some opportunities for power management might open up. For instance, eight leading consumer electronics manufacturers⁹¹ have joined together in the HAVi organization to promote a standard on interoperability of digital home audio and video devices when connected via a network in the consumer's home. HAVi specifications use the IEEE-1394 digital interface (i.LINK or FireWire)(HAVi, 2005), a high-speed serial bus that allows for the connection of up to 63 devices. IEEE-1394 contains definitions for five power consumption states⁹², which provide the basis for further standardization work (CEA, 2004).

Industry seems to have taken up the topic, for instance, the U.S. Consumer Electronic Association has published a White Paper on Power Management for A/V Network Capable Devices (CEA, 2004) with the objective of incorporating power management features into the R7.5 architecture for audio/video networks. R7.5 is a working group of the U.S. Consumer Electronic Association's, which develops and maintains standards for interoperability between digital audio-video entertainment applications of consumer electronics (CEA, 2005).

Still, the establishment of power management standards and the penetration with devices that are capable of using these standards will take time. For set-top boxes, the possibly best short-term solution is remote controls with additional functionalities. Remote controls that can control two or more products increase the likelihood that the STB is put into standby. They also provide additional consumer value, as users are faced with an increasing number of remote controls in their living room. In addition, STBs that are already delivered to the market and in use could be upgraded with a new remote control.

One lesson learned from ICT products should be, that implementation of power management features will not result in the expected energy savings when power management features are incorrectly configured or disabled. Studies by Roberson et al. (2004) showed that, for instance, the rate of power management features actually being used in desktop computers in office buildings is low. Lack of consistency in the terms, symbols, and indicators used for power management controls was pointed out as one reason for the low level of usage. As a consequence standard IEEE 1621 "User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments" was developed and finally approved in March 2005 (IEEE, 2005). The goal of this standard is to harmonize terms, symbols, and indicators of power management features of ICT and CE devices in order to increase the rate at which power management features are enabled and successfully operated.

⁹¹ Grundig AG, Hitachi Ltd., Matsushita Electric Industrial Co., Ltd. (Panasonic), Royal Philips Electronics, Sharp Corporation, Sony Corporation, Thomson Multimedia, Toshiba Corporation

⁹² disconnect/off, local standby, network standby, listen, active

5.3 Relevance of findings for other products

Many findings of this study are also applicable to other product in the sector of Consumer Electronics and Information and Communication Technology. Key similarities are:

- (1) Higher initial costs for energy saving features, which though over the life-cycle are outweighed by savings on power costs. In other terms, products are not optimized in terms of least life-cycle costs;
- (2) big variances in terms of features and rapidly evolving technologies and markets, which make it difficult to define standards within voluntary or regulatory measures;
- (3) lack of awareness and information deficits among consumers on the power consumption and the inherent power costs;
- (4) very competitive markets with new actors entering the arena;
- (5) and a global market with many producers and suppliers being based in countries with lower environmental standards than in Europe, the U.S., or Japan.

Nevertheless, there are some key characteristics of STBs that (still) distinguish them from the bulk of other CE products. These characteristics are (1) service providers defining STB specifications, (2) the fact, that STBs physically modularise functions that originally were in one chassis, and (3) the networking functionalities. However, the two latter characteristics are likely to also apply to the next generation of home entertainment systems. Consequently, set-top boxes can, together with for instance broadband modems and wireless-LAN routers, be considered as the forerunners of future networked homes. This is relevant from an energy perspective since the networking functionality was identified as a major source of energy needs for many STB types. When being networked, the box is always in some standby mode ready to receive and process external signals.

The penetration of CE and ICT products with network functionalities is likely to increase significantly. Industry envisions the convergence of ICT and CE in terms of harmonizing imaging, audio and video formats. Additionally, home entertainment networks should enable users to control, listen and watch content via peripheral devices that are spread throughout the home, and possibly even portable handheld devices that can be used outside the home. Similar to set-top boxes, the physical modularization of functionalities will have impacts on the electricity needs of the system. Both, clients and servers will be in a standby mode, listening and ready to act on external commands.

