TELEVISIONS

Active Mode Energy Use and 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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TABLE OF CONTENTS

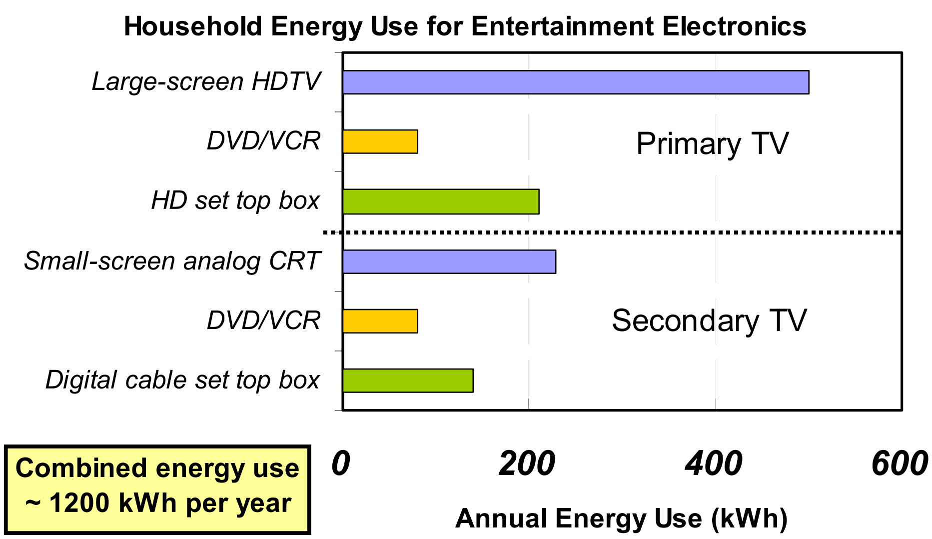
EXECUTIVE SUMMARY

Television energy use in the United States is currently riding a rapid growth curve. NRDC/Ecos estimates that U.S. televisions consumed more than 46 billion kilowatts per hour in 2004 or about 4 percent of national residential electricity use. We expect this number to increase to over 70 billion kilowatts per hour per year by 2009–an increase of over 50 percent–unless policy measures are taken to trim the expected growth in energy demand from this product category. The report that follows summarizes NRDCs efforts to further quantify TV energy use and to identify opportunities to reduce the power consumption of TVs sold in the future.

Five major trends are currently contributing to this increase in national TV energy use:

- The number of TVs in operation in the United States is growing.
- Consumers continue to purchase larger TVs that consume more power when they are turned on and typically operate multiple smaller TVs throughout their homes.
- Sales of digital televisions (DTV) are growing, as the TV market moves from low-resolution analog TVs to high definition TV (HDTV). Many HDTVs require more power to deliver higher picture quality.
- Sales of cathode ray tube (CRT) TVs are quickly being displaced by newer technologies (*e.g.*, plasma, liquid crystal displays, etc.), some of which consume significantly more power than CRTs when turned on.
- Americans are watching more hours of TV per day than in the past due to increased program offerings, DVD viewing, video games, etc. Figure 1 below illustrates the magnitude of household energy use related to a home's multiple TVs and some common associated peripherals (cable/satellite set top boxes, DVD players, etc.). This amount of annual energy consumption easily exceeds that used by two new refrigerators and would account for more than 10 percent of the electric bill in a typical U.S. household.

Figure 1



Current U.S. efforts to encourage energy efficiency in TVs, such as the U.S. Environmental Protection Agency's ENERGY STAR® program, only label products based on the amount of power they consume in standby mode (when the user believes the TV is "off") and do not consider the TV's power consumption when it is turned "on." Active mode – the time when the TV is turned on and displaying a picture – accounts for 80 percent to 95 percent of a TV's annual energy use, and yet is not currently part of the ENERGY STAR specification. Reducing active mode power represents the next big opportunity for reducing TV energy use and is slated to be a key component of EPA's specification when it is revised.

In 2004, the Natural Resources Defense Council (NRDC) retained Ecos Consulting to: 1) perform in-store measurements of TV active mode power use, 2) assess test methods used to measure TV active mode power, 3) estimate TV energy use in the United States, 4) estimate potential savings opportunities by addressing the energy efficiency of TVs in active mode, and 5) recommend policy actions designed to achieve these savings. Below is a summary of our major findings.

Recent TV Measurements

- Based on power measurements conducted by Ecos Consulting, we estimate that today's TVs typically consume between 100 and 400 kWh of electricity per year, with some high-end home theater models consuming in excess of 650 kWh per year.
- In so-called direct view display technologies, where the TV directly emits light from the screen's surface rather than reflecting projected images, active mode power use increases linearly with screen area. The larger the screen, the more power the TV will consume.
- Power consumption seems to be affected by the resolution capabilities of TV screens. Many high definition TVs (HDTVs) consume more power to deliver improved picture quality; however, technology exists today to deliver HD picture quality using roughly the same amount of power as low-resolution analog TVs.
- We have observed a large variation in active mode power within display technology families such as CRT, plasma, LCD, etc. The active mode power consumption of similarly sized TVs within a specific technology family can vary by as much as a factor of 2 between the least and most efficient units. These results demonstrate that it is technologically feasible to vastly improve the active mode energy efficiency of all types of TVs.
- Past measurements and numerous electronics publications indicated that plasma TVs used more power than other TVs of similar size and resolution; however, recent measurements indicate that this gap in power consumption is narrowing as manufacturers act to reduce active mode power consumption. Further measurements would be required to substantiate this finding.

National Energy Usage and Savings Estimates for TVs

- We estimate national energy use by TVs in the United States at 46 billion kWh per year. This is expected to rise to more than 70 billion kilowatts per hour per year by 2009 unless policy measures are enacted to encourage energy efficiency.
- Reducing active mode power consumption in TVs by 25 percent would save over 10 billion kWh per year in the United States once fully implemented. Annually, this would cut energy bills by nearly $1 billion and prevent emissions of about 7 million tons of CO_2, a key global warming pollutant.

Test Methods for Measurement of Active Mode Power in TVs

- The Department of Energy's (DOE) current test method for measuring the active mode power consumption of TVs is almost 30 years old, only covers black and white TVs, and therefore provides no guidance for measuring today's TVs.

- Unfortunately, this test method stands as the United States' only nationally recognized test method for measuring TV active mode power and must be replaced with something more current.
- The International Electrotechnical Commission's (IEC) test method for measuring TVs and other audiovisual equipment, IEC 62087, is the only available test method for measuring TV active mode power that is supported by an international standards organization, governments, and manufacturers.
- IEC 62087 has several major shortcomings that must be addressed in future revisions should policy makers in the United States select this test method as the reference test method for measuring TV active mode power:
  1. IEC 62087 does not provide specific provisions for measuring display technologies other than CRT, such as plasma, liquid crystal display (LCD), etc.
  2. The test method requires TVs to be measured at relatively low levels of brightness/contrast compared to the levels typically found in the home setting. We believe this result in fairly significant underreporting of annual energy use.

Recommendations

- U.S. and other international stakeholders should actively partake in the process to revise IEC 62087. The future test procedure should test TVs under conditions that closely mimic their in-home use by using a motion video test clip and approximations of real world display settings.
- A revised national specification should be developed for the United States for use in voluntary labeling programs like ENERGY STAR. This spec must be sure to address active mode power use. Because our results show that active mode power varies with screen area and picture quality, the specification should compare TVs of comparable size and performance. The specification should avoid setting levels for each class of display technologies. A universal approach will help foster competition between the various technologies (i.e. plasma vs. LCD).
- The DOE should use its existing authority to begin labeling TVs under the EnergyGuide mandatory labeling program. An EnergyGuide label for TVs will finally provide consumers with information about the total energy consumption of TVs and the costs associated with operating them – information that they are accustomed to seeing in retail settings for other high-power appliances like dishwashers and refrigerators, but which is currently absent in TVs.

INTRODUCTION

The EPA's ENERGY STAR® voluntary labeling program has been encouraging energy efficiency in a wide array of products since 1992 and has maintained voluntary labeling specifications for TVs and other audiovisual equipment since 1998. The upcoming third phase of the specification requires both analog and digital TVs to consume less than 1 watt when the TV is plugged in and turned off (standby mode) in order to earn the ENERGY STAR label. Less efficient models can consume between 3 and 20 watts in standby mode.

