CABLE AND SATELLITE SET-TOP BOXES

Opportunities for Energy Savings

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ABOUT NRDC

NRDC (Natural Resources Defense Council) is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1 million members and e-activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco. For more information, visit www.nrdc.org.

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EXECUTIVE SUMMARY

Given that nearly 90 percent of U.S. households subscribe to cable or satellite service, and the cable/satellite industry is rapidly moving to boxes with high definition (HD) and hard disk program recording capabilities (DVRs), NRDC retained Ecos Consulting to:

- Measure the energy use of a wide variety of the newest set-top boxes (STBs) in the marketplace, including multifunction STBs that have HD cable or satellite signal converters and DVRs.
- Provide recommendations on ways to reduce cable/satellite STB power consumption without compromising performance.
- Estimate the energy and carbon dioxide savings that could be attained by moving to more efficient STB models.
- Recommend next steps for interested researchers, policy makers, and energy efficiency advocates.

STB Market

Although “set-top box” is a label that applies to boxes with a wide variety of functionalities, the focus of this report is cable/satellite boxes, which includes digital cable boxes, satellite receivers, and multifunction DVRs. The current trend is toward multifunction set-top boxes that combine services, such as such as digital video recording (DVR) and high definition (HD) display capability, that have historically been in separate STB units (*e.g.* a stand alone TiVo recorder). Cable/satellite users almost always get their boxes as part of their agreement with service providers. These hardware services are used to retain and recruit customers. One analyst estimates that the worldwide multifunction cable/satellite market will grow 59 percent annually until 2008 at which point: 71.5 million units will be in use worldwide.[1] As more of these multifunction boxes, which have hard drives, software, and CPUs, are installed in homes, the energy consumption of cable/satellite STBs will only increase.

STB Measurement

To better understand cable/satellite STB energy consumption, we measured the AC power used by 22 of the newest cable and satellite STBs, including HD boxes and DVR-tuner combination units. Whether or not the power switch was “off” or “on,” all of the cable/satellite STBs in our data set were in some variation of on mode, either ready mode or active mode. These STBs consumed from 8 to 44 watts when the device is in ready mode (when the user perceives the device to be switched “off”) and 8 to 47 watts when the device is in active mode (when the user perceives the device to be “on”). This translates into a range of 70 to 390 kWh per year, assuming that STBs are on for five and off for 19 hours per day. Other major findings include:

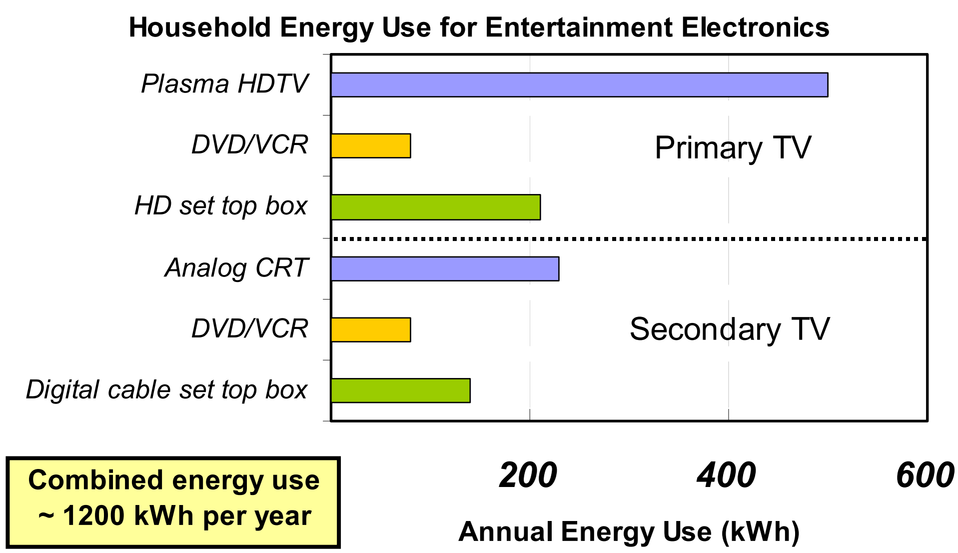
- With increased STB functionality comes increased energy use. Adding HD functionality adds 5 to 10 Watts of power use because the STB has to process more picture information, and further adding DVR functionality contributes roughly another 10 Watts of power use.
- Active mode and ready mode energy use are nearly identical for cable/satellite boxes (both converters and multifunction devices). Cable and satellite boxes consume nearly the same amount of energy when the user device is in ready mode as when the device is in active mode. In other words, physically turning off current STB, by pushing the power button does little to change the energy consumption of the device.
- STBs that perform the same basic functionality can consume radically different amounts of energy over the course of the year.
- No manufacturer in our data set consistently had boxes with lower energy use than other manufacturers.

In addition, we measured the efficiency of four STB internal power supplies, which are the components inside the STB that convert high voltage AC from the wall outlet to the low voltage DC needed to operate digital circuitry. At the STB's normal point of operation, efficiencies ranged from 68 to 82 percent, but power supply technology that achieves 85 percent efficiencies is available today.

Household Energy Use

So that different programs can be viewed simultaneously on two different TVs, many households have two or more STBs, bringing STB household energy use between 300 and 400 kWh per year, which is beginning to approach the annual energy use of a new home refrigerator. If the energy use of the TV and other home entertainment peripherals are included, household energy use of home entertainment components can easily exceed 1,000 kWh per year, or that of two new refrigerators (Figure 1). This amount translates to approximately 10 percent of residential electricity use and is greater than the average annual energy used to light the entire home.

Figure 1: Example of household annual energy use of home entertainment electronics.



Technical Approaches to Reduce STB Energy Use

We identified 2 methods to decrease energy consumption of STBs: 1) improve the efficiency of the internal power supply, and 2) create a STB sleep mode that would demand less power than ready mode, but would be automatically engaged and disengaged when the user is not watching TV for extended periods (*e.g.* between the hours of midnight and 6:00 A.M.). Improving the efficiency of a STB power supply is relatively easy to implement because STB power supplies are usually located on a board separate from the rest of the STB circuitry, such that no redesign of the STB functionality needs to occur.

Unfortunately, incorporating a sleep mode in STBs is more difficult to implement because a sleep mode solution would need to be developed and specified by service providers and agreed upon by hardware manufacturers, software developers, and communication protocol experts. A STB in sleep mode would need to "wake" when sent a specific signal from the service provider, so that programming could be downloaded and security of the system could be ensured. The STB would also need to wake if the user decided that he or she wanted to watch TV or record a program to the DVR. Later, after the downloads are complete, or the user has turned off the TV, the STB would transition back to the sleep mode. There is an opportunity to model a U.S. solution after a European service provider, Sky, who is planning on implementing low ready mode power in European systems.

Potential Energy Savings

In Table 1 below are three different national energy-saving scenarios that considered these two technical solutions separately and in combination. At a minimum, and without any redesign to the other components in a STB, power supply efficiency could be improved to 85%, which would have a first year savings of 156 million kWh, and a 4-year cumulative impact of 1.4 billion kWh. If STBs reduced ready mode power to 5 W and sleep mode power to 1 W, which is a more aggressive approach than the European Code of Conduct recommendations, first year savings would be approximately 440 million kWh in the first year, with a 4 year cumulative impact of approximately 4.4 billion kWh in total. If both of these strategies were to be combined 450 million kWh would be saved in the first year, and 4.5 billion kWh saved in total, 4 years after implementation. The average utility bill energy savings per box under this scenario is $12 per year per box.

Table 1: Range of environmental benefits associated with the energy savings initiatives

Initiative	National Energy Savings, 4 Year Cumulative Total (millions kWh)	National Carbon Dioxide Savings, Total 4 Year Cumulative (million tons CO_2)	National Value of Electricity Saved Total 4 Year Cumulative (millions of dollars)	Equivalent Number of American Households Powered for One Year
Power Supply Efficiency Improvement to 85%	1401	0.9	118.5	137,000
Aggressive Ready Mode Power Reduction and Sleep Mode Implementation	4384	2.9	370.9	428,975
Aggressive Ready Mode Power Reduction, Sleep Mode Implementation, and PS Efficiency Improvement to 85%	4550	3.0	385.0	445,000

Policy Recommendations and Next Steps

Work with service providers and wider industry players. In most cases, service providers such as Comcast and Dish specify the design features to be contained in the boxes and directly purchase millions of these boxes each year for distribution to their customers. As such, it is essential to engage service providers in a dialogue to convince them of the worthwhile nature of embarking on reducing energy consumption of STBs and to gain their support. We suggest that energy efficiency advocates and experts propose to service providers a two-tiered approach to reducing STB energy use. In the near term, energy savings could be captured with a known prescriptive power supply solution, which would set an absolute minimum value for STB power supply efficiency at 85 percent at normal active operation. In the long term, energy savings could be achieved by dropping ready mode power use and creating and implementing a sleep mode industry standard that would enable minimal power use while the STB is not performing any active function for the service provider or the home user. To bring these energy savings initiatives to fruition, additional outreach will also be needed to other key stakeholders including the STB manufacturers, component suppliers, and software developers.