To manage the network in an energy-efficient way, standards on power management functionalities are inevitable. To reach a high level of power savings, power management functionalities should be default settings, but also should be easily understandable and adaptable to the user-needs. The use of standardized symbols and standardized procedures to enable power management functionalities as prescribed in IEEE 1621 should be helpful for this. Consumers should also get an idea of the cost savings they have by making use of power management functionalities. It is important to include power management into industry standards on the interoperability of CE and ICT products now when standards are still in the process of being discussed and established.

Industry and research should also consider the practicability to make power management more dynamic and more intelligent so that regular usage patterns are recognized and transformed into further savings. For instance, a set-top box (or any other device) that

recognizes that users only watch television from 8 to 11 in the evening, could automatically power down during the rest of the day. Similar, a device that isn't used for a longer period, for instance, a home server during holiday periods or office equipment during weekends, could also power down by automatically recognizing and analyzing usage patterns.

There are discussions whether networked homes with home automation functionalities offer potential for energy savings as especially the operation of heating-, climate- and lighting systems can be better adapted to the actual demand for these services. According to Aebischer & Huser (2000), networking in private households affects energy consumption both inside and outside the house, but the impacts have been described as diverse and uncertain. Electricity consumption is likely to increase significantly, whereas on the other hand the value of networking for efficient use of energy in private households is estimated as rather low. Self-sufficient control systems have been described to achieve similarly good results to those from networked management systems.

5.4 Is there need for an environmental impact assessment when establishing industry standards?

Industry standards can have a huge impact on the environmental performance of products and services that are designed and operated according to the standard. There are life-cycle assessments for products and environmental impact assessment studies for infrastructure projects in order to quantify and reduce the environmental impact of certain decisions and actions. The environmental impact deriving from a "poor" standard can be multiple the dimensions than from a "poor" product design or a "poor" infrastructure project. A product can be redesigned within a reasonable period and the negative environmental impact from a "poorly" designed infrastructure project is often only on the local or regional level. Industry standards are far more wide reaching. They are often global, long-lasting, time- and resource consuming to change as often many stakeholders have to agree upon the change, and they can affect a huge number of products. Hence, preventative action would be desirable to also optimize industry standards on their environmental performance. It remains to be discussed whether some kind of environmental risk or impact assessment is needed when establishing industry standards.

6 Conclusions & recommendations

6.1 Main findings

The digitization of television broadcasting via satellite, cable and terrestrial delivery platforms is a global trend and will create a fast growing market for set-top boxes, which are necessary for the reception, conversion, and decoding of the digital signals. Due to their network functionalities, with the box always being connected to the broadcaster and ready to receive and process external signals, standby power consumption is, depending on the broadcasting platform and equipment with features, in the range of 5 - 10 Watts for most models. With entire national stocks of television-sets expected to become equipped with set-top boxes, the impact on energy use will be significant. In high case scenarios, set-top boxes can account for up to 1 % in Sweden, and even around 4 % in the UK of national final electricity consumption. In best-practice scenarios, the impact can be considerably lower. Uncertainty of these future projections is high as the technology is evolving rapidly.

Some STB manufactures did considerably reduce power needs of their models in recent years. Still, standby power levels are, due to the boxes' network functionalities, significantly higher than for most other modern consumer electronics devices. Furthermore, considerable variations in power needs do exist between different models with similar functionalities. This indicates an unexplored potential for energy efficiency and opportunities to limit the impacts on energy consumption that will arise from the digitization of television broadcasting.