Significant progress has been made by addressing standby mode power in TVs. A Lawrence Berkeley National Lab's (LBNL) report on TVs estimates that, since the inception of the ENERGY STAR spec, the United States has saved about 9 billion kWh of electricity from lower standby mode power consumption in TVs.

Unfortunately, standby mode represents a small piece of the broader energy consumption picture in televisions and many other consumer electronics. Active mode–the time when a TV is functionally "on" and displaying pictures and sound–accounts for 80 percent to 95 Percent of the energy consumed by a TV, even though TVs only spend a few hours per day turned on. The reason is that today's TVs typically draw more than 100 watts when turned on, with power-hungry sets sometimes drawing upwards of 300 watts. Our measurements indicate that some TVs are more efficient than others, and that a huge energy savings opportunity exists by addressing the power consumption of TVs in active mode.

Figure 2

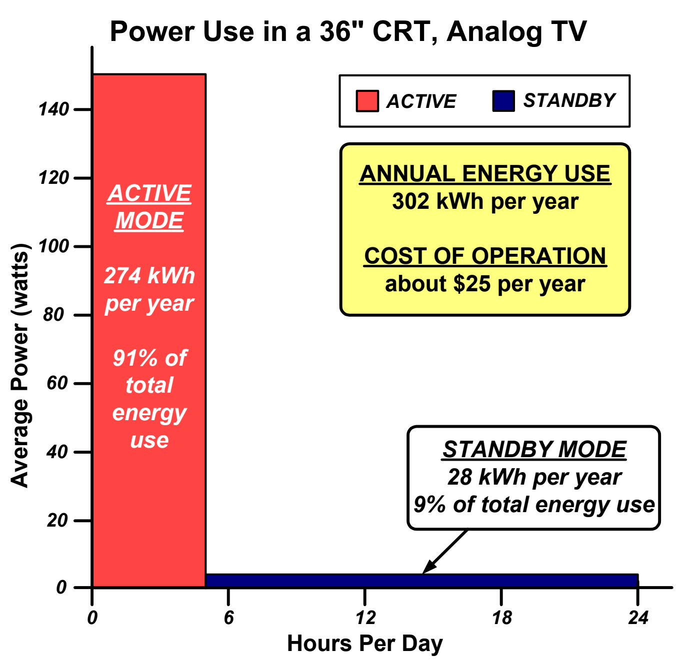


Figure 2 highlights this opportunity by showing the amount of power drawn in different modes of TV operation along with the amount of time typically spent in each mode. The total area occupied by each mode, thus, represents the energy consumed. As the annual energy consumption for the active mode is roughly 90 percent of the total annual energy consumption, this mode represents the big opportunity for future savings. Since standby mode power consumption has been so dramatically reduced over the years, further incremental improvements in this area would have minimal impact.

In order to better understand the current range of active mode power use in current TVs and to explore the potential energy savings opportunities in greater length, NRDC retained Ecos Consulting to answer the following questions:

- What are the major trends in the TV market that may influence the annual energy consumption of these products?
- What are the current test methods used around the world to measure TV active mode power? What are the pros and cons of these methods?
- How much energy do current TVs consume in the active mode? What trends do we see in the data?
- How much energy do we estimate current TVs use annually, and how much of this energy could be saved through incremental efficiency improvements in the active mode operation of TVs?
- What is the appropriate metric for comparing TV energy efficiency? How might future specifications for TV energy efficiency that include active mode power use be devised?

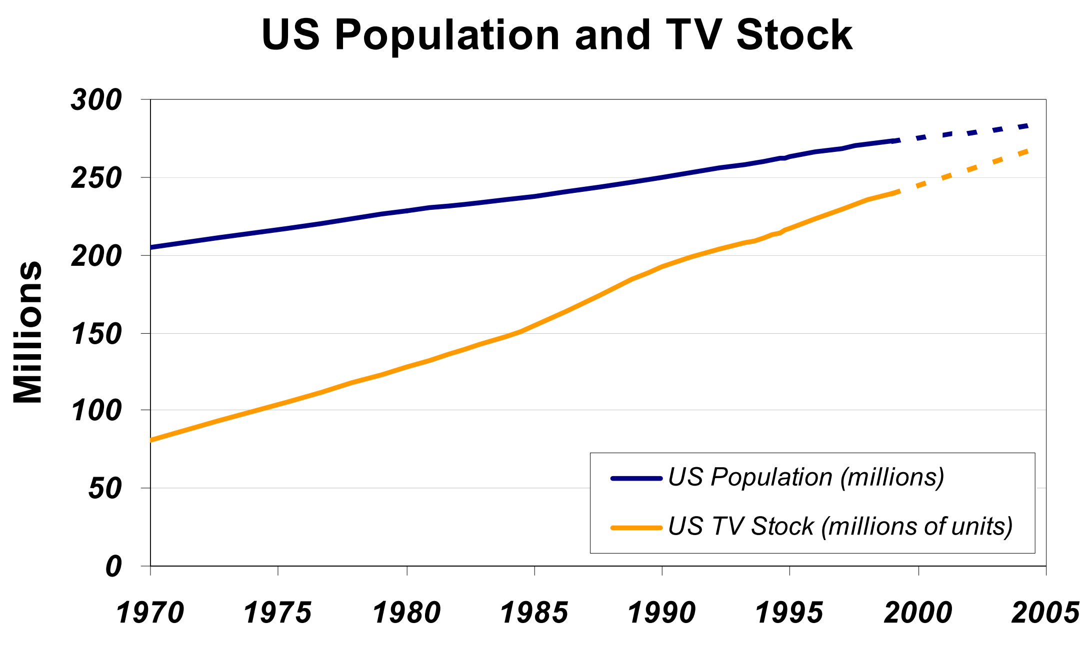
The scope of this report does not cover television displays/monitors, typically used with personal computers, or television combo units (TV-VCRs, TV-DVDs, etc.). We instead chose to focus our efforts on common TVs as defined in the ENERGY STAR program's eligibility criteria: "a commercially available electronic product consisting of a tuner/receiver and a monitor encased in a single housing."[1]

MARKET BACKGROUND AND OVERVIEW

TVs represent the single largest segment of the consumer electronics market, capturing more than 12 percent of dollar sales. Projected annual sales in 2004 will top over $12 billion, a figure that trumps even dollar sales of home-operated personal computers.[2] Within the growing U.S. TV market, NRDC/Ecos has identified a number of trends that will not only transform TV technology in the coming years but will also undoubtedly affect the ever-increasing amount of energy that these devices consume.

The number of TV sets per household is growing. The average U.S. household currently owns 2.4 TVs according to the latest available census data,[3] and in 2002 an estimated 41 million households owned and operated more than three TVs.[4] To put this in perspective, the number of installed TVs in the United States will soon eclipse the country's total population, with one TV for every U.S. resident. Consumers are adding TVs to their homes for bedrooms, kitchens, shops, recreational rooms, and even bathrooms. If the current trends in TV ownership continue with no check on the energy use of TVs, the share of U.S. household electricity used by TVs and the size of residential utility bills will only increase.

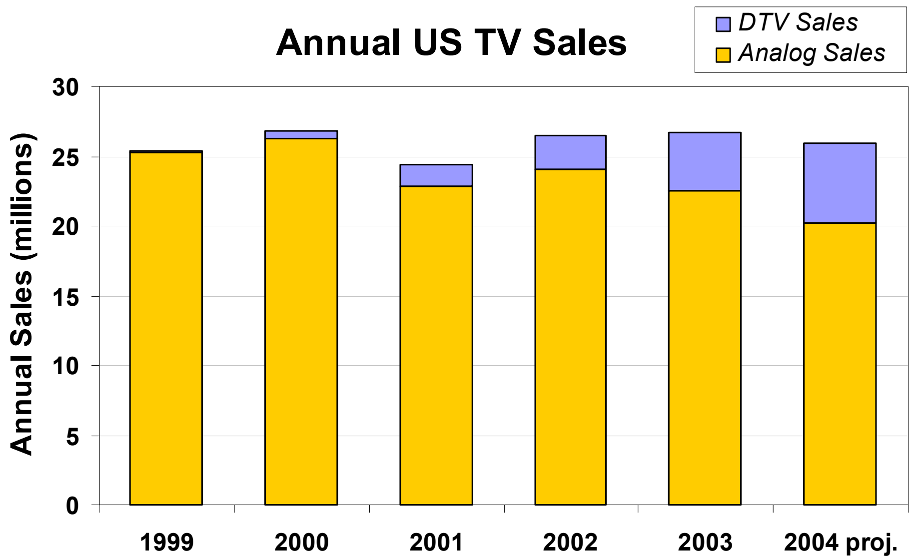
Figure 3



Sales of digital televisions (DTV) are growing, and along with them, sales of higher resolution TVs. The transition to digital television broadcasts was mandated by Congress with the passage of the Telecommunications Act of 1996, a law that stipulates that all TV broadcasts in the United States be digital by the year 2007. Most TVs currently on the market can tune an analog signal in which the TV picture and sound are represented by high-frequency radio waves. The Telecommunications Act requires that TVs be able to tune a digital signal in which the picture and sound displayed on the TV are encoded in digital ones and zeros. DTV offers performance advantages over analog TV signals through better reproduction of video and sound signals.

