# What's On the T.V.:
# Trends in U.S. Set-Top Box Energy Use, Design, and Regulation

*Leo Rainer, Davis Energy Group*
*Jennifer Thorne Amann, American Council for an Energy-Efficient Economy*
*Craig Hershberg, U.S. Environmental Protection Agency*
*Alan Meier, International Energy Agency*
*Bruce Nordman, Lawrence Berkeley National Laboratory*

**ABSTRACT**

What a set-top box is and does is rapidly evolving. If current trends continue, by 2010 electricity use by set-top boxes in the U.S. could approach 4% of total residential electricity use. In order to reduce this use, many programs and activities are underway in the U.S. including an ENERGY STAR® specification (now being revised), consideration of minimum efficiency standards in many states, and discussions of a variety of voluntary programs involving equipment manufacturers, cable and satellite TV providers, and efficiency experts. In addition, a variety of research is underway to better understand set-top box energy use and future trends, and to develop additional intervention strategies. This paper summarizes the current state-of-knowledge of set-top box energy use in the U.S., and describes current and emerging strategies for reducing this use.

## What Is a Set-Top Box?

In the process of understanding the current state of set-top boxes (STBs), we have found that the television industry seems especially enamored of acronyms, which can cause confusion for those not acquainted with the technology. To try and help, we have provided a list of some of the more regularly used acronyms in Table 1. Up until 10 years ago, the term set-top box usually meant one thing – an analog cable box, which was required to decode cable TV signals for display on a TV screen. Since that time, the number of boxes appearing on the top of TV sets has ballooned, fed by a combination of the conversion to digital media and the appearance of additional signal sources, including direct-to-home (DTH) satellite transmission and broadband over DSL or cable using internet protocol (IPTV). This has broadened the scope of products encompassed by the term STB, ranging from basic digital TV adapters (DTA) to integrated high definition TV (HDTV) cable boxes with digital video recording (DVR) and game playing ability. Some have defined an STB to be anything which puts out video content, which could include PCs and even many digital still cameras. For this paper, we consider a STB to be a device that receives a video signal and converts it for display on a television. We explicitly exclude PCs, dedicated DVRs, and video game consoles, although there is by no means a distinct line between say, a PC with TV tuning and recording ability, and a STB that is a PC in terms of hardware but runs a customized operating system and comes packaged in a consumer appliance case.

**Table 1. Common Set-Top Box Acronyms**

| Acronym | Term | Comment |
|---|---|---|
| IRD | Integrated Receiver Decoder | Cable or Satellite STB |
| DBS | Direct Broadcast Satellite | Satellite STB |
| DTH | Direct-To-Home | Another term for DBS |
| DTA | Digital Television Adapter | Converts digital signals for use by legacy analog equipment |
| DTC | Digital Television Converter | Another term for a DTA |
| DVR | Digital Video Recorder | Records the incoming signal on a hard disk |
| PVR | Personal Video Recorder | Another term for a DVR |
| HDTV | High Definition TV | Digital TV with a wider, higher resolution picture |
| IPTV | Internet Protocol TV | Video signals transmitted over a broadband connection |
| OTA | Over-the-Air | Standard broadcast TV, also known as Terrestrial |
| VOD | Video On Demand | Use of two-way communication to select personal content |

To help organize this cacophony of boxes and acronyms we propose to separate STBs into two classes: basic and advanced. A basic STB either decodes or converts signals from a terrestrial, cable, satellite, or IP source for display on a TV. It does not contain a hard disk or storage and it communicates in only one direction. Examples include basic cable and satellite receiver/decoders, digital television adapters (DTA), and HDTV adapters and tuners.

An advanced STB adds one or more functions or services in addition to basic decoding and conversion, including digital recording, video on demand (VOD), video games, and interactive TV. This class can become hard to differentiate from the new media center PCs that are starting to take on some of the traditional STB roles.

## Stock and Sales Trends

The STB market is evolving rapidly and is therefore difficult to characterize accurately. It is still dominated by cable boxes, but direct broadcast satellite (DBS) has made strong inroads and IP STBs are starting to be marketed by broadband providers. Our best estimate of the current U.S. stock of STBs is shown in Table 2. The number of digital cable subscribers is expected to draw even with analog this year as cable companies continue to convert their cable plants to digital. The stock for IP and DTA STBs are our best estimate as good figures are not available.