Driver and barriers that affect STB manufacturers to reduce energy consumption of their models are numerous and manifold. Key factors that drive the development of more energy-efficient STBs were found to be (1) developments in silicon technology, (2) technical co-benefits such as better thermal management and higher reliability, (3) environmental management systems that helped to implement eco-design approaches into the development process, (4) demand from service providers requesting the STB to keep certain power limits, (5) the Code of Conduct on Energy Efficiency of Digital TV Service System being the key stakeholder forum between industry and legislators at the European level, and (6) to some extent demand from private consumers for energy efficient STBs, which was partly reported from Germany.

Key barriers that limit and counteract to the development of more energy-efficient STBs were found to be (1) physical system modularization, meaning that the reception functionalities are not in the same chassis as the television display which lowers the chances that the STB is put into standby, (2) a trend to more features and higher data rates, (3) information and awareness deficits among producers and service providers, (4) a continuous standby-active mode being requested by service providers, (5) information and awareness deficits among end-consumers, (6) the additional cost for power saving features, which are difficult to accomplish in a very price-competitive market, (7) the lack of power management standards for consumer electronic products, and (8) certain features of the DVB broadcasting standard, setting a barrier for more power efficient tuner and demodulator techniques.

Some of the drivers and barriers are mainly driven by technology and market trends, and for this reason only have a low potential to be changed through policy intervention and industry action. These factors include (1) developments in silicon technology, (2) technical co-benefits, (3) physical system modularization, (4) the trend to more features and higher data

rates, and to some extent (5) the additional cost for power saving features. To address the other factors, a number of policy measures and other mechanisms are already in place, which though in some cases could be improved. The next section gives response to the second research question and suggests additional measures.

6.2 Recommendations

Various approaches for further action do exist. Following, suggestions are given on (1) the framework for an energy-labelling scheme, (2) the STB industry's potential to inform and train end-consumers, (3) the power of special-interest and consumer magazines on raising awareness and informing consumers on the power needs of CE and ICT products, (4) the dissemination of eco-design and best-practice approaches in the STB industry, (5) the need to involve service providers much more, (6) the need for international corporation in setting standards, and (7) the need for power management standards.

The failure of existing energy-labels could be overcome by adopting the principles and standards of the Code of Conduct and including it into an endorsement label. The advantages of such kind of a label are, that (1) standards of the CoC have already been developed and agreed upon in cooperation with industry, (2) standards can be adapted quickly to technological trends by the working group of the CoC, (3) the mechanism of power allowances for extra features entails that more advanced STBs are not punished for having more features, (4) signatory members to the CoC could display their efforts also to the private consumer market, and (5) a successful label could encourage other manufacturers to become signatory members of the CoC agreement. The label should be preferably based on an existing trademark, such as EnergyStar, and could be upgraded with some comparative features. For instance, top-performing STBs that are a certain percentage better than the base standard of the Code of Conduct could be awarded with an additional note. All criteria would automatically evolve with the standards of the CoC. A widely spread label would alert and inform consumers and stimulate the public discussion on energy consumption of set-top boxes.

Governments should also consider a mandatory scheme with an energy label declaring standby and off-mode power consumption. Such a label would certainly raise awareness on standby power, reveal set-top boxes as particularly power hungry devices, and could also be implemented at national levels. Industry is likely to be more reserved about this type of a mandatory label, as it would particularly reveal high standby power levels of advanced STBs with many features and possibly direct consumers to buy a simpler model.

The widely heard complaint of industry that customers of CE products are not aware and not informed, and hence are not willing to pay more for energy saving features is not a surprise. Currently, the STB industry spends little efforts on training their customers on this issue. Generally, instruction manuals of STBs only contain little information on power consumption and how to minimize it. Information on energy related issues were found to be impartial, often displayed in small print, dispersed throughout the handbook, and communicating technical information in a way that most people cannot grasp. It is suggested to industry to give this issue a much higher priority. Handbooks should contain a clearly visible textbox with information on how to save energy when operating the STB, and should explain the relations between energy, costs and the environment. In comparison to most other communication channels, the costs for these measures are likely to be very low.