Since 1996, the television market has undergone a rapid transformation as sales of DTVs increase year over year, up more than 1.5 million units in 2003 alone.[5] By the end of 2004, the Consumer Electronics Association (CEA) estimates that DTVs will constitute approximately 12 percent of all TVs installed in the United States; 53 percent by 2008.[6] Figure 4 below shows how DTV has been rapidly encroaching upon sales of traditional analog televisions.[7]

Figure 4



DTV has paved the way for improvements in television picture resolution due to the higher amount of information that can be transmitted in a DTV signal. There are three levels of DTV picture resolution defined by the CEA: standard definition television (SDTV), extended definition television (EDTV), and high definition television (HDTV). SDTV displays roughly as much picture detail as current analog TV, whereas EDTV and HDTV display anywhere from about 2.5 to 13 times the amount of pixel information as a standard analog signal. Although this report does not go into significant technical detail to explain the differences between each level of resolution, Table 1 provides a general overview of TV resolution and pixel counts for the various different CEA brands as well as analog TV. We draw a distinction in this table between "interlaced" and "progressive scan" TVs. In interlaced TVs, only half of the pixels are displayed on screen at any one instant; in progressive scan displays, all of the pixels are displayed at once. So for example, in a SDTV with 480i resolution (the "i" denotes interlaced, whereas "p" denotes progressive scan), only half of the 307,200 pixels would be displayed at any given instant.

Table 1: Summary of Resolution Levels in 2004 TV Market

"Branded" TV Resolution Level	Typical Resolution (horizontal x vertical pixels)	Number of Pixels Displayed	Interlaced/ Progressive Scan
Analog	330 x 480	158,400	Interlaced
SDTV 480i	640 x 480	307,200	Interlaced
EDTV 480p	852 x 480 (widescreen)	408,960	Progressive
HDTV 720p 1080i 1080p	1280 x 720 (widescreen) 1920 x 1080 (widescreen) 1920 x 1080 (widescreen)	921,600 2,073,600 2,073,600	Progressive Interlaced Progressive

HDTVs currently display the highest resolution pictures and constitute almost 90 percent of growing DTV sales, with EDTVs rounding out the remaining 10 percent. Prices on high definition televisions have dropped on average more than 20 percent in just the past year as HDTV equipment continues to improve and the volume of these types of high performance televisions grows. From our research, it seems that HDTVs will be the television of choice in the future as U.S. consumers begin to replace their older analog TV sets with cutting edge DTVs.[8,9]

The higher performance of HDTVs also results in higher energy use. HDTVs often consume more energy in active mode than today's analog TVs. As a result, the DTV revolution will likely increase the average active mode power use of TVs in the United States if efforts to improve energy efficiency are not made. Our measurements show that in some cases consumers have the choice to purchase high-performance DTVs that use roughly the same amount of energy as today's analog TVs. Unfortunately, consumers currently have no means of comparing the annual energy use of TVs in order to make this kind of informed purchase decision.

Sales of cathode ray tube (CRT) TVs are quickly being displaced by newer technologies. Consumers have never before had such a broad array of TV display technologies available to them when they walk into an electronics store. Most of the newer screen technologies take advantage of the high resolution HDTV signal, including plasma (PDP), liquid crystal display (LCD), liquid crystal on silicon (LCOS), Digital Direct Drive Image Light Amplifier® (D-ILA), and Digital Light Processing® (DLP). LCD TVs are predicted to overtake CRTs in sales and may eventually replace that market segment as CRT technology dies out.[10,11]

Due to the manufacturing constraints of producing direct view CRT TVs larger than about 37 inches large screens used to only be available in projection models; however, with the advent of so-called fixed pixel displays such as plasma and LCD, manufacturers have been able to produce direct view displays in excess of 40 diagonal inches. As a result, consumers can now purchase larger TVs that consume more power, mainly due to their increased size.

Americans are watching more hours of TV per day, making the active mode component of a TV's overall energy consumption even more important. Since the 1980s the time spent by the average American watching TV has risen more than 16 percent according to the Nielsen Group.[12] Much of this increase is due to the advent of cable/satellite services, home video, and video games. It should be noted that all of these additional services usually require extra audiovisual equipment such as set top boxes and video game consoles. Set top boxes can consume more than 175 kWh of electricity per year on their own. In the near future, a home with two TVs and associated audiovisual equipment such as DVD players and set top boxes could use approximately 1,200 kWh of electricity per year just to power entertainment electronics.[13] This would constitute more than 10 percent of the typical American household's *annual* energy bill, without even factoring in personal computers, or high-end surround sound systems that consumers might use to build an in-home theater setup.

Current Television Active Mode Test Methods

In order to reasonably compare the power use between TV models, a detailed test method is needed that produces reasonably accurate and reproducible test results. To date, a handful of test methods have been developed to measure active mode power in TVs (see Table 2 for a summary). The U.S. Department of Energy (DOE) currently accepts a method in the Code of Federal Regulations, entitled "Uniform Test

Method for Measuring the Energy Consumption of Television Sets," as the national test method for the measurement of TVs in active mode. Unfortunately, this test method dates back to the year 1977, when CRTs were the only TV display technology available, and most people still received TV programming through antennae. Under this method, a TV set's "operating power" is calculated by averaging the power consumed while displaying a white test pattern and the power consumed displaying a black test pattern. The method is so outdated that it is not even used by TV manufacturers in the United States to report active power use numbers to Underwriter's Laboratory (UL) and in the manufacturer's own product literature. These manufacturers simply use their own active power measurement techniques that approximate the "worst case" or highest power consumption by the device in active mode.

Table 2: Summary of Test Methods for TV Active Mode Power Measurement

	Measures black and white CRTs	**Measures color CRTs**	**Measures all new display types**	**Reflects real world power consumption**
DOE method	✓			
IEC 50301	✓	✓		
IEC 62087	✓	✓	✓	

The International Electrotechnical Commission (IEC) has recently created two test procedures to measure the active mode energy consumption of televisions. Approved in 2001, IEC 50301, "Methods of Measurement for the Power Consumption of Audio, Video and Related Equipment," was the first IEC standard addressing the measurement of TV active mode power. The standard provided a set of reference audio and video signals that would feed the inputs of the TV while its power use was measured. A still video test pattern was used to calibrate the TV's brightness and contrast settings such that all TVs tested could be measured under the same basic conditions. Unfortunately, industry opposed the test pattern used in IEC 50301, and thus, the standard lost support. The specification also quickly became outdated because it was only meant to deal with CRT display technologies, and as newer technologies appeared in the marketplace, the IEC decided to overhaul the standard.[14]

The result of this revision process was the current IEC 62087, "Methods of Measurement for the Power Consumption of Audio Video Related Equipment," which builds upon IEC 50301 and addresses industry complaints about the old standard. The standard was approved in 2002 and now supercedes IEC 50301. To address industry concerns about the setup procedure in IEC 50301, IEC 62087 uses an industry-approved three-bar black and white test pattern to calibrate a TV's brightness and contrast settings. As with the older standard, active mode power measurements are taken when the TV is playing a standard audio signal and displaying the static test pattern.

IEC 62087 was a success because it finally provided a test method for measuring active mode power in TVs that industry partners agreed upon. Mandatory and voluntary labeling programs in Europe, Australia, Japan, and China have adopted IEC 62087 as the accepted test method for energy efficiency programs dealing with TV active mode power use.