**Table 2. Current U.S. Stock of Set-Top Boxes (millions)**

| Type | 2004 Stock |
|---|---|
| Analog Cable | 20 |
| Digital Cable | 40 |
| Satellite | 30 |
| IP | 0.5 |
| Digital Television Adapter | 1 |
| TOTAL | 91 |

Source: ABI 2003, Instat 2003, Amann 2004

## Legislation

Forecasting future sales is even less certain because of three recent Federal Communications Commission (FCC) decisions. First, the FCC has mandated that all analog commercial TV broadcasts stop as of January 1, 2007 or when 85 percent of all homes with televisions are capable of receiving DTV, whichever comes first. Many industry spokespersons have questioned the viability of this deadline, but there is significant incentive as the government can then reclaim the analog airwaves from broadcasters and turn around and sell them to mobile telephone companies for advanced services, potentially raising billions of dollars. This broadcast conversion is the largest transition since the conversion from black and white to color, and will require all those who want to receive terrestrial broadcasts on legacy analog equipment to purchase a digital television adapter (DTA).

Second, the FCC voted in 1999 to allow cable TV customers to buy standalone cable boxes, TVs, VCRs, and other devices with built-in decoders from retail stores, rather than rent them from their cable provider. Cable providers will still control critical security features. However, to help create a retail market for the new set-top devices, the FCC rule bars cable operators from selling or leasing cable boxes with security built into them after July 2006. Currently, cable customers who don't have cable-ready TV sets must rent a set-top box for between $2 and $4 a month (and often up to $10/month for high-definition digital boxes).

Finally, in September 2003 the FCC adopted new TV-cable compatibility rules that make it easier for new digital TV receivers to hook up to cable systems. This "plug-and-play" rule will allow consumers to feed their cable or satellite signal directly into new TV sets, eliminating the need for a dedicated STB to convert the signal. The impact of this ruling is unclear, with industry research firm predictions ranging from "…might change the sector dynamics in the next 3 to 4 years" (ABI 2003) to "…impact will be minimal for the next several years" (InStat 2003). The lack of significant effect may be due to the fact that plug-and-play is not expected to affect satellite STBs as much as cable because most houses already have cable but require a service call to install a satellite dish and STB (Talwani 2003). From an energy perspective this may have even less effect, as while there may be small energy savings from combining functions in one device, the end result will just be the moving of energy use from the STB to the TV.

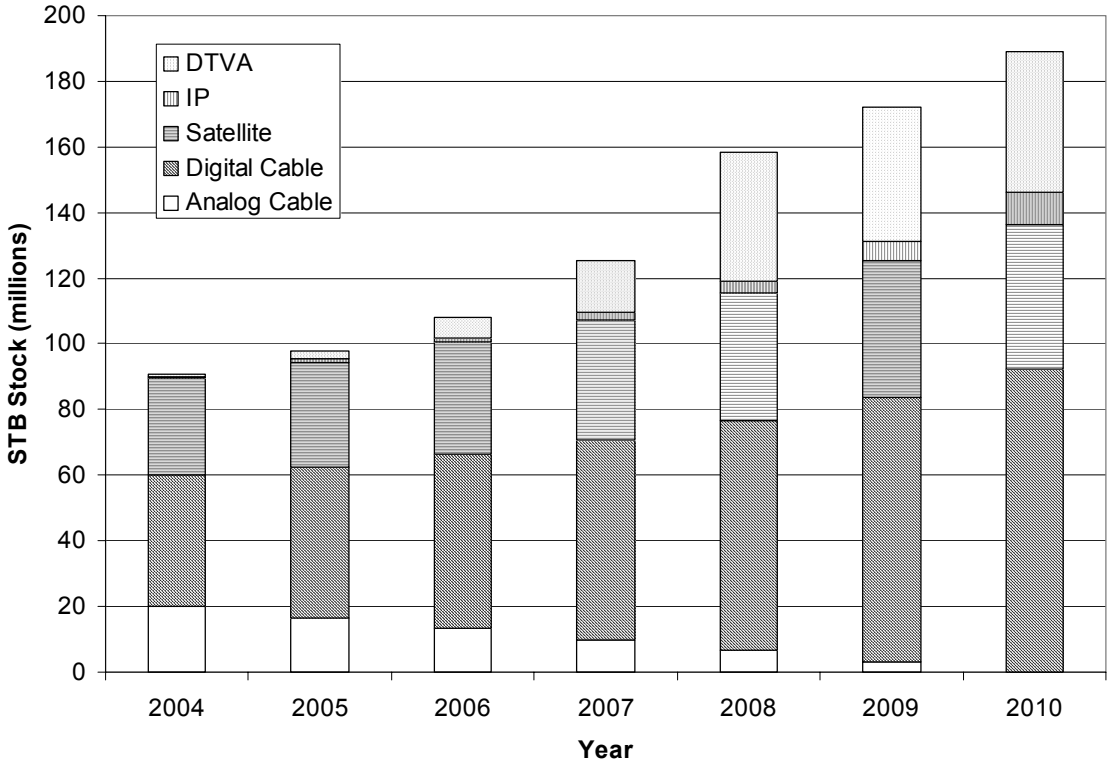
Taken together, these three decisions are expected to have opposing effects on STB growth. While sales of low cost adapters for second TVs and legacy VCRs are expected to be a major source of STB growth in the next decade, the need for basic cable and satellite boxes may be eliminated by new integrated TVs.