There are doubts about the efficiency and effectiveness of information campaigns targeting the issue of standby power. Campaigns directly addressed to the consumer are costly and do only motivate a fraction of consumers to act successfully. Furthermore, campaigns have to communicate simple, straightforward and easily understandable messages that are transformed into actions. Hence, campaigns can be useful to raise awareness of a newly introduced energy-label, for instance. On the other hand, campaigns are less effective to give consumers advice on how to operate their CE and ICT devices in an energy-efficient way, as these product groups differ so much in terms of features and thus actions required.

Partnerships with the media and particularly special interest magazines can be a cost-effective and powerful way for policy makers to raise awareness and to inform consumers on standby power of CE and ICT devices. These magazines should include power consumption figures into their test reports, downgrade models for a poor energy performance, and repeatedly report about the aggregated power costs that arise from standby power. The phase-out of analogue terrestrial broadcasting will gain much media attention that governmental agencies should use to raise awareness on set-top boxes and their energy consumption.

Policy makers should further encourage the dissemination of eco-design know-how among manufacturers, particularly among small- and medium-sized enterprises. Concerning set-top boxes, policy makers should disseminate best practice examples on power efficient designs. The arrival of industry standards on eco-design can particularly help SMEs to better implement eco- and energy-efficiency issues into their development process in a more structured way. However, generic guidelines should be refined with a best practice approach on how to optimize set-top boxes in terms of technology, ergonomics and information to the user.

Participation from service providers in the discussions is remarkably low and they should be encouraged to join the dialogue, which takes place under the Code of Conduct. Service providers have considerable power to contribute to the energy efficiency process, as they set the technical specifications that decide on the energy performance, and have significant purchasing power to raise awareness among manufacturers. Public pressure and a kick from environmental NGOs could potentially wake them up to take a more pro-active role in the process.

In Europe, the EuP-directive sets the framework for potential regulatory measures, which potentially might lead to minimum energy performance standards (MEPS) on set-top boxes. Low-end STBs and digital free-to air adapters might be reasonable targets for MEPS if other measures won't show the expected effects. Experiences from California and Australia will improve the knowledge base on the applicability of MEPS on set-top boxes. International cooperation with particularly legislators in China to adopt some kind of domestic energy standards could also be very beneficial from a European perspective.

Power management standards will be essential to operate future networked homes in an energy-efficient manner. It is important to include power management into industry standards on the interoperability of CE and ICT products now when standards are still in the process of being discussed and established. To better power manage set-top boxes in the short term, manufacturers and service providers are encouraged to add additional functionalities to the remote control, so that users can put both the TV-set and the STB into standby at the push of one button.

To conclude, STBs are a product group, which is complex to address from the perspective of energy efficiency for various reasons. Many of these challenges do also apply to other products in the CE and ICT sector. These similarities are (1) the higher initial costs for energy saving features, (2) very price competitive markets, (3) awareness and information deficits among consumers on the power consumption and the inherent power costs, (4) big variances in terms of features (5) rapidly evolving technologies and markets, and (6) many producers and suppliers being based in countries with lower environmental standards than in Europe, the U.S., or Japan, for instance. The fact that set-top boxes are placed in the interface between broadcasters and one or several local CE devices complicates the energy efficiency process as – compared to stand-alone devices - a larger number of stakeholders has to be involved. Other specific characteristics are that STBs physically modularise functions, which originally were in one chassis, and that they are devices bound into a network. These characteristics are likely to also apply to the next generation of home entertainment systems. Consequently, set-top boxes can be seen as a forerunner of future networked homes. To finalize, suggestions for further research are given.

6.3 Further research

A big potential for further energy savings does exist with low power ready modes, which would allow to wake up the STB with an external broadcasting signal and go to a full standby-active mode that would allow data downloads. To start with, the savings potential of low power modes in a European context should be studied more in detail. Additionally, research into the technical options for low power modes must be explored and a pilot trial should show the practical feasibility. For this purpose, it is essential to get a better understanding of the services and functionalities that currently motivate service providers to request STBs to be continuously in a standby-active mode.