However, technical experts that have consulted with the IEC on the current standard still feel that there is room for improvement in the way that IEC 62087 calibrates the luminance of a TV screen.[15] The luminance settings called for in the standard are known to be lower than typical user settings and significantly less than factory settings.[16] It follows that if one tries to estimate the annual energy consumption of a TV based on active mode power measurements conducted under IEC 62087, the calculation will always *underestimate* the energy that might be consumed by the TV in the home setting. This means that IEC 62087 may be acceptable for comparing the relative energy efficiency of a range of TV models, however, it is not suitable for predicting the actual energy use of a TV in a home setting.

This represents a significant hurdle for energy efficiency policy makers who wish to create incentives for consumers to purchase more efficient TVs or communicate the benefits of TV energy efficiency to electric utilities or environmental groups. For consumers, one needs to have an accurate estimate of the annual energy consumed by the device to highlight operational savings that result from energy efficiency. Electric utilities need to understand the loads placed on electric grids, and environmental groups may wish to understand how potential energy savings will relate to carbon emissions from power plants. Providing this kind of information requires a test procedure that accurately measures active mode power, and for this reason, IEC 62087 must be revised to better reflect typical brightness and contrast settings. Please refer to our “Technical and Policy Recommendations” section later in this report for detailed recommendations on the IEC 62087 revision process.

Despite these challenges, IEC 62087 is the best available official test procedure to measure TV active mode power consumption. If regulatory or voluntary measures involving the active mode energy efficiency and power use of TVs are ever to be pursued in the United States, work must begin to replace the DOE test procedure mentioned above with a revised version of IEC 62087. This is not only absolutely necessary for technical reasons but legal ones as well: As long as the DOE test method remains on the books, it will supercede all other proposed test methods for TVs on the national and state level.

Summary of 2004 NRDC TV Measurements

Through past work and additional testing in October 2004, NRDC/Ecos has compiled a database on the power consumption of more than 500 TVs. The data comes from the following three sources:

Table 3

Data Source	Basis of Data	Test Method Used
Lawrence-Berkeley National Laboratory published report[17] 1999	Measurements of TVs by repair shop technicians after TV repair services completed	Measured active mode power while TV displaying no signal
Ecos field measurements 2002 – 2004	In-store measurements conducted in Nevada	Measured average, minimum, and maximum active mode power while TV displaying in-store signals
Ecos field measurements October 2004	In-store measurements of 25 TVs conducted in Durango, CO	Measured average, minimum, and maximum active mode power over two-minute period using standardized test clip when possible

The Ecos 2004 measurements were made using a field test method that differed significantly from IEC 62087. Our testing was conducted exclusively in electronics retail stores, not a controlled laboratory setting. TV floor models were plugged into a power meter and turned on with the volume muted. When possible, the TVs were fed a standard test clip from Joe Kane Production’s *Digital Video Essentials* DVD. Otherwise, TVs were tuned to an available in-store signal (satellite, demo DVD, etc.). After a brief warm-up period, the power consumption of the TV was measured and logged over 2 minutes using a Watts Up? Pro power meter. We were able to capture the maximum, minimum, and average power consumption over the two-minute period.

This 2004 field test method for TVs was useful because it allowed NRDC/Ecos to collect a large amount of data on current TV models inexpensively, in a short amount of time, but the method also has limitations.

NRDC/Ecos did not attempt to calibrate the TV sets for brightness and contrast as is specified in IEC 62087. Our data is, thus, only indicative of relative TV active mode power consumption, and no firm conclusions should be drawn from this data.

At the same time, based on our conversations with sales representatives at electronics retail stores and with industry experts, we have reason to believe that results from NRDC/Ecos' test method may, in fact, represent the way consumers use their TVs better than some formal test procedures. Manufacturers set the brightness and contrast of their TV models in the factory to exceedingly high levels in order to create a bright picture that will draw consumers' attention on a showroom floor. When retailers display a TV in their stores, they rarely change these factory presets because they know that bright, vibrant pictures will sell TVs. Industry experts estimate that 95 percent of consumers leave TV brightness and contrast settings at their factory presets when they install a TV in their home. Therefore, the NRDC/Ecos test method would essentially mimic the end use behavior of the vast majority of TV owners, and provide a more realistic approximation of actual power usage.[18]

The focus of the latest testing was to gather additional information about newer display technologies like LCD and DLP, which had not been well represented in the NRDC/Ecos TV database to date. A total of 9 CRTs, 7 LCDs, 1 LCOS, 4 DLPs, and 4 plasmas were measured in the October 2004 testing, and a complete table listing of these models and their test results can be found in Appendix A. It should be noted that all graphs, tables, and estimates presented in this report are based on data from all four of the sources cited above that have contributed to the NRDC/Ecos TV power usage database, including old field measurements, LBNL measurements, and manufacturer data sheets.

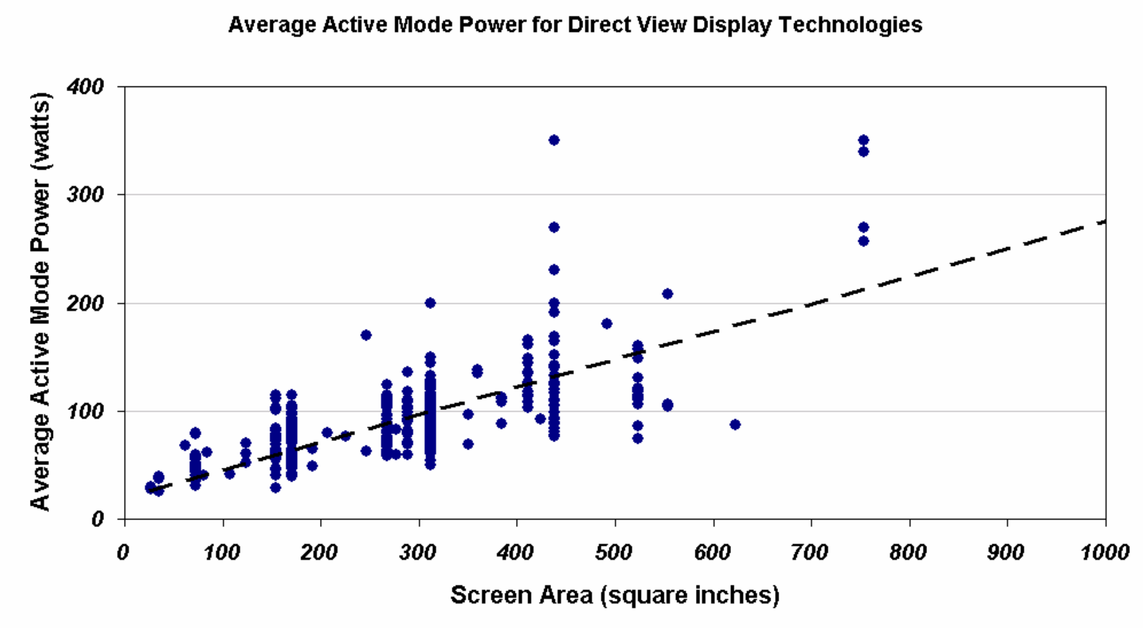
A statistical analysis of our updated database reveals three key factors that have a noticeable effect on the active mode power consumed by TVs.[19] Listed in descending order of importance, they are: 1) screen area, 2) display technology (CRT, LCD, etc.) and 3) resolution level.

Effect of Screen Size on Active Mode Power Use

Screen size has a general relationship on the average active mode power consumption of a television, as one might easily guess: the larger the screen, the greater the power consumption. This holds true primarily in direct view technologies, where the viewing surface emits light rather than reflecting projected light. Figure 5 shows a loose linear relationship between active mode power and screen area in direct view technologies. There is fairly broad scatter about the trend line, showing that direct view TVs are not necessarily created equally when it comes to active mode power consumption. Ecos and others have measured direct view TVs of similar size with a large variation in efficiency. Later in this report, we try to identify what role resolution plays in this variation.

In projection technologies, there is not a strong a relationship between screen area and power use because projectors incorporating lamps of identical lumen output can project images onto different sizes of screens without consuming significantly more power. As a result, the brightness of an image in projection displays can vary depending on the size of the screen and what size bulb is being used.