## The Future

Everyone, it seems, has a vision of where the STB is going and what it will be used for in the future. Some see it as a gateway appliance that will "…provide some or all home networking capabilities, and become the residential gateway of the future" (Xilinx 2004). Microsoft would have a STB on every display to convert signals as part of their Enhanced Media Center PC (WFD 2004). Numerous niche market STBs have begun to appear, ranging from Disney's MovieBeam STB that downloads content over the air (Hawn 2003), to Akimbo, a subscription digital TV service with esoteric programming such as nude newscasters and first run movies from Nigeria that uses a dedicated IP STB (Kanellos 2004).

STBs are relatively cheap and can be mass produced in huge numbers. Because no technology has established preeminence, a new technology can appear—and dominate—in only a few years. In Figure 1, we provide a scenario of the growth in STB stock over the next six years. Analog cable boxes continue to be replaced by digital with modest growth in the total. Satellite boxes continue their steady growth and IP boxes start to increase substantially. DTV adapters experience major growth in 2007 and 2008 driven by the terrestrial DTV conversion, eventually reaching 20% of TVs, but then flatten out as legacy analog TVs are replaced. Total STB stock reaches 190 million by 2010. Note that this assumes that some STBs serve more than one TV, as many new STBs can. In addition to the growth in STB stock, there will be an increase in the use of advanced features as basic STB functions are usurped by integrated TVs and STB manufacturers look to maintain high profit margins.

**Figure 1. Estimated Set-Top Box Stock 2004–2010**




## Power Modes and Connectivity

A key issue for the energy consumption of most electronic devices is the set of possible power modes and the distribution of time spent in each mode over the course of a year. An important set of efficiency measures shift time from higher to lower power modes. Power modes are not rigorously defined, but can be grouped into three basic categories: on, sleep, and off. These modes can apply both to the users perception of the state of the device and to the actual power use level. On modes are either active (performing a principal function), or immediately "ready" to do so. Because ready can often transition to sleep without user interaction, it need not be used for a large portion of time, though may be used that way on devices without such control. True “off” modes usually require a mechanical switch to be engaged. Sleep modes

occupy the space between, and usually offer substantial power savings while retaining connectivity and responsiveness to several signal sources, including remote controls and networks. While devices that are off usually lack any network connection, those that are merely asleep need to retain some responsiveness, which requires energy. The standby power level can occur in the on, sleep, or off mode, depending on the device. A convenient definition of standby is that used by International Electrotechnical Commission (IEC) standard 62301. It defines standby as "the lowest power consumption mode which cannot be switched off (influenced) by the user…" (IEC 2004). The IEC committee responsible for this standard (TC59) envisages that numerous low power modes will be present in different products and that these modes will be further defined at the product committee level.

## Energy Use

Like all consumer electronics, STB energy use is dependent on both the power use in each mode of operation and the usage pattern to which it is subjected. STBs can have many operating modes, including active and passive standby, and a number of active states, but we will use only standby and active to keep our estimates simple. Rosen, Meier, and Zandelin (2001) measured over 100 cable and satellite STBs but did not make any measurements of IP or DTA STBs. Both of these devices are so new that there is very little data on their energy use in the literature. DTA data was obtained from measurements of four British terrestrial DTAs from the EPIC database (EPIC 2004) and eighteen measured by the Australian Greenhouse Office (NAEEEC 2004). No data was found for IP STB power use and so we used our best estimate based on power use from similar devices. A summary of the average power levels, rounded to the nearest watt to reflect the uncertainty of the data, is shown in Table 3. Note that with the exception of DTAs, the standby and active power levels are very close, indicating that there are little or no operational differences between the modes.