Another field for some technical research could be the applicability of more intelligent power management functionalities and their effect on power savings. Intelligent power management is defined by the author to be a function that automatically recognizes, analyzes and learns from how people operate their devices and subsequently steers devices according to recurring usage patterns. Such features could omit the necessity to manually configure power management settings and eventually lead to higher energy savings

As part of this study, set-top boxes were identified as an exemplary product where functionalities, which previously were placed in one chassis (tuner and display function in one TV-set), become physically separated. The reason for this is that the technologies that serve different functions evolved at a different pace. Receiver technology developed very quickly in response to the transition of digital broadcasting platforms, whereas the displays had not reached their normal end-of life stage. Consequently, people buy a set-top box instead of a new iDTV. It might be interesting to conduct some research on this issue, the environmental implications of physical integration versus physical modularization. A device with two or more functions being integrated into one chassis is likely to be advantageous from the perspective of initial resource consumption and energy consumption in the use phase, since only one power supply is necessary and power management is a lot easier than with physically separated functions. On the other hand, upgrading or simply repairing single functions when they become outdated or defect is a lot more problematic, than if the functions were in two or more physically separated chassis'. For this reason, modularized functions could also be advantageous from an environmental perspective.

A related aspect is the future role of software in upgrading devices. The digitization of consumer electronics entails that in many devices software is increasingly used to fulfill functions that previously were served by pure hardware solutions. Software can be upgraded a lot easier than hardware to technological trends and new consumer needs, so from this point of view, software can help to prolong the lifetime of products. On the other hand, as shown by the history of the PC, software is a very powerful driver for new and more powerful hardware. There are presumably no simple answers to these two trends, about what is better and what is worse from an environmental point of view. Nevertheless, this is what it could make it interesting to look into.

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Abbreviations

AC	Alternating current
B2B	Business-to-business
CE	Consumer electronics
CoC	Code of Conduct
CPU	Central processing unit
CRT	Cathode ray tube
CSR	Corporate social responsibility
DA	Digital adapter
DC	Direct current
DOE	Department of Energy (U.S.)
DSSRP	Digital service system receiver platforms
DTT	Digital terrestrial television
DVD	Digital versatile disk
EACEM	European Association of Consumer Electronics Manufacturers
EE	Energy efficient
EEA	European Economic Area
EEPROM	Electrically Erasable Programmable Read-Only Memory
EICTA	European Information and Communication Technology Industry Association
EMS	Environmental management system
EPA	Environmental Protection Agency (United States)
EuP	Energy-using products
GEEA	Group for Energy Efficient Appliances
GWh	Gigawatt-hour
HAVi	Home Audio Video interoperability
HDD	Hard-disc drive
I/O	In / out
ICT	Information and communication technology
iDTV	Integrated decoder television set
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IR	Infrared
IRD	Integrated receiver decoder
ISO	International Organization for Standardization
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LCA	Life cycle assessment
LNB	Low noise block converter
m	Meter
MEPS	Minimum energy performance standards
MJ	Mega joule
MPEG	Moving picture experts group

MW	megawatt of electricity, or $1 \text{ Watt} \times 10^6$
MWh	Megawatt-hour
NGO	Non-governmental organization
nm	nano meter
NOVEM	The Netherlands Agency for Energy and the Environment
NTSC	National Television Systems Committee
OECD	Organisation for Economic Co-operation and Development
PAL	Phase alternating lines
PC	Personal computer
PSTN	Public switched telephone network
PSU	Power supply unit
R&D	Research and development
RF	Radio frequency
SCART	Syndicat des Constructeurs d'Appareils Radiorécepteurs et Téléviseurs
SDRAM	Synchronous Dynamic Random Access Memory
SECAM	Système Electronique Couleur Avec Memoire
SMEs	Small and medium sized enterprises
STB	Set-top box
TV	Television
TWh	Terrawatt-hour
UHF	Ultra high frequency
USB	Universal serial bus
V	Volts
VA	Voluntary agreement
VCR	Video cassette recorder
W	Watt
yr	year