Figure 5



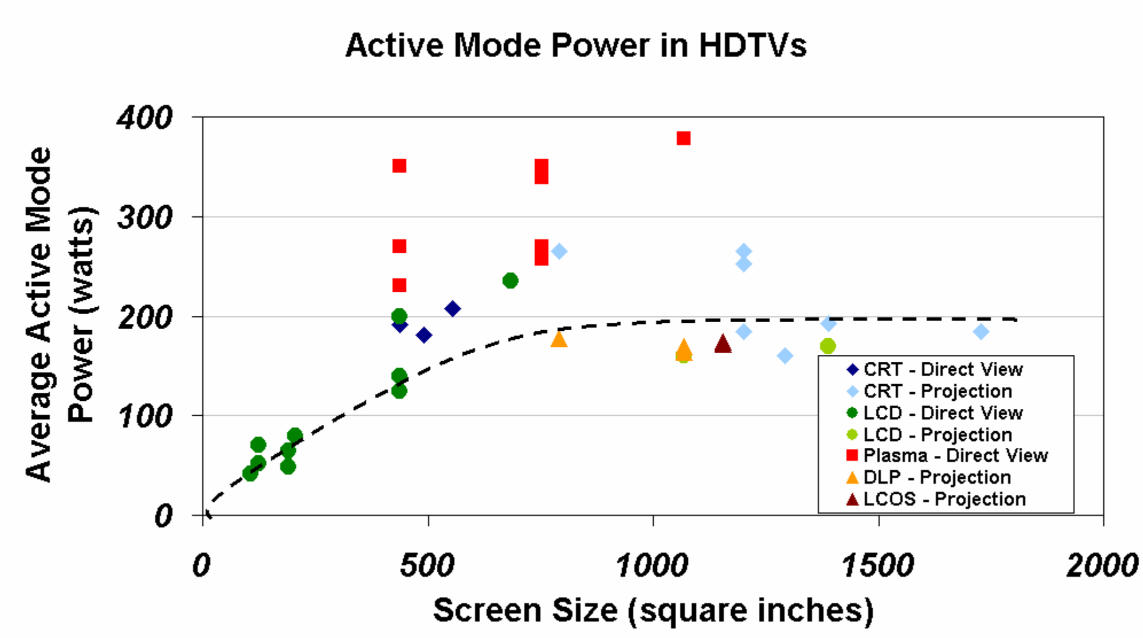
Effect of Display Technology on Active Mode Power Use

Today's analog TVs follow a fairly consistent trend in power consumption with relation to size. There is a "power ceiling" of about 200 watts for most analog CRT TVs, above which most analog CRT TVs typically do not operate.[20] This is because direct view CRTs are limited to sizes below 37inches and larger analog CRTs are projection units, which, as mentioned above, can project onto large screens without consuming significantly more power.

On the other hand, today's DTVs, 90 percent of which are HDTVs, use a wide variety of display technologies, including plasma, LCD, DLP, LCOS, etc. Figure 6 shows the wide variety of screen technologies in HDTVs and the subsequently wide range of power consumption. The dotted black line shows how much power is used by a typical analog direct view and projection CRT TVs.[21]

Note that the direct view display technologies (CRT, plasma, and LCD) fall roughly along a diagonal line that represents a fixed power per unit screen area, similar to the trend noted in Figure 5. The direct view CRT technology is currently limited to 37inches diagonal screen sizes, and so it generally falls below the 200 watt "ceiling". The larger sized plasma and LCD displays typically require anywhere from 200 to almost 400 watts in active mode and shatter the 200 watt "ceiling" seen in analog TVs because they can be produced in larger screen sizes. The projection displays (DLP, LCOS, CRT projection, and LCD projection) fall along a horizontal line that represents a fixed power independent of screen area.

Figure 6



It is important to note that we were unable to identify a single display technology as the clear "winner" in energy efficiency. For example, LCDs are commonly regarded as the most energy-efficient display technology when used in computer monitors; however, once LCDs exceed the size of a typical computer display and get as large as 40 diagonal inches, the LCD technology has no consistent efficiency advantage.[22,23] The most efficient TVs in the chart above utilize a wide variety of display technologies, and thus it would not be useful to try to assign a "best-in-class" status to any one technology. A better approach is to determine the most efficient TVs of a given size and resolution regardless of the type of display.

Effect of Resolution Level on Active Mode Power Use

As mentioned in our market analysis, there are a number of different levels of TV resolution on the market today. Analog TV displays the lowest picture detail and is the dominant resolution found in today's U.S. households. The market is moving to DTV, which the CEA divides into three resolution categories: SDTV, EDTV, and HDTV.[24] SDTVs have similar picture detail compared to current analog TVs, whereas EDTVs and HDTVs can display anywhere from about 2.5 to 13 times the pixels of current analog sets. To simplify our results, we have lumped analog TVs and SDTVs into one category called "standard" that is representative of the resolution capabilities of most TVs in the United States today.[25] To represent the next generation of DTVs capable of displaying higher resolution pictures, we lumped EDTVs and HDTVs into a second category called "ED/HD," although the vast majority of these are HDTVs.

The results of recent testing make it clear that resolution plays some role in power consumption. Generally, the greater the resolution a TV can display, the more power it must consume to deliver this higher quality picture. In fixed pixel displays like LCDs, where pixels are formed by a grid of small "windows," bright backlighting must be used to achieve acceptable picture brightness, thus driving up power use. In CRTs, where most of the power is used to direct a beam of electrons at the TV screen, high definition designs require more power to direct a greater number of electrons. As shown in Figure 7, most of the standard TVs consume, on average, less than 200 watts in active mode, whereas numerous ED/HD TVs consume between 200 and 400 watts (many of these are large diagonal direct view LCD and plasma displays). However, as Figure 6 above and Figure 7 both illustrate, there are HDTVs that deliver vastly improved performance while consuming roughly the same power in active mode as similarly sized analog TVs. As we illustrated in the previous section, all types of display technologies are capable of reaching this level of efficiency. Several TV manufacturers have indicated that they intend to reduce active mode power consumption in their products because this will reduce the bill of materials and help their models to be more price competitive and quieter, in the case of models that now have cooling fans.

Figure 7

Active Mode Power Consumption of TVs by Resolution Category

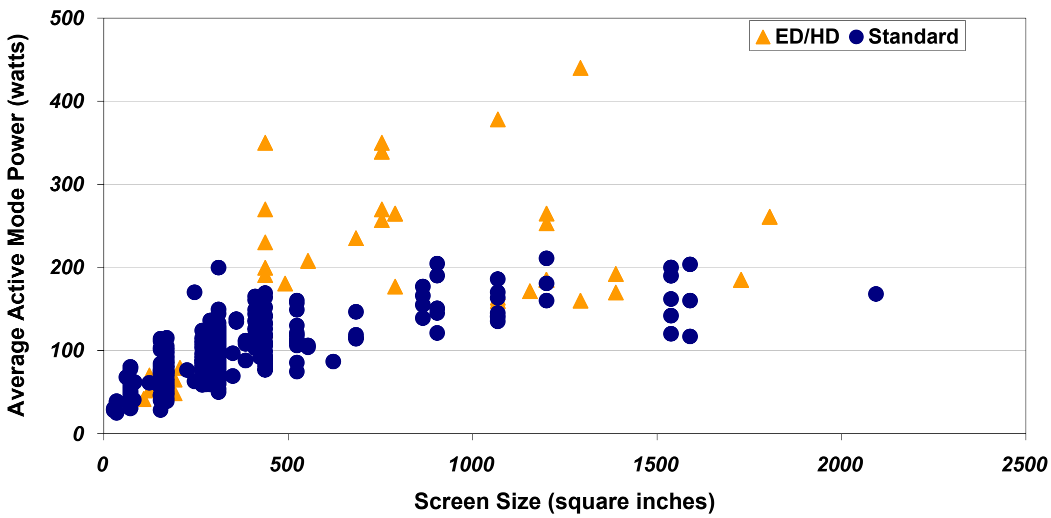


Figure 7 also illustrates that ED/HD and standard TVs of similar sizes can consume drastically different amounts of power in active mode. For example, one ED/HD television in the our data set with a screen of 438 square inches (32 diagonal inches in the 16:9 widescreen aspect ratio) consumes 140 watts in active mode, whereas another ED/HD television in the data set with exactly the same size and screen resolution consumes 2.5 times as much power in active mode (350 watts) without any apparent added functionality.