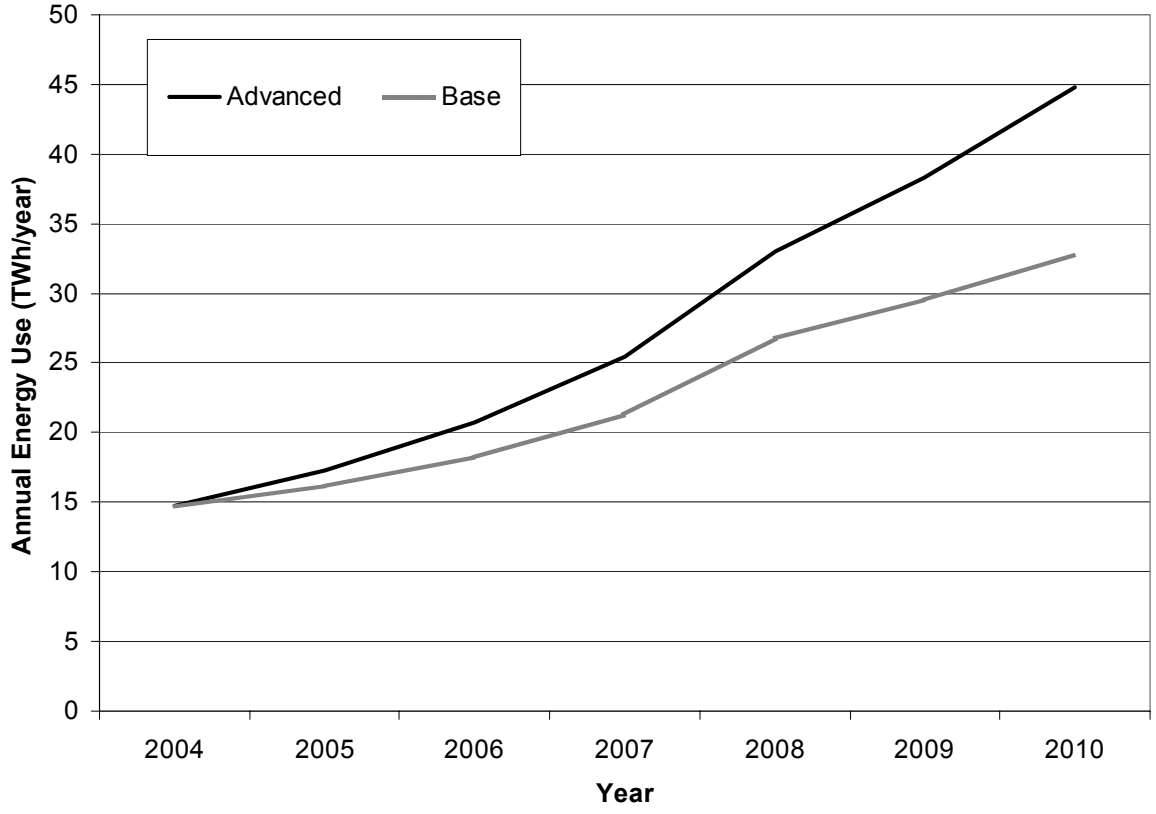
**Table 3. Average Set-Top Box Power Levels**

| Type | Standby (W) | Active (W) |
|---|---|---|
| Analog Cable | 10 | 12 |
| Digital Cable | 22 | 23 |
| Satellite | 16 | 17 |
| IP | 14 | 15 |
| Digital Television Adapter | 8 | 17 |

Combining these power levels with the stock numbers from Table 2, we calculate current national STB energy use at 15 TWh/year or about 1.3% of residential electricity use. Figure 2 shows two possible energy use growth scenarios. The base case assumes that STB unit power use stays the same as current and shows the effect of stock increase and digital cable box conversion. 2010 energy use is 33 TWh/year – a 12.4% compound annual growth rate and now 2.9% of 2010 residential electricity use. The second curve displays the effect of a gradual penetration of advanced capabilities (such as DVR) and a commensurate 30 watt active power use would have on total energy consumption. 2010 energy use for this scenario is 45 TWh/year – an 18.2% compound annual growth rate and 4% of 2010 residential electricity use. We have assumed that the STBs are in standby mode 78% of the time – the average amount of time that TVs are off in the US (Rosen, Meier, and Zandelin 2001). The actual active time is not known but errors from

this assumption are minor due to the small power difference between standby and active mode. As STBs begin to have lower standby power levels it will become imperative to understand their operational profiles better.