Standards/Specifications. A single or multitiered energy performance specification should be developed by voluntary labeling programs like ENERGY STAR®, and by future mandatory standards bodies at the federal or state level, as appropriate. **A key to a successful specification is that the STB not only have a low power mode, like sleep, but that it automatically goes into this mode during extended periods of inactivity.** A national specification would make it easier for bulk purchasers to request the more efficient boxes, and would provide an efficiency target for interested STB manufacturers and their suppliers.

Revise Test Procedure. NRDC/Ecos recommends that U.S. energy efficiency advocates engage in an international process to revise the STB international energy test procedure, IEC 62087. These revisions should focus on: 1) modifying mode definitions in the test procedure to encompass multifunction and more advanced STB and 2) improving STB loading guidelines so that more complex boxes can be accurately measured.

Support digital television converter initiatives. Although specific details about digital television converters (DTCs) are outside of the scope of the larger discussion of this report, we support the international 8 Watts active, 1 Watt sleep initiatives currently under way for DTCs. Not only should these DTCs have a low power mode, but they should also be able to enter them automatically when the device is not actively being used. Further, we recommend that advocates working to improve the efficiency of cable/satellite STB make efforts to use similar language and approaches and test procedures as what is being developed for the DTCs, so that communication with industry is more effective.

MARKET AND POLICY SUMMARY

Although often overshadowed by the newest television, the latest progressive scan DVD, or the surround sound system, the set-top box (STB) is a silent but necessary component of U.S. home entertainment centers. Usually provided by the cable or satellite service for a nominal fee, the basic STB takes the signal from the cable feed or satellite dish and converts it into a signal that can be used by a TV, sound amplifier, DVD, VCR, or TiVo™ unit. Increasingly, these STBs contain digital video recorders (TiVo type units usually abbreviated DVR), which give the user the ability to rewind a program while it is being broadcasted, record programming on a hard drive for future viewing, and fast forward through commercials. Adding a DVD burner allows users to create DVDs of programming to carry along and play on a friend's computer or DVD player. These and other added functionalities, including Internet and e-mail access and pay-per-view programming, also come with an energy penalty. This penalty is compounded by the hardware and software configurations of most of today's STBs, which are designed to be on, in either ready or active mode, 24 hours per day, seven days per week, even while the user may think the box is turned off. The most complicated boxes can consume 300 kWh per year.

The energy efficiency community has raised concerns about the energy use of today's STBs because the power needed by the STB when the user is watching/recording programming and the power needed by the STB when the user has physically hit the off button are virtually the same. It seems there is a potential to add a lower sleep type mode already found in most other consumer electronics such as computers, printers, faxes, and office copiers in these boxes that are in the majority of American homes.

NRDC retained Ecos Consulting to research the near-term opportunities in one STB segment, cable and satellite network boxes (represented in the white sections in Figure 2). The scope did not address opportunities associated with digital TV converters, video game consoles, media PCs, or DVR-only units (such as TiVo), although some of these types of boxes were used for comparison to the cable and satellite units. NRDC chose to focus on the cable and satellite market for the following reasons:

- nearly 90 percent of households subscribe to cable and satellite service;
- a large number of units are installed every year; and
- the industry is rapidly moving to boxes with high definition (HD) and hard disk program recording capabilities (DVRs).

Types of STBs

Although the focus of this report is cable and satellite STBs, STBs is a label that applies to boxes with all types of functionalities. Increasing the number of services provided by STBs, and combining services that have historically been in separate STB units, have created more functional and more energy consumptive STBs in the marketplace. As a result, there is an ever-blurry line between a set-top box that sits next to the television and a personal computer that is in the home office. The main categories of STBs include (in order of increasing functionality and on mode power use):

Digital television converters. Used with older "analog" televisions to interpret basic digital off-air signals, these STBs are uncommon today, but will become necessary in the near future for viewing programming off-air.

Cable and satellite converters, which interpret cable and satellite signals and feed that signal to a TV, DVD, etc. These basic units often include modems and memory to download and store program guide information and enable pay-per-view functions.

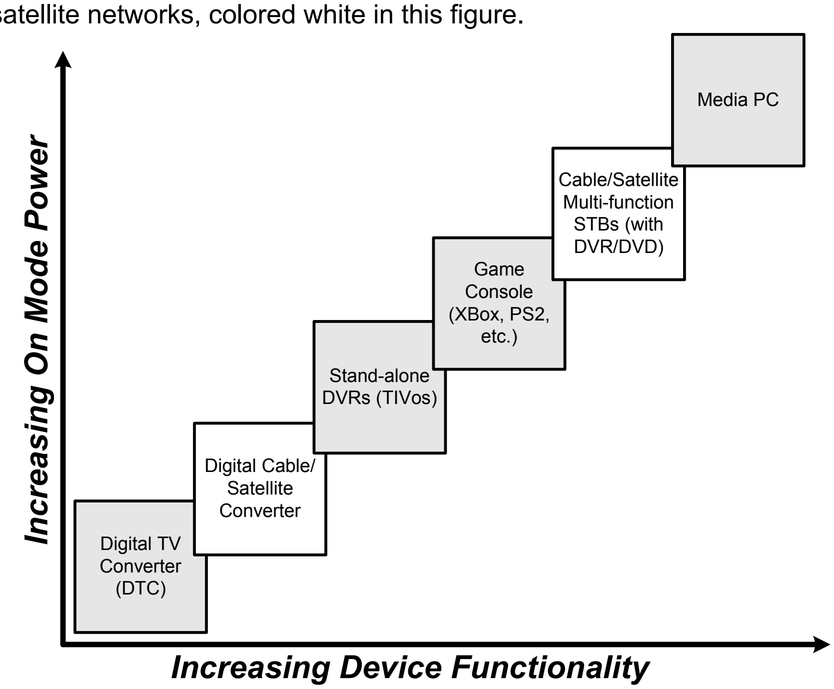
Digital video recorders (DVRs or TiVos). These stand-alone DVRs take input from a cable or satellite converter, a digital television converter, or an off-air antenna, and record and play back programming using a hard drive.

Cable and satellite multifunction STBs. In addition to interpreting cable and satellite signals, these STBs contain recording and playback functionality, either using a DVR or DVD technology, or other added services, including Internet and e-mail access, or connection to a network of boxes that service other TVs in a household.

Game consoles. These small, scaled-down PCs, with processors, memory chips, and hard disk drives, render video games for the user.

Media PCs. Computer manufacturers, including large players like HP and Gateway, have created PCs that are meant specifically for use with the home entertainment system and use roughly six times more power than today's typical STB when in active mode. These media PCs were featured on the cover of the November issue of *PC Magazine*.[2]

Figure 2: Continuum of STB functionality and energy use. The focus of this paper is STBs that are used with cable and satellite networks, colored white in this figure.



Off-Air, Cable, and Satellite

When television signal transmission began, analog National Television Standards Committee (NTSC) signals were broadcasted from a station through the air, and users needed only an antenna on top of a TV to pick up the broadcast signal. Today, 89 percent of U.S. households receive television programming through cable and satellite providers, and most of those households need a STB to properly view the programming provided.

Table 2: Percent market share of the three television signal distribution methods[3]

Means of Distribution	Pay to View?	Percent of U.S. Households
Off-Air (Terrestrial)	No	11%
Cable	Yes	69%
Satellite	Yes	20%

Policy changes by the Federal Communications Commission (FCC) in the last 10 years are reshaping the television programming options available to consumers. The Telecommunications Act of 1996 mandated that, by the end of 2006, off-air TV transmission must move entirely from analog to digital, improving picture quality and introducing the need to supplement the standard tuners in most of today's TVs with digital television converters (DTCs). This format change opened up the door for programming providers to provide some programming in high definition (HD) format, which gives a higher quality picture than the standard definition format (SD). Regulations were modified in 1999 so that cable boxes could be purchased in retail, instead of only leased from the cable company directly, but most cable subscribers today still lease their boxes from the provider. Most recently, a 2003 initiative was undertaken to create a solution that allows digital cable to be viewed without a STB; a card slides into the back of a compatible TV and the cable plugs directly into the television itself (CableCARD™ is now commercially available).