Active Mode Power Consumption of Current TVs

For the purposes of reporting our findings on active mode power consumption in TVs, we have divided the diverse stock of TVs into several categories based upon their size and resolution capability, which we have found to be influential factors in TV active mode power consumption:

Table 4

Standard, small-screen TV	A TV only capable of displaying standard resolution/analog signals < 40" in its diagonal screen size.
Standard, large-screen TV	A TV only capable of displaying standard resolution/analog signals > 40" in its diagonal screen size.
ED/HD, small-screen TV	A TV capable of displaying EDTV/HDTV digital signals < 40" in its diagonal screen size.
ED/HD, large-screen TV	A TV capable of displaying EDTV/HDTV digital signals > 40" in its diagonal screen size.

The representative active mode power consumption for each of these TV categories is listed in Table 5 below. Each value listed represents the average TV of a particular type. For the purposes of calculating the annual energy consumption of each TV type, we assumed a duty cycle of five hours per day in active mode and 19 hours per day in standby mode based on U.S. Census statistics from the year 2000 on average daily TV viewing time (duty cycle assumptions were slightly altered for macroscale, nationwide energy calculations; see Appendix B).[26]Since the measured standby power of the TVs in our database does not vary much based on TV technology or screen size, we used the median standby power of 3.9 watts for the purposes of our energy calculations.[27]

Table 5: Energy Consumption Baseline for Current TVs in the U.S. Market

TV Type	Active Mode Power Use (W)	Overall Annual Energy Consumption (kWh per year)
Standard, small-screen TV	86	184
Standard, large-screen TV	156	312
ED/HD, small-screen TV	150	301
ED/HD, large-screen TV	234	455

NATIONWIDE ENERGY USE AND SAVINGS ESTIMATES

Nationwide Energy Use by TVs

We estimate that there are approximately 266 million TVs currently installed in homes in the United States, growing at a rate of about 3.5 million TV sets per year. (See Appendix B for the assumptions that entered this estimate.) Based on market data available from the CEA, about 88 percent of these installed TVs would fall into our standard category (analog TVs and SDTVs), with ED/HD TVs making up the remaining 12 percent (the vast majority of these are HDTVs). Sales figures from the CEA[28] and consumer survey information from the 2002 RECS survey were used to estimate how many of these TVs fall into the four TV categories outlined above.

Knowing roughly how much energy each of the four categories of TVs use per year and what percent of the total U.S. TV stock these categories comprise, we can arrive at an estimate of the United States's annual energy use by TVs. We estimate TVs in the United States consume more than 46 billion kWh every year, which constitutes about 4 percent of U.S. residential electricity use. This is roughly the same amount of electricity used annually by all of the households in the state of New York. Annual TV energy use in the United States, 80 percent of which is used in active mode, results in $4.7 billion in consumer utility bills and about 31 million tons of CO_2 emissions from power plants.

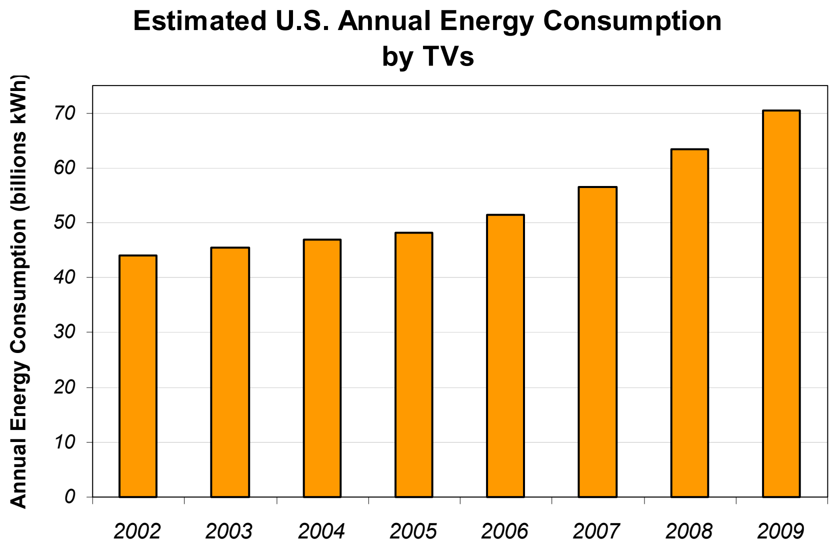
Table 6: Summary of Nationwide U.S. TV Energy Use Estimates – 2004

TV Type	*Percent of U.S. Stock*	*Nationwide Energy Use (billion kWh)*
Standard, small-screen TV	71%	27.2
Standard, large-screen TV	17%	10.6
ED/HD, small-screen TV	6%	3.6
ED/HD, large-screen TV	6%	5.4
	TOTAL	**46.9**

These figures only represent a snapshot of how much energy TVs used in 2004. As mentioned in our market analysis, a number of trends are emerging that will influence aggregate TV energy use in the United States, and as a result, we only expect the annual energy consumption figures to rise. NRDC/Ecos has developed a simplified model that predicts how nationwide TV energy use will expand in the coming years. Our estimates are based upon several trends in the TV market, including:

- Continued linear growth in the amount of TVs installed in households nationwide at a rate of about 3.5 million units per year.
- Continued growth in sales of DTVs (almost entirely ED/HD TVs) based on CEA predictions that DTV will reach more than 50 percent penetration in U.S. households by 2008.

Figure 8



As shown in Figure 8, our model predicts that in the absence of improved efficiency, annual energy consumption by TVs in the United States could increase by almost 50 percent by 2009 due to the combined growth in numbers of TVs and sales of ED/HD TVs. Multiple TVs in the home, greater TV viewing time, and purchases of higher performance, power-hungry TVs will also fuel this growth.

Energy Savings Estimates

In order to estimate potential TV energy savings, we have created two cases for comparison: the base case, which represents the *status quo* energy consumption, and the improved case, which is what we estimate to be achievable in the market. The base case is identical to the national energy use estimates quoted above.

For the improved case, we observed that 25 percent reductions in active mode power use appear to be technologically achievable across all four types of TVs. Because televisions are complex, multi-component systems, we did not examine specific component-level savings opportunities achievable, for example, by implementing more efficient power supplies or display technologies. We simply observed that, within each of the four TV types listed above, we have measured TVs that consume 25 percent less power in active mode than the average TV of the same size in that same category.[29] This means that consumers can currently choose TV sets with the same resolution capabilities and roughly the same size that consume 25 percent less power in active mode and about 23 percent less electricity[30] on an annual basis than a typical model of the same type.

Also as a component of our improved case, we assume that the 1 watt TV standby specification set by ENERGY STAR is readily achievable in efficient TVs. A summary of the annual energy consumption of the base and improved case is shown in Table 7.

Table 7: Comparison of Baseline and Improved Cases for TV Energy Consumption

TV Type	Base Case Annual Energy Consumption (kWh per unit per year)	Improved Case[31] Annual Energy Consumption (kWh per unit per year)
Standard, small-screen TV	184	125
Standard, large-screen TV	312	221
ED/HD, small-screen TV	301	212
ED/HD, large-screen TV	455	328

Using the base and improved cases outlined above, we estimate that the United States could save anywhere from 1 to 11 billion kWh per year by encouraging these energy efficiency improvements in TVs. The amount of energy saved per year depends on the percent of sales that would meet our improved case energy efficiency goals and the growth of the TV market in coming years, particularly in the ED/HD sector. These yearly savings would add up to more than 21 billion kWh in saved electricity by 2009 if, starting in 2006, all TVs sold in the United States were able to match our improved case assumptions (25 percent active mode power reduction and 1 watt standby). The cumulative savings achievable by the beginning of 2009 are equivalent to $2.2 billion in utility savings and 14.4 million tons of avoided CO_2 emissions from power plants.

The sale of these energy-efficient models found in the improved case above could be encouraged through a voluntary labeling program such as ENERGY STAR; however, such a program is unlikely to directly affect 100 percent of the TVs in use across the country. Figure 9 shows several distinct TV energy use paths in the United States that could be achieved given the varying levels of success of such a market-driven program. The top line represents the current base case, whereas the lower lines show what the improved cases might look like depending on various levels of program penetration. By penetration, we mean that 25 percent, 50 percent, or 100 percent of the TV models sold in the United States would meet the new energy efficiency guidelines.