Appendix

Table A-1: Personal communication

Person	Organization	Country	Date	Type of communication
Andersson, Marina	Com Hem AB	S	23.08.2005	phone
Armishaw, Mathew	Market Transformation Programme	UK	11.07.2005	e-mail
Bertoldi, Paolo	European Commission, DG-TREN, Joint Research Centre	I	03.08.2005	phone
Blomqvist, Fredrik	Emitor AB, Stockholm	S	18.08.2005	e-mail
Carlsson, Stig	Jakobson´s	S	17.08.2005	e-mail
Dale, Ken	Pace Micro Technology plc	UK	08.08.2005	phone
Eriksson, Mats	A2B Electronics	S	05.08.2005	phone
Evans, Peter	Sony Europe	UK	04.08.2005	phone
Holliday, David	British Sky Broadcasting	UK	11.08.2005	phone
Holst, Mikael	Swedish Consumer Agency	S	12.08.2005	phone
			24.08.2005	e-mail
Huang, Bill	Tunercom Technology Co., LTD	PRC	03.09.2005	personal interview
Huang, Steven	Sunfone Electronics Co.	Taiwan	02.09.2005	personal interview
Hultgren, Ulrika	Canal Digital	S	23.08.2005	e-mail
Hürther, Mr.	Technisat Digital GmbH	D	15.08.2005	phone
Janson, Sven	Zenterio AB	S	24.08.2005	phone
Kön, Stefan	TechniSat Digital GmbH	D	11.07.2005	e-mail
Löhmman, Henning	Arcon GmbH	D	03.09.2005	personal interview
Mordziol, Christoph	German Federal Environmental Agency	D	10.08.2005	phone
Nordman, Bruce	Lawrence Berkeley National Laboratory	USA	29.08.2005	e-mail
Oberst, Jochen	Stiftung Warentest	D	05.07.2005	e-mail
			08.07.2005	e-mail
Persson, Anette	Swedish Energy Agency	S	03.08.2005	phone
Saez, Evaristo	TechniSat Digital GmbH	D	02.09.2005	personal interview
Sagebiel, Mr.	SM Electronic GmbH	D	16.08.2005	phone
Schoenmakers, Theo	Philips Consumer Electronics	NL	22.07.2005	phone
Siderius, Hans-Paul	Senter-Novem, Netherlands	NL	19.08.2005	phone
Steckel, Philipp	Technical University Braunschweig	D	02.09.2005	personal interview
Wahlberg, Erik	Modern Times Group MTG	S	23.08.2005	e-mail

Table A-2: Additional organizations, of which representatives were interviewed on various issues related to the study topic at IFA-Berlin, 2/3 September 2005.

Organization	Country
DiBcom	France
Humax Digital	South Korea
Kathrein –Werke KG	Germany
Metronic	France
Samsung Electronics	South Korea
Sharp Corporation	Japan
B2C Electronics	Germany
Shenzen Coship Electronics Co. LTD	China

Table A-3: Reviewed instructions manuals

Manufacturer	Model
Emitor AB	Smartbox T10
Force Electronics A/S	3 series
Humax	VA Fox T
Nokia	Mediamaster 150T
Nokia	Mediamaster 230 T
Pace Micro Technology	Freeview adapter
Pace Micro Technology	CD TV 415
Panasonic	TU-CT30E
Philips	DTR 320
Philips	DTR 1000
Radix	DT 2000T/2010T
SM Electronic (Skymaster)	DTL 1000
Strong	SRT5155
Strong	SRT5120
Technisat	DigiPal 2
Thomson	DTI Series 500 / 1000 / 2000
Triax	Sat-Conax