Cost, added functionality, and quality of signal will continue to determine which distribution channel (over-the-air, cable, and satellite) is chosen by consumers. The conversion from analog to digital does not in general directly impact cable and satellite content providers, but it does *indirectly* force them to take action in order to remain competitive. Offering STBs with added functionality, such as digital video recording (DVR) and high definition (HD) display capability, is expected to be an important technique used by satellite and cable service providers to encourage consumers to subscribe. For example, Time Warner Cable recently offered combined programming and DVR services for less than $10 a month, charged no upfront fee for the STB hardware, and signed up more than 200,000 subscribers in just one year.[4] Similarly, the satellite service, Dish Television, has an advertisement online that offers to provide a STB network so that all televisions can display a different channel of satellite programming, and a DVR capability so that programming on other channels can be recorded simultaneously (Figure 3). These hardware-focused initiatives undertaken by service providers are in response to other emerging technologies that compete with STBs, including the CableCARD and the Media PC, which combines Internet accessibility, television programming, hard disk recording, and video gaming in one box.

Figure 3: Advertisement from Dish Television focusing on providing low cost hardware services to consumers.

STB Stock Estimates

With fierce competition among cable and satellite companies, the sales and stock of specific types of units is difficult to predict. Nevertheless, analysts agree that unit sales of DVRs, especially as part of the multifunction cable/satellite service platforms, are only going to increase in the next few years. Strategy Analytics estimates that the worldwide multifunction cable/satellite market will grow 59 percent annually until 2008: roughly 900,000 of these units shipped in 2002 and 28 million of these units shipped in 2008, with a worldwide total of 71.5 million units in use worldwide by 2008.[5] Acme Electric Corporation estimated the stock of broad categories of STBs, which are listed in Table 3.

Table 3: Stock estimates of Cable/Satellite STB categories. The percentage of HD and DVRs in each category is expected to increase in time. [6]

Products	2003 Stock (millions)	2010 Stock (millions)
Cable Converters HD Cable Converters Multifunction Cable Converters (including DVR)	35	65
Satellite Converters HD Satellite Converters Multifunction Satellite Converters (including DVR)	32	42
TOTAL	67	107

Policy Summary

A number of governments around the globe have taken an interest in the energy use of cable and satellite STBs. Table 4 gives a summary of the current initiatives relevant to cable and satellite markets.[7] Additionally, China's Center for Energy Conserving Products (CECP) is considering adopting STB specifications as the government prepares to give low interest loans to cable providers in order to accelerate the placement of digital to analog signal converter boxes, or DTCs, in Chinese homes before the 2008 Olympics.[8] Korea's Standby Power Program is also considering STB energy use.

Table 4: Summary of policy initiatives associated with cable and satellite market[9]

Government Organization	Year In Effect	Program Type	Relevant Products Affected	Current Specification/Standard	Notes
U.S. EPA ENERGY STAR®	2001	Voluntary	Digital cable and satellite boxes and multifunction devices (e.g., DVR combined with digital cable)	Standby power < 15 W for less functional products and as much as <35 W for more complex products	Covers a wide range of other products, including video game consoles and videophone boxes. Tier 2, scheduled to take effect in 2004, is postponed indefinitely. To date, the program has not been particularly effective due to low participation by manufacturers and excessively high standby levels allowed.
European Union Code of Conduct	2003	Voluntary	Digital cable and satellite boxes and multifunction devices (e.g., DVR combined with digital cable)	Standby-active power < 9 W to < 15 W, depending on functionality. Standby-passive < 6 W	Absolute power allowed in standby modes to drop in 2006. Also covers digital converters.
Australia[10]	April 2006	Mandatory	Digital cable and satellite boxes	Standby power < 15 W	Mandatory initiatives also underway for digital converters that would require < 8 W for On mode and < 1W for standby mode

TEST METHOD, MEASUREMENT, AND DATA ANALYSIS

STB Test Method and Mode Nomenclature

The International Electrotechnical Committee (IEC) has created the only formal test method available for measuring power use of STBs. This method, IEC 62087, also covers TVs, video recording equipment, and audio equipment.

A number of different systems are currently in use to define the modes of STBs, but we found none of them fit well with the current U.S. consumer electronics nomenclature used with computers, office copiers, and fax machines. With input from Bruce Nordman, from Lawrence Berkeley National Laboratory (LBNL), we have developed mode names and definitions that match more closely to other electronic equipment mode names, and can easily be understood by the consumer (Table 5).[11] These mode names will be used throughout the course of the discussion. For convenience, we cross-reference Camco Inc./IEC names that are currently in use, and give the approximate power use of today's typical cable converter in each of the modes. Although the absolute power levels of an individual STB may vary widely depending on the functionality of the box, the power differences among the modes will only vary slightly from one STB to another. For example, the ready mode is usually only 1 to 2 Watts below active mode, even though the active mode of one box might be 12 Watts and the active mode of another box might be 30 Watts. We also include in this column power targets that are used in the energy savings scenarios and policy recommendations.

There seem to be two ways that the STB could move among the modes of active, ready and sleep. The STB could use ready mode as its "home base" mode, or the STB could use sleep as its "home base" mode. For the purposes of describing these two scenarios, assume that this is a multifunction STB in active mode. The user is watching TV and programming the STB's internal DVR to record a show that occurs on late-night TV. The user gets finished programming the STB and uses the remote to" turn off" the TV and STB.

In the ready mode "home base" scenario, the STB goes into ready mode for a certain period of time, and then, after a set period of time passes with no signal from the service provider or from the remote of the home user, the STB falls automatically into sleep. Later, it "wakes" from sleep into active mode to record the program the user had indicated. After the program is complete, the STB falls into the ready mode, and then after the same set period of time, into sleep mode. Later, the box wakes out of sleep mode and into ready mode by the service provider for a programming guide update. Although using ready mode as the "home base" is a more linear approach to moving up and down the mode structure with inputs from the service provider and the user, if there is a significant power use difference between ready mode and sleep mode, then energy is being consumed in active mode when it is not providing and increased functionality to the user.

If instead, we consider sleep as the "home base" mode, there are fewer transitions from mode to mode, and the box is not spending a significant amount of time and energy in ready mode. Instead the STB goes alternately into ready mode and active mode as it needs to provide different services to the user. So in this scenario, after the user presses the power button on the remote to "turn off" the STB, the STB falls immediately into sleep mode, waking up later with a timing circuit to go into active mode to record the program requested. After the program is complete, the

STB falls into sleep mode. Later, the box wakes out of sleep mode and into ready mode by the service provider for a programming guide update.

If the power levels of sleep and ready were both relatively low power, the energy consumption difference between the two scenarios outlined above would be minimal. But instead, if sleep mode required significantly less power than ready mode, and one were interested in saving energy, it would be preferable to create a protocol that enabled the most aggressive use of sleep mode by using sleep mode as the "home base" mode.

Table 5: STB Modes of operation.

Mode Category	Recommended Mode Name	Definition of Mode	IEC/COC Mode Name	Mode Observed in Today's STBs	Approximate Power Use of a Typical Cable Converter
On	Active	In current STBs, user perceives STB to be "on" when in this mode. This is when the user is watching or recording a show. The STB is plugged in and is performing any number of functionalities for the user, including, but not limited to: video signal processing, DVR recording and playing, DVD recording or playing, feeding video signal to multiple televisions, etc.	On (Play), but the definition only includes video signal processing	Yes	Today: 31 W
	Ready	In current STBs, the user perceives the STB to be "off" in this mode, but this mode is actually a form of on. The STB is plugged in and is exchanging data with, or downloading programming from the service provider. It is not necessary that the user distinguish between this mode and the sleep mode. A switch on the STB itself, or a signal from the remote control can move the STB into the Active mode from this mode. After some period of time, the STB automatically transitions from this mode to the lower power sleep mode. Currently, this mode has nearly the same power consumption as the active mode. Likely, this is because other relevant circuits, like the signal processor, etc. is not being disengaged when the user is not watching TV.	Standby Active (high and low)	Yes	Today: 30 W Target: 5 to 9 W
Sleep	Sleep	This mode does not exist in today's STBs. STB is plugged in, all services other than communications provided by the STB are disengaged, including signal processing, DVR recording, and data downloading from service provider. STB can be turned to ready or active mode with the remote control, a switch on the STB itself, a signal from the service provider, or a signal from the internal clock of the STB that tells the STB that it needs to "wake up" to record a show on the DVR.	Standby Passive	No	Does not exist today Target: 1 to 6 W
Off	Unplugged	STB is unplugged and drawing no power. Box cannot communicate with service provider, and when plugged in, must download programming from service provider, which can take hours.	Disconnected	Yes	NA

Wall Plug STB Measurements and Data Analysis

Because our testing was conducted in electronics retail stores and residential settings, Ecos found it necessary to deviate from the IEC 62087 test standard to gather data on STB active mode power use. For the purposes of our tests, STBs were powered by the wall outlet and connected to relevant video and audio signal input from the service provider. Then, after a brief warm-up period, the high and low power values observed on a power meter were recorded in two modes: active and ready. Although not always possible, we tried in all cases to measure the STB when it was under typical user conditions, including video signal input, hard drive spinning on DVR, video signal being sent to TV, etc. We did not observe a sleep mode, as described above, in any of the STBs that we measured. This field test method was useful because it allowed Ecos to collect a large amount of data on current STB models that are too expensive to purchase and test in the lab. At the same time, because the signal input varied from unit to unit tested and each box may have had different setup conditions that varied with the user and service provider, the data is not necessarily repeatable but only *indicative* of STB power use. As such, we caution the reader against drawing definitive conclusions about the specific energy use of one box compared to another.