Figure 9

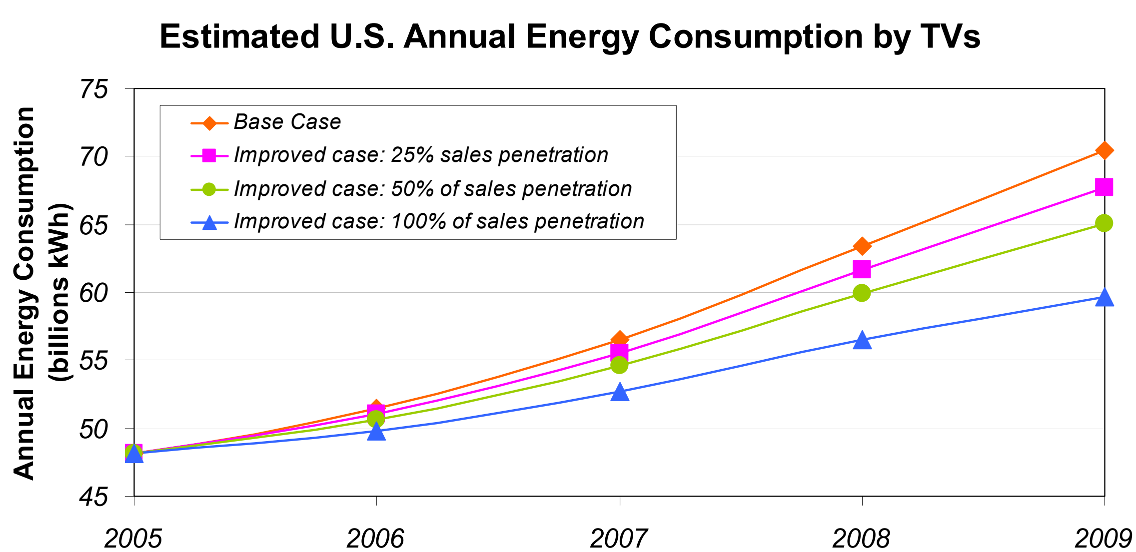


Table 8 breaks down the potential nationwide energy savings by 2009 based on the penetration of the energy-efficient units. The potential savings are still substantial even though the program would be voluntary and would only affect new sales. The savings achievable even at the lowest rate of market penetration are noteworthy. Even at 25 percent sales penetration, the United States would save 5.4 billion kWh of electricity between 2006 and 2009, enough energy to power about 500,000 average U.S. homes.

Table 8: Nationwide Cumulative Energy Savings from 2006–2009 from TV Efficiency Improvements

Market Penetration	**Nationwide Energy Savings by 2009 (billion kWh)**	**Nationwide Utility Cost Savings by 2009 (billions USD)**	**Nationwide Offset CO_2 by 2009 (million tons)**
100%	21.5	2.2	14.4
50%	10.7	1.1	7.2
25%	5.4	0.5	3.6

POLICY REVIEW

U.S. National Policy Review

ENERGY STAR is the only national program in the United States today that addresses energy efficiency in TVs. Through its marketing label, the ENERGY STAR program encourages TV energy efficiency by setting target standby power consumption levels. The current ENERGY STAR spec for TVs has been separated into three tiers that steadily lower the standby power levels, as shown in Table 9 below.

Table 9: ENERGY STAR Spec for TV Standby Power (Version 2)

Tier I **Effective 7/1/2002**	**Tier II** **Effective 7/1/2004**	**Tier III** **Effective 7/1/2005**
All TVs: ≤ 3 watts	Analog TVs: ≤ 1 watt Digital TVs: ≤ 3 watts	All TVs: ≤ 1 watt

Estimates by Lawrence Berkeley National Lab (LBNL) claim that the ENERGY STAR program in the United States has saved about 9 billion kWh in electricity in the United States since its inception in 1998. Prior to the ENERGY STAR specification, standby power levels could exceed 25 watts; however, today standby levels of less than 1 watt are achievable due to a successful market transformation. ENERGY STAR has demonstrated an interest in active mode energy use of electronic products with its recent revision of the computer monitor specification,[32] creation of the external power supply specification,[33] and its announcement to include active mode consideration in its imaging equipment and personal computer specifications.[34] There may be opportunities for ENERGY STAR to consider active mode in future specification revisions for televisions as well.

California Energy Commission (CEC) Policy

In December of 2004, the commission adopted mandatory energy efficiency standards for more than 20 types of appliances, including TVs. The maximum allowable standby power level for TVs is currently set to 3 watts and should be achievable by a large number of units on the market. This mandatory level will go into effect January 1, 2006.

International Policy Review

There are currently a handful of mandatory and voluntary programs in industrialized nations around the world that encourage TV energy efficiency. Programs that address standby mode energy use have been around for several years, but a number of active mode programs are coming into effect that have collectively raised the bar for TV energy efficiency. All of the international programs that we have identified to date use the IEC 62087 test procedure to measure active mode power consumption in TVs in a standardized way. Most of these programs also use a comprehensive performance metric known as the energy efficiency index (EEI) to rank TVs by energy efficiency. Below we provide a summary of the major TV energy efficiency programs in use around the world, region by region.

European Union

There are currently three main initiatives in the EU that promote TV energy efficiency in active mode. The Group for Energy Efficient Appliances (GEEA) and the EU's Eco Label program both endorse energy-efficient TVs using active mode efficiency as one of the criteria. The programs use the IEC 62087 audiovisual equipment test procedure to test active mode energy consumption in TVs. They record active mode energy efficiency using a metric first proposed by Hans-Paul Siderius and others, known as the energy efficiency index (EEI), which takes a TV's screen area, scan rate, tuner, and other factors into account to rate the unit's overall energy efficiency compared to a reference TV.[35] An EEI of 2 would mean that the measured TV consumed twice as much energy as the reference TV. In brief, the lower the EEI, the more efficient the TV is compared to the baseline.

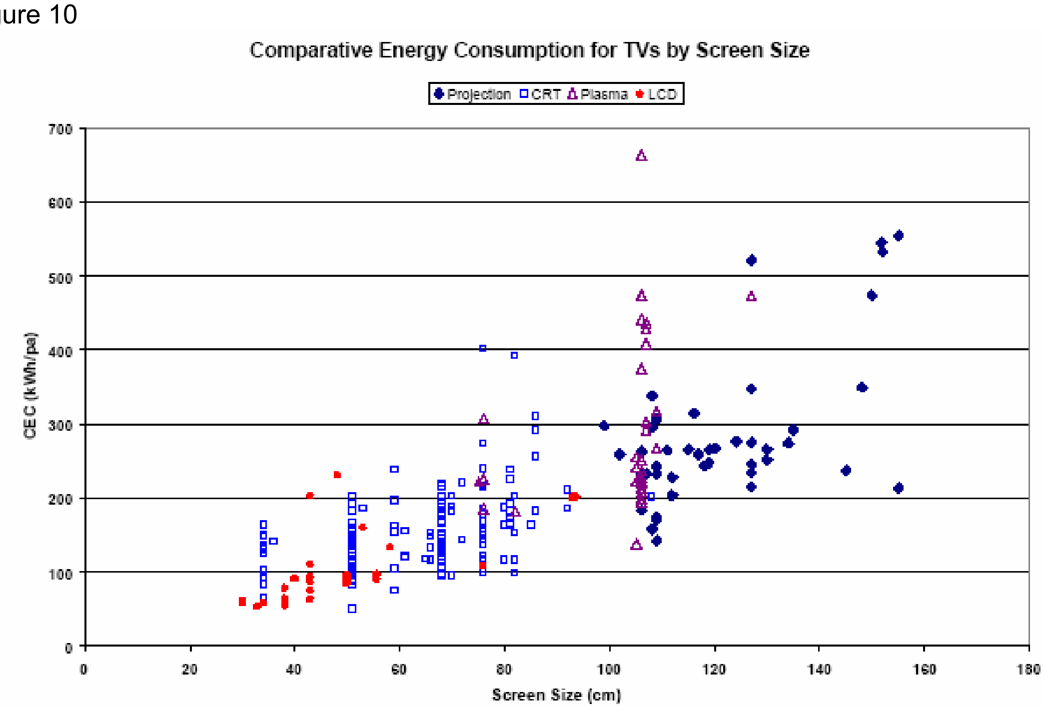
The European Commission's Code of Conduct agreement with TV manufacturers currently requires them to report active mode power consumption as measured using the IEC 62087 test procedure in order to meet active mode energy efficiency guidelines.

Australia

The Australian Greenhouse Office (AGO) operates several mandatory and voluntary programs to encourage energy efficiency in home appliances. The AGO is an international partner in the ENERGY STAR program, and manufacturers selling TVs in Australia can receive an ENERGY STAR label on their sets if they meet the current standby mode power levels.