**Figure 2. Possible U.S. STB Energy Use Trends**




## ENERGY STAR Specification

There are currently thirteen manufacturing partners in the U.S. Environmental Protection Agency (EPA) ENERGY STAR program for set-top boxes. As of March 9, 2004, six of these partners have qualified products which meet the current Tier 1 ENERGY STAR specification (see Table 4). The qualified products and their low-power levels (which EPA refers to as standby/low power) are shown in Figure 3.

The Tier 2 ENERGY STAR specification was originally scheduled to take effect on January 1, 2004, but it has been delayed and the Tier 1 specification extended. Due to shifts in the economy and other factors, the set-top box technology and marketplace have not progressed as quickly as originally envisioned when the specification was introduced in 2000. As a result, the EPA felt it was necessary to review the Tier 2 specification and make appropriate adjustments to ensure that the specification will reflect the most energy-efficient models on the market when it takes effect.

The goal of revising the Tier 2 specification is to ensure that the new energy-efficiency criteria will recognize the top quartile of the current marketplace for set-top boxes, incorporating a wide variety of products and features. To accomplish this, EPA intends to work closely with manufacturers and other interested stakeholders during the specification revision process. It is

hoped that this will result in a challenging yet sound revised Tier 2 specification, which addresses industry concerns about the current Tier 2 specification. As part of the specification revision process, EPA intends to gather and analyze data on the power consumption of set-top boxes, not only in low-power but also in active modes. Through this data collection and analysis, EPA will determine the feasibility of incorporating an active mode component into the revised Tier 2 specification for set-top boxes. Active modes may be addressed in one of two ways: either by setting energy efficiency criteria for active mode, or by incorporating the ENERGY STAR power supply into the set-top box specification as a requirement.

**Table 4. Energy-Efficiency Criteria for ENERGY STAR Qualified Set-Top Boxes**

| Product Category | Tier 1: Standby/Low-power Mode | Tier 2: Standby/Low-power Mode |
|---|---|---|
| **Category 1**<br>• Analog Cable TV Set-top Box<br>• Advanced Analog Cable TV Set-top Box<br>• Digital TV Converter Set-top Box<br>• Internet Access Device<br>• Video Game Console<br>• Videophone Set-top Box<br>• Set-top Box (e.g., Internet access device) with Cable Modem for enhanced communications in low-power mode | ≤3 watts | One specification for all set-top boxes: |
| **Category 2**<br>• Digital Cable TV Set-top Box<br>• Satellite TV Set-top Box<br>• Wireless TV Set-top Box<br>• Personal Video Recorder | ≤15 watts (for satellite systems, add 5 watts for each LNB) | ≤7 watts (for satellite systems, add 5 watts for each LNB) |
| **Category 3**<br>• Multifunction Device (i.e., a physically integrated device that has the core function of a satellite TV set-top box, digital cable TV set-top box, wireless TV set-top box, or personal video recorder plus one or more additional functionalities, such as an Internet access device or video game console) | ≤20 watts (for satellite systems, add 5 watts for each LNB) | |