For this study, Ecos focused on measuring 22 of the newest cable and satellite STBs, including HD boxes and DVR-tuner combination units, but when possible we also measured other types of high functionality STBs for comparison. Ecos measurements were combined with 14 measurements from Cadmus [12] and three measurements from LBNL, for a total of 39 units measured. The results are summarized in Figure 5 and fall into the following categories:

Satellite converter. Interpret satellite signals and feed that signal to a TV, DVD, etc. Can be standard definition (SD) or high definition (HD).

Cable converter. Interpret satellite signals and feed that signal to a TV, DVD, etc. Can be SD or HD.

DVRs or TiVos. Take input from a cable or satellite converter, a digital television converter, or an off-air antenna, and record and play back programming using a hard drive.

Game Consoles. Computes information in scaled-down PC to render video games.

Cable and satellite multifunction DVRs. Interprets cable and/or satellite signals, records and plays back programming using a hard-disk drive.

Media PCs. Interprets cable and/or satellite signals, records and plays back programming using a hard-disk drive, computes information in a scaled-down PC to render video games, enables access to the Internet and e-mail, creates DVDs, etc.

The following observations can be made of these data (which are detailed in Appendix A):

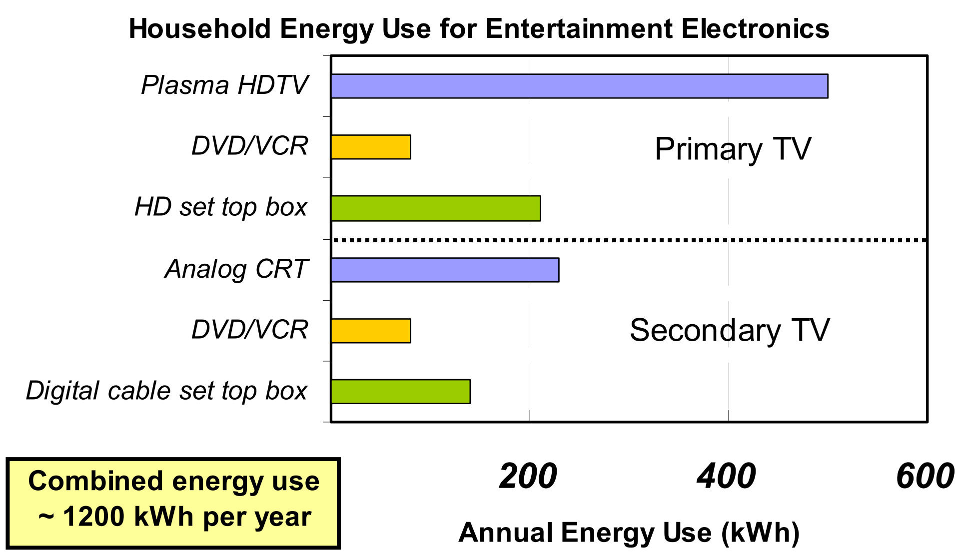
With increased STB functionality comes increased energy use. The STBs on the left-hand side of Figure 5 are designed to perform a single function, either signal tuning, digital video recording, or video gaming. Notice that the boxes with the lowest power requirements are those that only receive and tune cable or satellite signals. Adding HD functionality adds 5 to 10 Watts of power use because the STB has to process more picture information, and further adding DVR functionality contributes roughly another 10 Watts of power use. On the far right of the chart is a Media PC that consumes roughly 130 Watts when active and combines all the functionalities already mentioned, plus Internet and e-mail accessibility, digital photo viewing, DVD burning, etc. As the prevalence of these higher functionality boxes increases, we should expect to see a rise in energy use of STBs nationwide, especially if these boxes do not have a low power sleep mode for extended periods of inactivity.

Active and ready mode energy use are nearly identical for cable/satellite boxes (both converters and multifunction devices). Cable and satellite boxes consume nearly the same amount of energy when the consumer has powered the device "Off" (ready mode) as when the consumer turns the device "On" (active mode). The exception to this rule are Media PCs, which are already equipped with an energy-saving low power mode that can be enabled by the user, and game consoles, which are never connected to a cable or satellite signal.

STB energy use is approaching that of a refrigerator. STBs are contributing to the increasing energy consumption by consumer electronics in the last 10 years:

One STB today can consume 200 kWh or more per year. Many households have a second TV with a STB in the bedroom, playroom, or kitchen, that can bring the total annual household energy use of STBs to around 400 kWh per year per household (Figure 4), which is approaching the energy use of a new refrigerator. Further, STB networks, like those being advertised in Figure 3, can have up to four STBs, where household energy use can reach 600 to 700 kWh per year for the STBs alone. If the energy use of the TV and other home entertainment peripherals are included, household energy use of home entertainment can exceed that of two new refrigerators, roughly 1,000 kWh per year. Addition of a home theater sound system would increase household energy use related to TVs even further.

Figure 4: Example of household annual energy use of home entertainment electronics



Other Cable and Satellite Trends:

- Satellite converter power use is generally 3 to 5 watts lower than cable converter power use, both in standard models and HD models (Figure 5).
- STBs that perform the same basic functionality can consume radically different amounts of energy over the course of the year: The RCA 1 satellite converter consumes half of the amount as the Sony 2 satellite converter.
- We measured boxes from eight different manufacturers: Dish, Hughes, Motorola-General Instruments,[13] Pace Micro, RCA, Samsung, Scientific Atlanta, and Sony, and not one manufacturer consistently had low power use relative to the other manufacturers. In fact, Dish had the highest and lowest annual energy use for the Multifunction Cable/Satellite DVR units, and Motorola/General Instruments had the highest and lowest annual energy use for the Cable Converter STBs (Figure 6).

Power Supply Measurements

The other portion of our work involved measuring the efficiency of four STB internal power supplies, which are the components inside the STB that convert high voltage AC from the wall outlet to the low voltage DC needed to operate digital circuitry. To perform this work, Ecos retained Electric Power Research Institute to measure the power supply efficiency of four STBs currently in the market: the General Instruments DCT 2000, the Pace Micro 510, and the Scientific Atlanta Explorer 3100 (cable converter), and the Scientific Atlanta Explorer 8000 (HD cable tuner with DVR). We found efficiencies[14] can be as low as 68 percent and as high as 82 percent at the STB's normal point of operation, where these STBs operate all of the time. Power supply efficiency was higher than the average efficiencies measured in comparable products, like computers and monitors, but there is still an opportunity for incremental energy savings if the power supply efficiency were to shift to the most efficient available: 85 percent.[15]

Table 6: Power supply efficiency of 4 STBs at normal point of operation

STB Manufacturer and Model	DC Output Power at Normal Point of Operation (watts)	AC-DC Efficiency at Normal Point of Operation
General Instruments DCT 2000	15.6	68%
Pace Micro 510	11.4	78%
Scientific Atlanta Explorer 3100	13.9	82%
Scientific Atlanta Explorer 8000	23.3	73%