Table A-4: Distribution of power consumption of a digital converter in on- and standby-mode ⁹³

Device	Mode	supply current [mA]								
		1.8 V	2.5V	3.3 V	5 V	9 V	12 V	32 V		
Tuner	on				290				10	
	standby				0					
RF-TV Modulator	on				110					
	standby				0					
Front-End	on	200		92						
	standby	20		6						
Microprocessor	on		800	150						
	standby		153	12						
SDRAM	on			120						
	standby			120						
Flash	on			20						
	standby			20						
EEPROM	on			1						
	standby			1						
PCM1740 Audio DAC + PLL	on				30					
	standby				0					
Audio Buffers	on					5				
	standby					0				
Video Buffers	on				100					
	standby				0					
Miscellaneous Peripherals	on				20					
	standby				20					
Total Current	on	200	800	383	550	5	0	10		
	standby	20	153	159	20	0	0	0	SUM	
Devices Power Consumption	on [mW]	360	2 000	1 264	2 750	45	0	320	6 739	
	standby [mW]	36	383	525	100	0	0	0	1 043	
Power supply from mains	on [mW]								10 640 *	
	standby [mW]								2 218 *	

* The difference between the sum of power consumption in the single circuits and the power supply from the mains derives from losses in the power supply unit and the power distribution chain.

⁹³ (Spini, 2002)

Table A-5: Energy related design recommendation in ECMA-341⁹⁴

The designer shall....

- identify specific power modes, which apply to the product under development.
- consider energy efficiency measures for the identified power modes
- identify where power is consumed with the product and which units or components can be improved to reduce overall power consumption.
- consider using low power components and design options as well as efficient power supply components such as voltage regulators and DC-DC converters to reduce the power consumption in the on modes.
- consider identified modes when specifying the power supply. The AC-DC conversion efficiency should be high in the most used modes.
- consider the true specification needs for the product. For example, over specifying the rating of the power supply can lead to an energy inefficient design.
- consider the effect of the operating environment specification provided to users and installers.
- consider practical design options to automatically switch from on mode to save modes save mode settings should be adjustable by the user. Other innovative solutions shall be considered
- consider the effect of the time to resume on the user acceptance to use the save modes extensively, for example the delay time for the first copy/print to start from save mode on a copier/printer
- consider design options to reduce the power consumption in the energy save modes by also applying similar methods as described in the “operational modes” clause
- inform the user of the higher power consumption if the save mode is disabled
- consider design options to automatically switch from save mode to off mode where practical
- consider design options to reduce the power consumption in the soft off modes to lowest values (zero Watt if feasible).
- place the main power switch on the product such that the user can easily reach and use it.
- inform the user through documentation or other means if zero Watt in the state a user would consider hard off is not achievable.
- consider design options that reduce power consumption of no load mode to the lowest value.
- Information on the power consumption and, where applicable, their related power modes shall be made available to the user.
- Products belonging to product categories which are covered by the international ENERGY STAR® program should be compliant to the program requirements
- should enable the most energy efficient on modes and transitions to save mode as default. If this is not possible, instructions on proper use of available energy saving controls and/or settings shall be provided to users
- balance the flexibility of software running on multipurpose devices and the energy efficiency of special purpose hardware.

⁹⁴ derived from (ECMA, 2004)