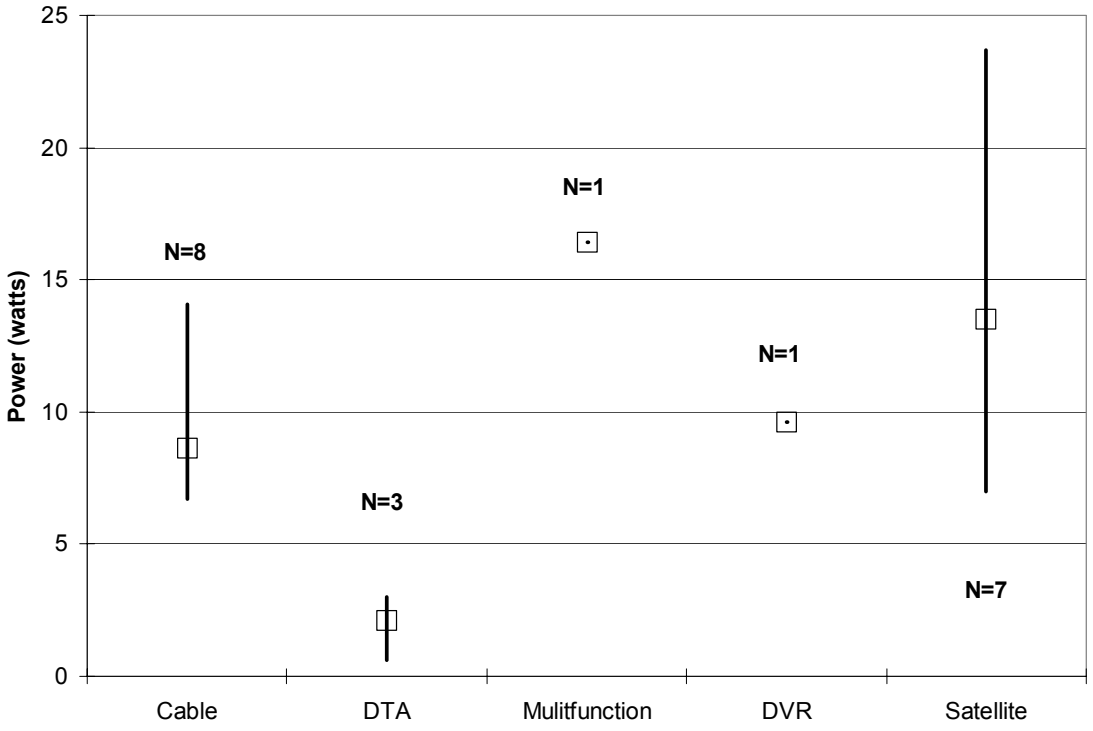
Source: ENERGY STAR

One proposal already submitted to EPA for consideration is based on an "additive" approach similar to that used by the European Code of Conduct (EC 2003), and would decrease the number of product types able to qualify under the ENERGY STAR specification. Three primary product types are defined based on signal source: satellite, cable, or terrestrial. A "base-level" of energy consumption is allocated to each type of set-top box, and then extra power allowances are granted, depending on any additional functionality or peripherals attached. This is similar to the 5 watt allowance granted for each low noise block (LNB) in the current set-top box specification.

A drawback of this proposal is that a number of advanced STB products, such as game consoles and DVRs, would not be able to qualify as ENERGY STAR. However, the specification might be easier to implement and revise in the future. Basing the specification on power allowances for functionality and peripherals may allow it to be more dynamic and flexible than the traditional product type approach, assuming that testing, qualification, and labeling issues can be adequately addressed.

It is EPA's intent to solicit feedback from stakeholders on all proposals received, prior to making a final decision on the direction of the revised Tier 2 specification. This will ensure that all relevant set-top box products are covered under the revised ENERGY STAR specification.

**Figure 3. Low-Power Levels of ENERGY STAR Qualified Set-Top Boxes**




## Mandatory Standards

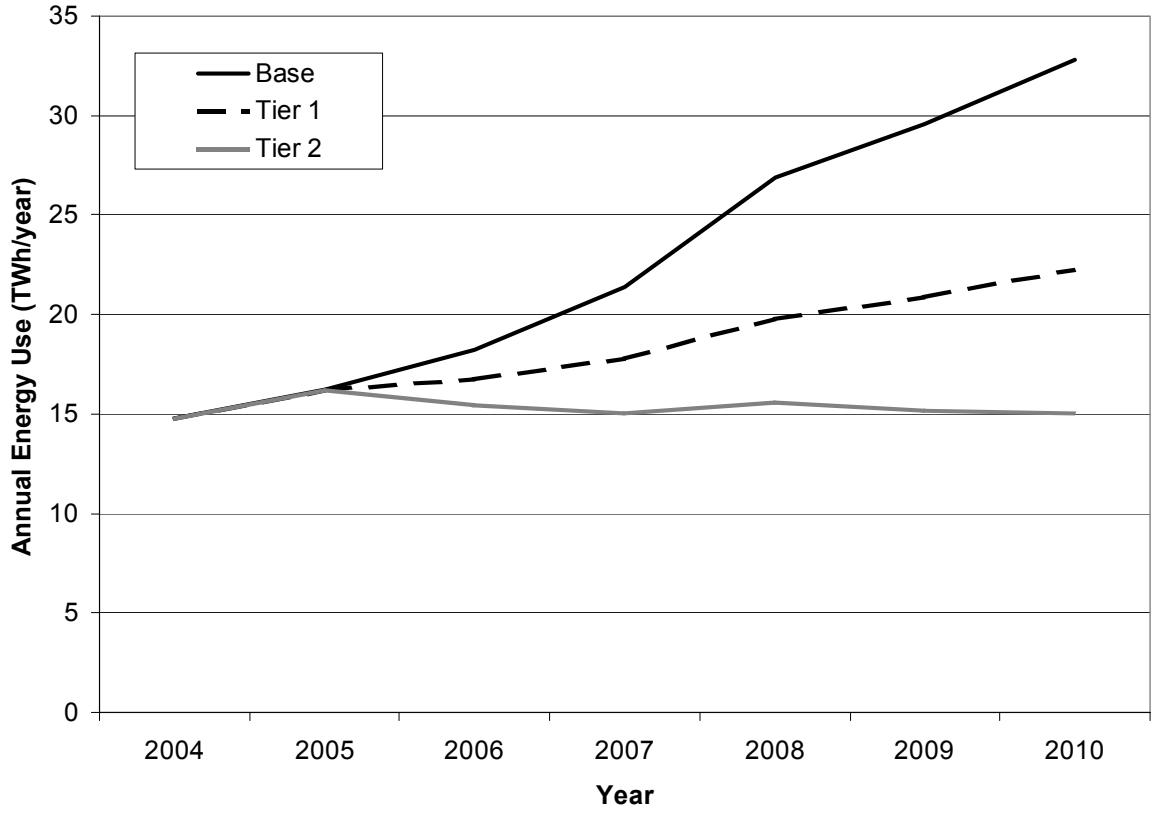
The current version of the Senate energy bill has language directing the Department of Energy (DOE) to initiate a rule-making on standby power, but does not directly address STBs. Until such time as DOE acts, states are free to regulate STB power levels and a number of them are considering legislation to do so. California has historically been a leader in appliance and building standards, often preceding federal standards by many years. Revisions to California's 2005 appliance standards are currently being drafted and one of the proposals includes maximum standby power levels for STBs. If adopted, basic STBs and DTV adapters would have to meet ENERGY STAR Tier 1 levels.