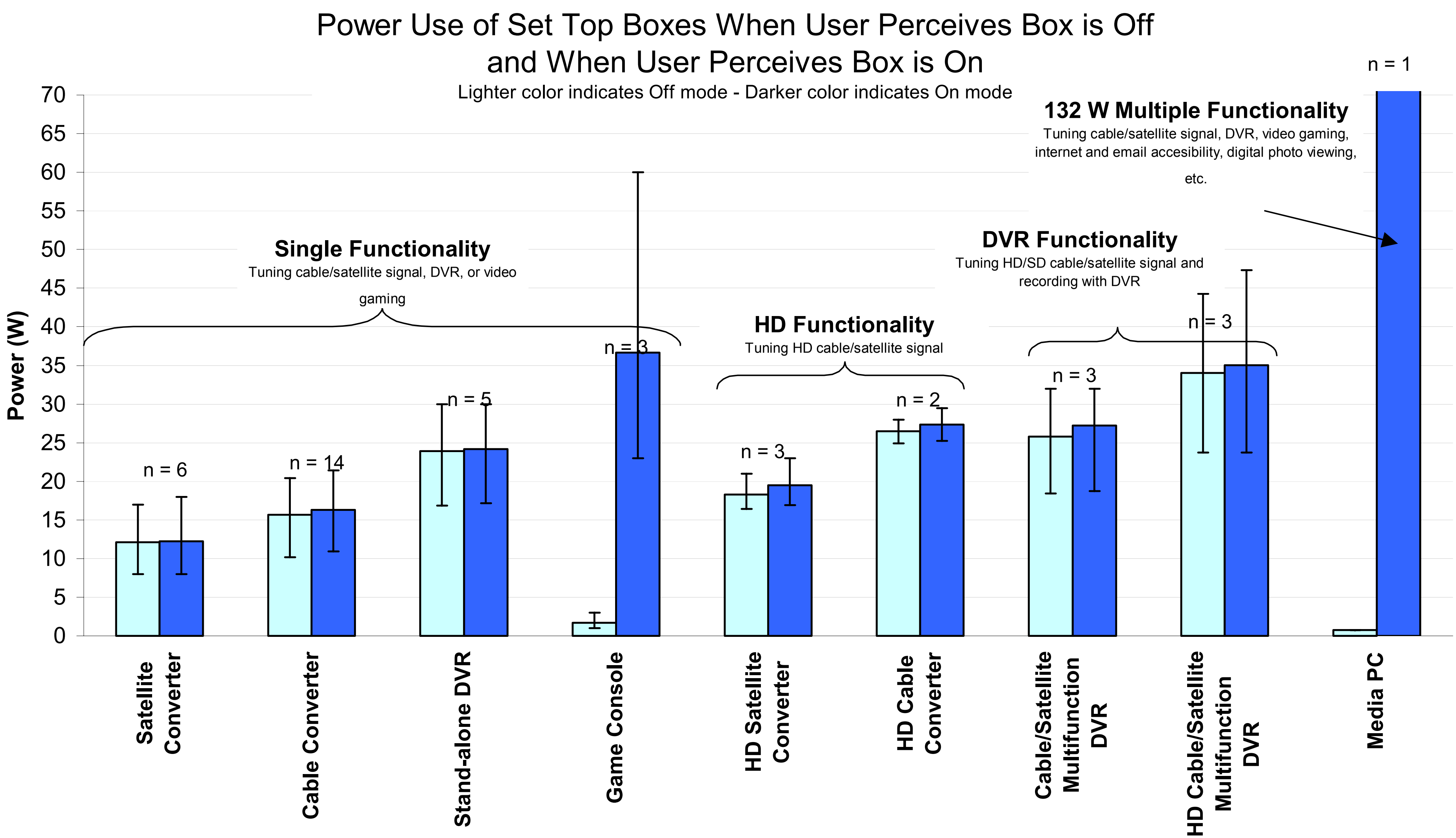


Figure 5: Summary of STB units measured. Values shown are averages; the error bar indicates the range of measurements between models within a STB type.

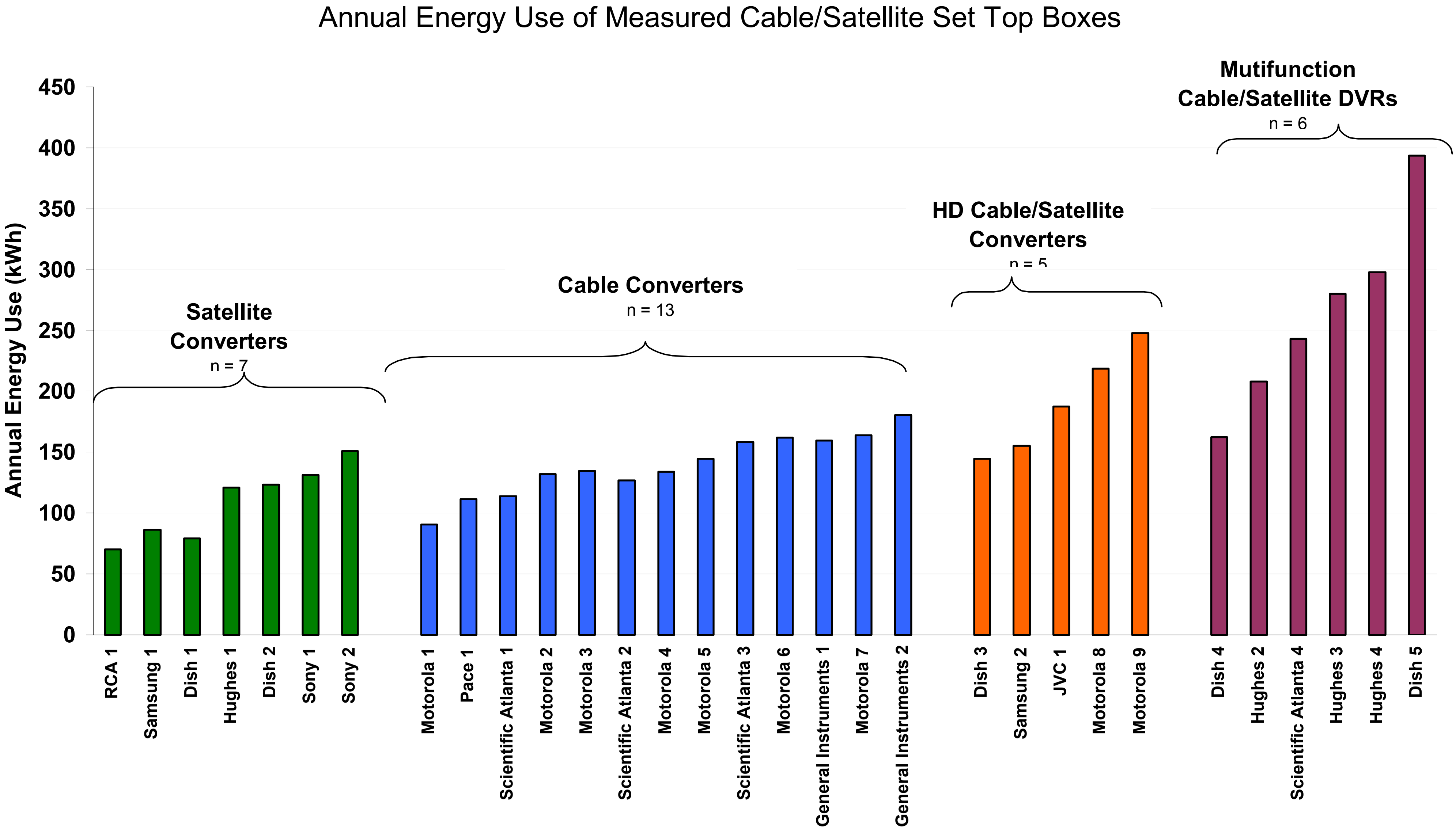


Figure 6: Summary of Cable/Satellite STB Units Measured. For brevity, cardinal numbers are substituted for model numbers. For more detailed information, please see Appendix A.

TECHNICAL RECOMMENDATIONS

Creation of Sleep Mode

One of the main technical findings of our research was that power use of Cable/Satellite STBs is virtually the same whether the user perceives the box to be "On" (active mode) or the user perceives the box to be "Off" (ready mode). **This means that when the consumer has powered the device "Off," the unit continues to consume nearly as much energy as when the user perceives that it is "On."** The main reason that the STB has such high power consumption in ready mode is because the content provider needs access to the device from the head-end to download programming, update software, and perform subscription verification. Rather than powering down unnecessary circuits and falling into sleep mode in between updates and downloads, STBs are in effect continuously powered up, always waiting for the head-end to communicate.

Because the functionality of STBs is in flux and the markets rapidly advancing, defining and regulating the active mode efficiency of a STB is a difficult prospect. A huge number of variables would need to be taken into account and measured, including video processing, DVR functionality, DVD writing, etc. (See Appendix A for further examples of these variables.) Therefore, it is likely the best near-term technical solution to reduce STB energy use when the STB is not in active mode, where the STB of today spends the majority of its time (when the user is not watching TV or recording a program). It seems that there is an opportunity to not only reduce ready mode power requirements, but also introduce a sleep mode, which is even lower energy consumption than the ready mode. This can be achieved by following the model that European television service provider Sky is planning to implement: automatically shutting off those circuits in a STB that perform no useful function.[16]

Four of the five savings scenarios outlined in the next section achieve energy savings by automatically transitioning the STB from ready mode of today into a low power, sleep mode that has significantly reduced energy use. We have not observed this mode in the boxes that are currently available on the market, but this type of sleep mode has been suggested as part of the European Code of Conduct (COC) process and elsewhere as an option for reducing energy consumption of STBs. In order for the STB to be able to enter a low power mode, called standby passive by the COC, at least three issues must be addressed:

Hardware solutions. In order for a circuit to power down, there must be some physical mechanism for reducing or eliminating current in that circuit. This type of powering down is analogous to the "sleep" technology developed by Intel and others in the PC world, which is available in nearly all PCs and monitors in stores today. Because STBs are essentially task-specific PCs, it seems possible to borrow the hardware technology that has been developed in the PC world and apply it to STBs. In fact, Intel, one of the largest players in the computer market, has developed chip sets for STBs.