Table A-6: Projection of energy consumption of DVB-T set-top boxes in Sweden

	power demand of single average DVB-T set-top box		usage of standby-mode	DVB-T STBs for primary TV-set					DVB-T STBs for secondary TV-sets and VCRs					all DVB-T STBs
				numbers	usage hours per year		annual energy consumption		numbers	usage hours per year		annual energy consumption		total annual energy consumption
scenario	on-mode	standby-mode	usage of standby-mode		numbers	on-mode	standby-mode	single average STB		all STBs	numbers	on-mode	standby-mode	
	[W]	[W]	[%]	[]	[h/yr]	[h/yr]	[kWh/yr]	[GWh/yr]	[]	[h/yr]	[h/yr]	[kWh/yr]	[GWh/yr]	[GWh/yr]
2005 low	9	6	100%	450 000	1 460	7 300	57	26	76 500	730	8 030	55	4	30
2005 high	9	6	50%	450 000	5 110	3 650	68	31	76 500	4 745	4 015	67	5	36
2008 low	10	5	100%	1 254 300	1 460	7 300	51	64	1 103 784	730	8 030	47	52	116
2008 high	13	6	50%	1 254 300	5 110	7 300	110	138	1 103 784	4 745	8 030	110	121	260
2013 low	15	4	100%	1 284 300	1 460	7 300	51	66	1 194 399	730	8 030	43	51	117
2013 high	20	5	50%	1 284 300	5 110	7 300	139	178	1 194 399	4 745	8 030	135	161	339

Table A-7: Projection of energy consumption of DVB-S set-top boxes in Sweden

	power demand of single average DVB-S set-top box		usage of standby-mode	DVB-S STBs for primary TV-set					DVB-S STBs for secondary TV-sets and VCRs					all DVB-S STBs
				numbers	usage hours per year		annual energy consumption		numbers	usage hours per year		annual energy consumption		total annual energy consumption
scenario	on-mode	standby-mode	on-mode		standby-mode	single average STB	all STBs	on-mode		standby-mode	single average STB	all STBs		
	[W]	[W]	[%]	[]	[h/yr]	[h/yr]	[kWh/yr]	[GWh/yr]	[]	[h/yr]	[h/yr]	[kWh/yr]	[GWh/yr]	[GWh/yr]
2005 low	17	9	100%	820 000	1 460	7 300	91	74	139 400	730	8 030	85	12	86
2005 high	17	9	50%	820 000	5 110	3 650	120	98	139 400	4745	4 015	117	16	114
2008 low	11	5	100%	974 173	1 460	7 300	53	51	847 531	730	8 030	48	41	92
2008 high	17	7	50%	974 173	5 110	7 300	138	134	847 531	4745	8 030	137	116	250
2013 low	15	4	100%	997 473	1 460	7 300	51	51	917 675	730	8 030	43	40	90
2013 high	20	5	50%	997 473	5 110	7 300	139	138	917 675	4745	8 030	135	124	262

Table A-8: Projection of energy consumption of DVB-C set-top boxes in Sweden

	power demand of single average DVB-C set-top box		usage of standby-mode	DVB-C STBs for primary TV-set					DVB-C STBs for secondary TV-sets and VCRs					all DVB-C STBs
	on-mode	standby-mode		numbers	usage hours per year		annual energy consumption		numbers	usage hours per year		annual energy consumption		total annual energy consumption
scenario	on-mode	standby-mode	usage of standby-mode	numbers	on-mode	standby-mode	single average STB	all STBs	numbers	on-mode	standby-mode	single average STB	all STBs	total annual energy consumption
	[W]	[W]	[%]	[]	[h/yr]	[h/yr]	[kWh/yr]	[GWh/yr]	[]	[h/yr]	[h/yr]	[kWh/yr]	[GWh/yr]	[GWh/yr]
2005 low	10	6	100%	241 000	1 460	7 300	58	14	40 970	730	8 030	55	2	16
2005 high	10	6	50%	241 000	5 110	3 650	73	18	40 970	4 745	4 015	72	3	21
2008 low	10	5	100%	300 000	1 460	7 300	51	15	264 000	730	8 030	47	13	28
2008 high	15	6	50%	300 000	5 110	7 300	120	36	264 000	4 745	8 030	119	32	68
2013 low	15	4	100%	2 140 500	1 460	7 300	51	109	1 990 665	730	8 030	43	86	195
2013 high	20	5	50%	2 140 500	5 110	7 300	139	297	1 990 665	4 745	8 030	135	269	566