The appliance standards legislation recently passed in Maryland originally had a STB component within its proposed scope which was removed after negotiation with industry. The state will still monitor the status of the ENERGY STAR program and assess the feasibility of a future standard. Five other states, including New Jersey, Pennsylvania, Massachusetts, Vermont, and Rhode Island, have bills pending that would implement the Appliance Standards Awareness Project's model bill which sets digital cable, satellite, and converter box standby power levels at ENERGY STAR Tier 1 levels (deLaski 2004).

## Potential Energy Savings

Because of their short life times and high ownership growth rates, STBs provide an opportunity for significant short term energy savings. Figure 4 shows the effect of two possible standby power levels on total U.S. STB energy consumption. It assumes that all STBs sold after 2005 meet either ENERGY STAR Tier 1 or Tier 2 and that all STBs have a five year life. Energy savings in 2010 would be 10.5 TWh/yr for Tier 1 and 17.7 TWh/yr for Tier 2.

**Figure 4. U.S. STB Energy Savings Options**




### Energy Savings Options

Reducing the energy use of set-top boxes is complicated by their multiple complex operating and communication modes. Although improvements in power supply design and efficiency will be effective in reducing STB energy use, the major energy savings will be obtained through the use of protocols and software to better control the device (energy management). For example, STBs that download enhanced program guide (EPG) information can wake up periodically to update the information but spend most of the time in a sleep state. Or, the network interfaces on STBs can be made with enough intelligence to identify network communications that call for the device to be awake. Some of these methods require new features in network protocols, but others can be implemented with current specifications. STB hardware and software is governed by numerous voluntary communication and operation protocols, none of which currently have a dedicated energy use component.

## Proposed Intervention Strategies

Reducing STB energy use presents three unique challenges to regulators and energy efficiency advocates: Integration of multiple functions in a single device, complex power modes, and a high rate of technical change.

### Integration

As described previously, the term STB encompasses a wide and ever changing variety of products. As fast as STBs are acquiring new advanced functions such as video-on-demand or interactive TV, many of the basic functions are moving to newly integrated products. This makes the STB category difficult to define from a regulatory perspective. Most products end up falling into the catch-all category of multi-function device which must by default use a high minimum power level for a target due to continually evolving functionality.

### Power Modes

The complex power modes that STBs operate in and their interaction with network and signal provider protocols make the traditional regulation of standby power problematic. A voluntary or mandated standby power level is simple to implement and may be easy for manufacturers to obtain, but the resulting energy savings may fall far short of expectation due to the short time that the product spends in standby mode. A key example is that of the DTA. This product can attain standby power levels below 1 Watt, but research indicates that the majority of consumers will not switch them to standby mode, thereby negating any potential savings unless they can be designed to follow the state of the device they are feeding (MTP 2003). Without a thorough understanding of STB operating profiles, regulatory program energy savings estimates are sure to be wrong.