It seems there are also other opportunities to borrow more efficient hardware solutions from the PC world. For example, some STBs have no permanent method of storing information, so that if the STB is unplugged inadvertently, programming must be downloaded for hours when the STB is attached again plugged in. These temporary memory storage devices also require some amount of energy to continually refresh and update the memory. Many types of hard drive technology currently employed in desktops (such as Flash cards and other less expensive technologies) could be used instead of temporary memory that requires continuous energy use.

Lastly, outreach should be done to chip manufacturers to develop “power partitioning” chips that allow the chips in the set box to operate at multiple power voltage and frequency levels. AMD’s Cool and Quiet technology and Intel’s Demand Based Switching technology are two examples of proven strategies that could be translated to the STB platform.17 Most chips currently used in set-top boxes do not include this potential energy saving capability.

Software solutions. Powering down hardware cannot be enabled without software that is able to interact with the hardware to enable these features. We recommend that the software enable sleep functions for all unnecessary circuitry automatically when the user turns off the STB, or during extended periods of inactivity in the event the user has left the box on overnight, etc.

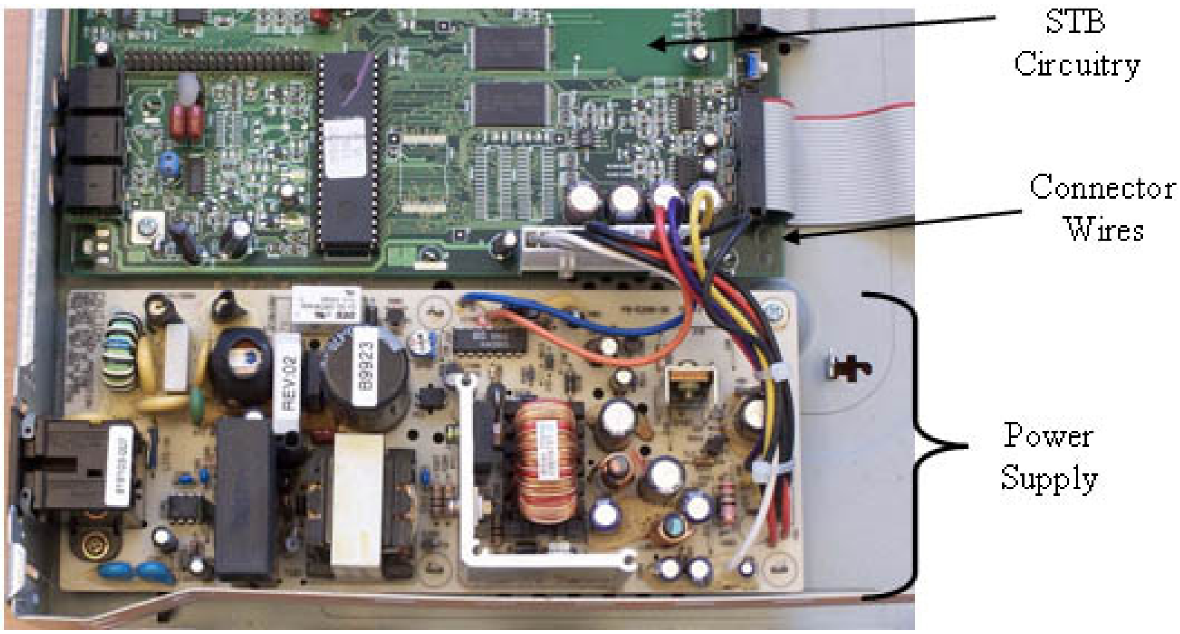
Communication protocol revision. Communication protocol currently used by cable and satellite providers forces high standby power use because the content provider requires 24-hour access to the device to download programming, update software, and perform subscription verification. In order to allow the STB to power down to a sleep mode, “wake-up” and “sleep” communication procedures must be developed not only for communication between the service provider and the STB, but also for communication among STBs themselves, because it is increasingly popular to have networked STBs, especially for satellite service where different content is provided to multiple TVs.

Finally, and most important, service providers, such as Time Warner and Comcast, must enable whatever solution is developed as a default. The technical solution, however elegant, cannot be adopted if it does not meet the needs of the customer that is served. As a result, service providers, software developers, communications specialists, and hardware developers must equally engage to find a solution that enables U.S. STBs to enter a low power sleep mode. This will require extensive communication and coordination among the various parties.

Improving Power Supply Efficiency

In the near term, while hardware solutions, software solutions, and alternative communication protocols that allow lower power modes are being developed, power supply efficiency can be a way to reduce overall power use regardless of mode of operation or software employed. Improving power supply efficiency reduces the energy use of STBs, and the energy savings are readily available and automatic. In all of the boxes surveyed for this project, the STB power supply was located on a board separate from the rest of the circuitry, and the two boards were connected with some type of wire connector. This suggests that the design and circuitry layout associated with the functionality of the STB does not have to be altered in order to introduce a more efficient power supply into future STB designs (Figure 7). In other words, more efficient internal power supplies should be viewed as a simple to achieve “drop-in” upgrade that does not require the manufacturer to retool their production process. We do not have sufficient information to determine the potential incremental cost of the more efficient models.

Figure 7: Typical configuration of a STB has the power supply located on a board separate from the circuitry that controls the functionality of the STB.



Revisions to IEC 62087

Based on our research, we recommend that small modifications be made to IEC 62087 to more closely match the U.S. STB market of today. Because U.S. STBs are not currently designed to minimize their energy consumption and enter lower power modes, such as sleep, IEC 62087 defines more power modes than U.S. STBs currently employ. (Please refer to Table 5 for more information.) Additionally, because recording devices, such as DVRs, were not combined with a digital cable/satellite tuner when the last version of IEC 62087 was released, the definition of active mode (referred to as "On" mode in the test procedure) does not include recording or feeding signals to other boxes. It is likely that extending the definition of active mode to include DVR operation and other functionalities, either by extending the definition of active mode or creating a new mode that includes recording, playing, accessing the Internet, etc., will be a necessary modification. We recommend that U.S. stakeholders engage to reconsider the modes in the test procedure, potentially removing those modes that are no longer relevant (such as "Off"), and adding or extending mode definitions related to the active mode.

We also found that the mode names found in IEC 62087 do not fit well with the current U.S. consumer electronics nomenclature used with computers, office copiers, and fax machines. We recommend that the mode names in Table 5 be adopted, at least in the United States, and if possible, on a more international scale.

Because the STB market has changed since the standard was created, using IEC 62087 to measure the newest multifunction boxes is likely to underestimate the power used under normal operation in a home. IEC 62087 specifies that the STB be powered by an AC reference source and fed standard audio and visual signals while the low-noise blocks on a satellite STB are loaded to a specified level (there are no such loads on the cable STB). Unfortunately, STB models that are on the market today have a different LNB[18] load than what is specified in the procedure,[19] and sometimes have other loads than just processing and outputting video and audio signal, including recording that signal to a hard drive, providing video signals to other boxes in the house, or burning a DVD. Because the STB market is constantly in flux, modifying the test procedure to require today's load levels on each terminal will only ensure that the test procedure is outdated as soon as it is finalized. So, in order to reduce the need to frequently modify the test procedure, Robert Harrison, U.K. government consultant scientist, recommends that the test procedure include a methodology for determining the loads placed on an individual STB, rather than prescribing individual levels for each component in the STB.[20] For example, rather than prescribing the video and audio signals for the STB, the test procedure might read similar to the following:

The "On" mode power of a STB shall be measured such that maximum power is used by the STB. This requires that all components and functionalities in the STB shall be powered "On", all LNBs shall be loaded, all DVRs shall be recording, DVDs burning, etc. In the case that there is a range of loads that is expected when the box is under normal operation, the maximum for each component shall be used.

Energy Savings Scenarios

Ecos/NRDC considered these technical findings to create a number of scenarios to decrease energy consumption of cable and satellite STBs.[21] To calculate the possible energy savings, we used the following data:

- Averages of active and standby power data summarized in the previous section were used to determine the base case power levels of active and standby power for the following categories of products: Digital Cable Tuner (active 16.3 Watts, ready 15.6 Watts), HD Digital Cable Tuner (active 27.4 Watts, ready 26.5 Watts), Satellite Receiver (active 12.2 Watts, ready 12.1 Watts), HD Satellite Receiver (active 19.5 Watts, ready 18.3 Watts), DVR with tuner/receiver (HD and SD) (active 31.1 Watts, ready 29.9 Watts).
- Power supply efficiency data measured by EPRI-PEAC was used to determine 75percent as the base case level for power supply efficiency.
- 2005–2008 unit sales estimates for Digital Cable Tuner, HD Digital Cable Tuner, Satellite Receiver, HD Satellite Receiver, and DVR with tuner/receiver (HD and SD) based on ACEEE's 2004 research were used to approximate the market shares of these product categories.

Standard duty cycle assumptions that included five hours per day active, and 19 hours per day in ready. When applicable, time in ready was split into two hours in ready and 17 hours per day in sleep. Because power is similar in active and ready modes, duty cycle assumptions currently have minimal impact on power use calculations of today's cable and satellite STBs. These assumptions will matter increasingly in the future as manufacturers create lower standby modes of operation, like sleep.

Using this data, we estimated the cumulative four-year impacts of the following energy efficiency initiatives:

Power Supply Efficiency Improvement. Improving the efficiency of the power supply to 85 percent efficient at normal operation. This scenario is possible without changing existing hardware and software associated with the functionality of the STB.

European COC Code of Conduct Recommendation. Implementing suggestions made by the European COC by reducing ready mode level to 11.2 Watts for the multifunction cable/satellite STBs and reducing ready mode level to 9 Watts in all other STBs. Additionally, implementing a sleep mode level that would be no higher than 8.2 Watts for multifunction cable/satellite STBs and no higher than 6 Watts for all other STBs.

Aggressive Ready Mode Reduction and Sleep Implementation. Reducing ready mode level to 5 Watts for all STBs and implementing a sleep mode level that would be no higher 1 Watt for all STBs.

COC Recommendations and Power Supply Efficiency Improvement. Combination of ready and sleep recommendations suggested by the COC and simultaneous power supply improvement.

Aggressive Ready Mode Reduction, Sleep Implementation and Power Supply Efficiency Improvement. Creating a sleep mode that consumes no more than 1 Watt, a ready mode that consumes no more than 5 Watts, and simultaneous power supply efficiency improvements.

Table 7 gives the estimated four year cumulative impacts of each of the energy savings initiatives described above. For the power supply improvement initiative, we assume that 50 percent market penetration is possible in the first year, because many of the designs are already quite efficient and this requires no design changes to software or hardware communication protocols. For the initiatives that include ready mode reduction and sleep mode implementation requiring revamping software and hardware and working with industry players to sort out the details of the communication protocols, we assume that a market penetration of 25 percent is possible.

Table 7: 4-year cumulative impacts of five different energy savings scenarios

Initiative	Market Average Annual Energy Savings per Unit (kWh/yr)	Average Total Number of Units Sold in U.S. per Year (millions of units)	Average Percent of Units Sold that Meet Initiative Guidelines Each Year	2005 First Year National Energy Savings (millions of kWh)	2005-2008 Cumulative National Energy Savings (millions kWh)
Power Supply Efficiency Improvement	23	13.2	50%	156	1401
European COC Recommendations	93	13.2	25%	311	3,104
Aggressive Ready Mode Reduction and Sleep Mode Implementation	132	13.2	25%	439	4,384
COC Recommendations and PS Efficiency Improvement	98	13.2	25%	328	3,280
Aggressive Ready Mode Reduction and Sleep Mode Implementation and PS Efficiency Improvement	137	13.2	25%	456	4,550

The range of savings that are possible if one of the initiatives were undertaken above is 1.4 billion kWh to 4.5 billion kWh. Table 8 gives the resulting environmental impacts resulting from that range of savings, which is the equivalent amount of power for 137,000 to 445,000 households for one year. We assume relatively modest national adoption rates, only 50 percent of total units shipped for the improved power supply scenario, and only 25 percent of units shipped with reduced ready mode and sleep mode implementation. To get the sense of the impact if the entire nation switched to incorporate a particular initiative, simply multiply the savings numbers by 4.

Table 8: Range of environmental impacts associated with the energy savings initiatives

Initiative	**National Energy Savings, 4 Year Cumulative Total (millions kWh)**	**National Carbon Dioxide Savings, Total 4 Year Cumulative (million tons CO_2)**	**National Value of Electricity Saved Total 4 Year Cumulative (millions of dollars)**	**Equivalent Number of American Households Powered for One Year**
Power Supply Efficiency Improvement to 85%	1,401	0.9	118.5	137,000
Aggressive Ready Mode Power Reduction and Sleep Mode Implementation	4,384	2.9	370.9	428,975
Aggressive Ready Mode Power Reduction, Sleep Mode Implementation, and PS Efficiency Improvement to 85%	4,550	3.0	385.0	445,000

POLICY RECOMMENDATIONS AND NEXT STEPS

Engage with Service Providers and Other Industry Players

Because service providers specify and distribute STBs that are ultimately used by the consumer, they have a powerful influence on the STB market. Any technical solution, no matter how elegant, is worthless if not employed and specified by service providers, such as Comcast and Dish. Early outreach should be conducted specifically to these players to convince them of the worthwhile nature of embarking on reducing energy consumption of STBs.

We suggest that energy efficiency advocates and experts propose to service providers a two-tiered approach to reducing STB energy use. In the near term, energy savings could be captured with a known prescriptive power supply solution, which would set an absolute value for STB power supply efficiency at 85 percent at normal active operation. We suggest that the energy efficiency community engage STB specifiers, such as Time Warner and DirecTV, and work toward creating industry power supply efficiency standards, similar to what has been achieved with Intel in the desktop computer arena. Additionally, if manufacturers incorporated more efficient power supplies into their boxes in the short term, it could help them achieve standby levels set by ENERGY STAR and others.

In the long term, service providers could capture energy savings by dropping ready mode power use and creating and implementing a sleep mode industry standard that would enable minimal power use when the STB is not performing any active function for the service provider or the home user.

After initial outreach to service providers and other stakeholders, a larger dialogue could be in the form of a U.S.-based summit on STB energy use and potential solutions. Although energy focused summits have been held in Europe, the United States, which has nearly 90 percent of households subscribing to cable and satellite, is significantly different than Europe and Australia, where the majority of homes are served by terrestrial broadcasts. This will likely require that energy efficiency leaders facilitate a U.S.-based dialogue that includes STB hardware manufacturers, STB software developers, cable and satellite service providers, and energy efficiency advocates and experts to work toward a solution that would enable a sleep mode and simultaneously reduce ready mode power use. (This would include hardware solutions, software solutions, and communications solutions. Please see technical recommendations for more information.) The dialogue could potentially be within the context of a larger standards organization, and would focus on meeting the needs of the service providers (including security, updates, etc.) and enabling the STB to transition into a sleep mode when information is not being transferred on the network. Before this full-scale dialog takes place, the energy efficiency community would need to learn and understand in greater detail the ways in which software, hardware, service providers, and the current communication protocol interact.

Test Procedure Revisions

NRDC/Ecos recommends that U.S. energy efficiency advocates engage in an international process to revise IEC 62087, as well as encourage other U.S. manufacturers to participate in that process. A test procedure that works well with U.S. boxes is necessary to be able to fairly and consistently compare the energy consumption of one STB to another. These revisions should focus on reconsideration of the mode definitions in the test procedure and loading guidelines for more complex boxes currently not covered underneath the procedure. For more information, please refer to the technical recommendations.

STB Standards Approaches

A single, or multitiered energy performance specification should be developed by voluntary labeling programs like ENERGY STAR and future mandatory standards bodies at the federal or state level, as appropriate. A national specification would make it easier for bulk purchasers to request the more efficient boxes, and would provide an efficiency target for interested STB manufacturers and their suppliers. Although more research is needed to sketch out the details of the exact levels that would be used for a mandatory standard or voluntary specification, STBs would be measured according to a modified version of IEC 62087 in the appropriate modes. (Please see Technical Recommendations section.) The resulting specification/standard could be developed in one of two ways: A universal specification could be developed that would be applicable to all cable/satellite boxes, or the boxes could be grouped by functionality or provider network types and separate specifications could be developed for each type.