### Technical Change

Few consumer electronic products are changing as fast as STBs. Companies, products, and protocols change from year to year, mostly driven by cable and satellite companies trying to maintain market share through added features and functionality. This has provided the industry with its strongest argument against regulation: that it will stifle this ongoing flow of new features and deprive consumers of the functionality they crave. Regulations or agreements which use the STB operating protocols have a much higher chance of being accepted and may even be enthusiastically adopted if they can be shown to increase consumer demand and add non-energy benefits.

## Recommendations

There is currently little publicly-funded research into STB energy efficiency strategies. While ENERGY STAR does a good job in its labeling activities, it lacks the resources to address network and active mode related energy consumption issues. Because industry has many other issues to grapple with and because end users rarely make purchase decisions with energy

consumption in mind, industry has not paid attention to energy issues. For these reasons, progress will only be made if an outside entity prods industry to take energy issues seriously.

As to what should be done in the near term, there is a need to confirm, document, and possibly uncover other significant energy problems related to operating modes and transitions. In addition, we need people whose prime interest is energy efficiency to work with industry to fix existing problems to the degree possible, and be part of the development of new products and protocols to ensure that they are "friendly" to energy efficiency. It is simply not realistic to expect industry to make this a sufficient priority on its own, but it can be expected to cooperate with efficiency researchers who do their share of the work in technology development.

Many energy-saving opportunities in STBs can be achieved only through coordination with the many different players in the technology and communications network. In addition, the major component manufacturers and service providers operate internationally. For these reasons, the International Energy Agency (IEA) is convening meetings of interested parties to identify ways to enhance efficiency that can be implemented globally

Two specific near-term needs are: 1) Review major network protocols and standards (current and in development) to determine how power management might be incorporated, and 2) Develop cost-effective smart network interfaces that allow STBs to drop into low-power modes for long periods of time.

Better understanding of these issues can help the energy efficiency community develop programs to assist industry in their efforts to improve the energy performance of STBs and build customer demand for more efficient STBs.

## References


ABI. 2003. "Bundling of Multiple Services Will Save the Day for Cable MSOs." ABI Research. Oyster Bay, N.Y.: ABI.

Amann, Jennifer Thorne. 2004. *Set-Top Boxes: Opportunities and Issues in Setting Efficiency Standards.* Draft. Washington, D.C.: American Council for an Energy-Efficient Economy.

deLaski, Andrew (Appliance Standards Awareness Project). 2004. Personal communication. April 8.

[EC] European Commission. 2003. *Code of Conduct on Energy Efficiency of Digital TV Service Systems*. European Commission, Directorate-General Energy and Transport.

[EPIC] U.K. Environmental Product Information Consortium. 2004. "Product Information Base." http://www.ukepic.co.uk/productinformationbase.aspx. Dicot, United Kingdom: U.K. Environmental Product Information Consortium.

Hawn, Andrew. 2003. "First Look: Disney's MovieBeam." http://www.techtv.com/freshgear/products/story/0,23008,3581462,00.html. November 26.

[IEC] International Electrotechnical Commission. 2004. "IEC 62301 Ed 1.0: Measurement of Standby Power." IEC 59/362/CDV. Geneva, Switzerland: International Electrotechnical Commission.

InStat. 2003. "Digital TV Services and Equipment: A Look Back at 2003 & a Quick Peek into the Future." Scottsdale, Ariz.: In-Stat/MDR.

Kanellos, Michael. 2004. "Akimbo Seeks Obscure Entertainment du Jour." http://news.com.com/2100-1041-5176273.html. March 19.

[MTP] Market Transformation Programme. 2003. *BNDA1: Energy Efficiency Performance Recommendations for Digital Adaptors.* http://www.mtprog.com. Dicot, United Kingdom: Market Transformation Programme.

NAEEEC. 2004. *Free-to-Air Digital Set Top Boxes Product Standby Profile.* Canberra, Australia: National Appliance and Equipment Energy Efficiency Committee.

Rosen, Karen, Alan Meier, and Stephan Zandelin. 2001. *Energy Use of Set-top Boxes and Telephony Products in the U.S.* LBNL-45305. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

Talwani, Sanjay. 2003. "TV Makers: Approve Plug-and-Play." TVTechnology.com. Falls Church, Va.: IMAS Publishing.

[WFD] Windows for Devices. 2004. "ATI Xilleon SoC to Power Windows Media Center Extenders." http://www.widowsfordevices.com/news/NS2784787461.html. Windows for Devices.

Xilinx. 2004. "Set-Top Box End Applications. http://www.xilinx.com/esp/dvt/cdv/end_apps/stb.htm. San Jose, Calif.: Xilinx, Inc.