Digital Television Converters

Although specific details about digital television converters (DTCs) are outside of the scope of the larger discussion of this report, we support the international 8 Watts/1Watt initiatives currently under way for DTCs. Future specs for this category should not only include a meaningful low power mode, but should also require that the box enter this mode when the user is not watching or recording a show. Otherwise, the significant savings that could be derived from the low power mode would simply be “paper savings” and the real savings would not be achieved. Further, we recommend that advocates working to improve the efficiency of cable/satellite STBs make efforts to use similar language and approaches and test procedures as what is being developed for the DTCs, so that communication with industry is more effective.

APPENDIX A

Summary of NRDC Set-top Box Units: Power Data and Functionality

						Signal Source			Video Output			Other Connections		Recording and Playing			Head-End Communication		
STB Model	Manufacturer and ID#	Test Organization	On Mode Power Use (W)	Standby Power Use (W)	Annual Energy Consumed (kWh)	Off-Air	Cable	Satellite	Analog	SDTV	HDTV	Digital Audio	DVI	D-VHS	DVD	DVR (Hard Disk Drive)	Modem	DSL Modem	Cable Modem
301	Dish 1	Ecos	10	8.8	79	○	○	●	●								●		
	Dish 2	Ecos	14.5	14	124														
921	Dish 5	Ecos	47.4	44.3	394	○	○	●	●	●	●	●	●			●	●		
811	Dish 3	Ecos	16.9	16.4	145	○	○	●	●	●	●	●	●				●		
500	Dish 4	Ecos	18.8	18.5	163	○	○	●	●			●				●	●		
DCT 2244/1161/ ABCDE	General Instruments 2	Ecos	21.4	20.4	181	○	●		●			●							
DCT 2244/1161 ABCDEF	General Instruments 1	Ecos	19	18.1	160	○	●		●			●							
HDVR-2	Hughes 2	Ecos	23.8	23.8	208	○	○	●	●			●					●		
	Hughes 4	Cadmus	34	34	298														
HIRD-E1	Hughes 1	Cadmus	13	14	121			●	●								●		
SD-DVR40	Hughes 3	Cadmus	32	32	280	○	○	●	●			●				●	●		
TU-DP811RU	JVC 1	Ecos	23	21	188	○	○	●	●	●	●	●	●				●		
DCT 2244/1161	Motorola 7	Ecos	20.6	18.2	164	○	●		●			●							
DCT 2244/1161/ BCDEG	Motorola 4	Ecos	15.6	15.2	134	○	●		●			●							

● indicates primary functionality of box ○ indicates functionality of box not normally enabled

						Signal Source			Video Output			Other Connections		Recording and Playing			Head-End Communication		
STB Model	**Manufac-turer and ID#**	**Test Organization**	**On Mode Power Use (W)**	**Standby Power Use (W)**	**Annual Energy Consumed (kWh)**	**Off-Air**	**Cable**	**Satellite**	**Analog**	**SDTV**	**HDTV**	**Digital Audio**	**DVI**	**D-VHS**	**DVD**	**DVR (Hard Disk Drive)**	**Modem**	**DSL Modem**	**Cable Modem**
DCT 2244/1161/ ABCDEFG	Motorola 5	Ecos	17.1	16.4	145	○	●		●			●							
	Motorola 6	Ecos	18.8	18.4	162														
DCT 2244/1661/ ACDEFG	Motorola 2	Ecos	15.4	15	132	○	●		●			●							
DCT 2524/1631/AC	Motorola 1	Ecos	10.9	10.2	91	○	●		●			●					●		
DCT 2000	Motorola 3	Cadmus	15.4	15.4	135	○	●		●			●							
DCT 5100	Motorola 8	Ecos	25.3	24.9	219		●		●	●	●	●	●						●
6200/1000	Motorola 9	Ecos	29.5	28	248		●		●	●	●	●	●						●
510 A	Pace 1	Ecos	12.9	12.7	112		●		●			●							
HDR212	Philips 1	Ecos	20.8	19.7	175	○	●		●	●	●					●	●		
DRD222RD	RCA 1	Cadmus	8	8	70	○	○	●	●								●		
RTV-5504	Replay TV 1	Cadmus	30	30	263		●		●	●	●	●				●	●		
SIR-S60W	Samsung 1	Ecos	9.5	10	87	○	○	●	●								●		
SIR-TS360	Samsung 2	Ecos	18.5	17.5	155	○	○	●	●	●	●	●	●				●		
Explorer 3100	Scientific Atlanta 2	Ecos	15.5	14.2	127		●		●			●							●
Explorer 2000	Scientific Atlanta 3	Ecos	18.5	18	159		●		●			●							●

● indicates primary functionality of box ○ indicates functionality of box not normally enabled

						Signal Source			Video Output			Other Connections		Recording and Playing			Head-End Communication		
STB Model	**Manufac-turer and ID#**	**Test Organization**	**On Mode Power Use (W)**	**Standby Power Use (W)**	**Annual Energy Consumed (kWh)**	**Off-Air**	**Cable**	**Satellite**	**Analog**	**SDTV**	**HDTV**	**Digital Audio**	**DVI**	**D-VHS**	**DVD**	**DVR (Hard Disk Drive)**	**Modem**	**DSL Modem**	**Cable Modem**
Explorer 3250 HD	Scientific Atlanta 1	Cadmus	13	13	114		●		●	●	●	●	●						●
Explorer 8000 HD DVR	Scientific Atlanta 4	Ecos	30.9	26.9	243		●		●	●	●	●	●			●			●
Sat A-2	Sony 1	Cadmus	15	15	131	○	○	●	●			●					●		
Sat B-2	Sony 2	Cadmus	18	17	151	○	○	●	●			●					●		
SVR-2000 TiVo (40GB)	Sony 3	Ecos	17.2	16.9	149		●		●	●	●	●				●	●		
TCD 130040	TiVo 1	Cadmus	29	29	254	●	●	●	●							●	●		
R240040	TiVo 2	Cadmus	24	24	210	●	●	●	●							●	●		

● indicates primary functionality of box ○ indicates functionality of box not normally enabled

ENDNOTES

[1] "DVR Sales to Grow Fivefold by 2008,", prepared by Strategy Analytics, March 23, 2004. Excerpt from report accessed on www.itfacts.biz/index.phph?id=P936, December 14, 2004.
[2] Howard, Bill "The Home PC, Perfected," *PC Magazine,* November 16, 2004, pp. 30–36.
[3] Thorne Amann, Jennifer "Set-top Boxes: Opportunities and Issues in Setting Efficiency Standards," ACEEE report number A041, 2004
[4] Britt, Glenn "Remarks by Glenn Britt: Chairman and CEO Time Warner Cable and Chairman of the National Cable and Telecommunications Association." Washington Metropolitan Cable Club, September 24, 2003.
[5] "DVR Sales to Grow Fivefold by 2008," prepared by Strategy Analytics, March 23, 2004. Excerpt from report accessed on www.itfacts.biz/index.phph?id=P936, December 14, 2004.
[6] Thorne Amann, Jennifer "Set-top Boxes: Opportunities and Issues in Setting Efficiency Standards," ACEEE report number A041, 2004.
[7] California is considering mandatory standards for digital converters not covered under the scope of this document. For more information, please see http://www.energy.ca.gov/appliances/index.html.
[8] Bryant, Jeremiah "Power Points," *Darnell in Depth*, Volume 2, Issue 9, page 4, September 2004.
[9] For more information on these initiatives, Please see Amann, 2004.
[10] Personal communication with Shane Holt, Australia Greenhouse Office, October 20, 2004.
[11] These mode definitions are likely to transition over time, but we have chosen these for the purposes of this discussion.
[12] Personal communication with David Beavers, Cadmus group, November 7, 2004.
[13] Motorola and General Instruments are now merged.
[14] Efficiency of a power supply is defined as the total output power divided by the total input power. For more details, please see the current draft of the internal power supply test procedure available at www.efficientpowersupplies.org.
[15] Mansoor, Arshad Calwell, Chris Foster, Suzanne and Geist, Tom "Designing AC-DC Power Supplies for Improved Energy Efficiency: A Technical Primer," prepared for the California Energy Commission PIER Program, 2004.
[16] Personal communication, Robert Harrison, U.K. government consultant scientist, domestic electronic products. December 2, 2004.
[17] Other power partitioning technologies are available from Sun, Apple, and Transmeta.
[18] In satellite distribution systems, one Low Noise Block is required for each independent TV channel streamed to a household. So, if one wanted to be able to view programming in the living room TV, record a program on a DVR, and have another live program viewed in the bedroom, 3 LNBs would be required.
[19] Personal communication, Robert Harrison, U.K. government consultant scientist, domestic electronic products. December 2, 2004.
[20] Personal communication, Robert Harrison, U.K. government consultant scientist, domestic electronic products. December 2, 2004.
[21] Energy savings initiatives were not considered for game consoles or media PCs. These were outside the scope of this project.