A proposal by the National Appliance and Equipment Energy Efficiency Program (NAEEEP) would add TVs to the AGO's Energy Rating mandatory labeling program and create a minimum energy performance standard (MEPS) for TVs.[36] Australia has already adopted a national standard in harmony with the IEC 62087 TV test method that will guide future measurements of TV active mode power in Australia. In its October 2004 report, the AGO and its consultants measured standby and active mode power consumption in a wide range of TVs in retail settings. Figure 10 shows estimated annual energy consumption for the units measured and is largely in agreement with NRDC/Ecos' findings.[37]

Figure 10



Recent discussions indicate that Australian researchers are evaluating approaches similar to those advocated by NRDC/Ecos in later sections of this report. For example, Australia may modify its IEC-based test method to include a standardized moving image sequence from a DVD as opposed to the static image that IEC 62087 calls for. In addition, the AGO has indicated that it may pursue an annual kWh approach to rating TV energy efficiency.

China

The Center for Energy Conserving Products (CECP) harmonized with the U.S. ENERGY STAR standby power guidelines for TVs and has been following these guidelines since 2002.

The CECP and the Chinese National Institute of Standards (CNIS) recently announced that China will begin to regulate active mode energy efficiency in TVs in addition to standby power levels. Beginning in 2005, both organizations will begin to use IEC 62087 and the EEI metric to rate CRT TVs based on their overall energy-efficiency. The CECP will run a voluntary labeling program that will promote the most energy efficient TVs, whereas CNIS will impose a MEPS with less stringent guidelines to mandate minimum energy efficiency performance.[38] Under both the mandatory standards and the voluntary labeling program, non-CRT display technologies such as plasma, DLP, and LCD will not be included.

Japan

Japan enforces a MEPS for TVs under the Top Runner program, and was the first nation to regulate the active mode of TVs. IEC 62087 is the preferred test method for measuring TV active mode power consumption under this program.

Korea

The Korean “Energy Boy” program is a voluntary endorsement used to encourage lower standby power in TVs and other consumer electronics in Korea. The current standby power level for TVs is set at 3 watts, similar to the ENERGY STAR program.

TECHNICAL AND POLICY RECOMMENDATIONS

TV Active Mode Test Method

The DOE test procedure mentioned earlier is currently the only official test method for measuring active mode power of TVs in the United States. The method, which was designed to measure CRT TVs with antennae, is hopelessly out of date since it had not anticipated the advent of new display technologies and signal formats. In order for U.S. institutions to include active mode power use in future TV energy efficiency policies, the DOE test procedure must be replaced. IEC 62087 is built upon a solid foundation of manufacturer support, and would be a promising candidate to replace the DOE procedure; however, the test method's screen calibration settings are known to cause systematic underestimation of "real world" power use of TVs in the active mode.

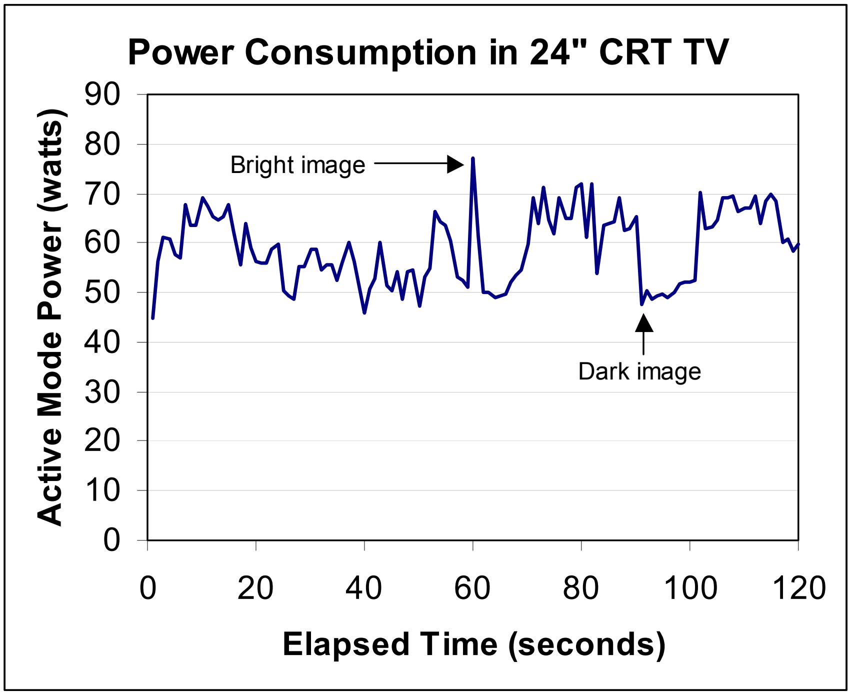
In order to properly inform policy initiatives, we recommend that the United States collaborate with international partners in the near future to help revise the current international standard for TV active mode power measurement, IEC 62087. This would enable energy efficiency programs like ENERGY STAR and governing bodies like the CEC to reference the new standard for use in their programs, eliminating the need to develop a new and independent test method. We recommend that U.S. advocates focus on the following issues:

- Maintain the use of static test patterns in the procedure for setup and calibration, but utilize a standard clip of moving images to make an energy measurement over a period of time.
- Ensure that brightness/contract/luminance settings are revised to more accurately reflect how TVs are typically setup in the home, and include set up conditions for not only CRT TVs, but also other display technologies.

Energy Measurement

IEC 62087 currently references a static, three bar black and white video test pattern to measure active mode energy use of a TV however, the advent of DTV and digital video compression means that certain TVs may consume more power to display moving images than to display still images because of the processing power required to decompress digital video. A static test signal would normally not account for this power consumption. Furthermore, TV technologies like CRT and plasma are also highly sensitive to the brightness of the image being displayed and consume more power when generating bright pictures than dark ones. Figure 11 illustrates how the power consumption in a 24" CRT TV can range by as much as +/- 25 percent from the average power depending on the image being displayed. A static test signal would fail to capture the peaks and troughs in power consumption due to the variation of the brightness of an image.

Figure 11



NRDC/Ecos recommend measuring TV power consumption while displaying a standardized, moving image test clip that has an average pixel level (APL) or an average percent of maximum brightness that is comparable to typical TV signals.[39] The average power consumption over the course of the standard video sequence would be the "average active power." Maximum and minimum power could also be recorded to take the variability of a particular TV's power consumption into account. This test method is a close approximation to real world viewing conditions and should not require significantly increased laboratory time to perform.

Test Setup Conditions

The current version of IEC 62087 only specifies screen calibration conditions for CRT TVs, and these screen calibration conditions, which include brightness/contrast settings, tend to underestimate CRT TV active mode energy use because the luminance level to which screens are calibrated does not reflect real world viewing conditions. For other display technologies, the method stipulates no specific values, indicating that manufacturer-recommended settings should be used. In order to ensure uniform testing of TVs that reflects actual home TV energy use setup conditions of TVs should be revised to include all TV technologies as well as reflect typical levels found in home-operated TVs.

It seems there are two approaches that could be used to select relevant and meaningful TV setup conditions:

Field survey to determine prescriptive setup conditions. Measure TV luminance levels and brightness/contrast control settings as part of a field survey of a representative sample of households. The survey could identify typical light output and screen settings for each type of display technology. The results of the survey would inform revisions to IEC 62087 to ensure that test conditions for each display technology match real world use conditions. The survey/testing could be performed by trained home theater technicians working for organizations like the Imaging Science Foundation (ISF). Organizations like ISF routinely calibrate TV systems for home theater enthusiasts and could include brief pre-calibration power measurements as part of their normal procedure. Depending on the data collected, one universal setup condition could be applied to all TVs, regardless of technology, or different setup conditions could be specified for different technologies.

This approach would create setup levels that closely mimic those used in homes, and would not significantly increase the complexity of the test procedure, but it would be relatively time consuming to conduct the survey to understand what the setup levels should be. Additionally, regular revision to the test method would be required to keep up with the new display technologies entering the marketplace as well as changes in user behavior.

Use image sequence to create optimal picture performance before testing. Rather than selected individual levels for each setting, and possibly for each technology, use a series of calibration instructions that would adjust the TV screen settings such that the TV displays optimal picture quality. Audiovisual professionals at the ISF and Joe Kane Productions have developed well-defined procedures and reference video patterns for finding the optimal screen settings for all types of TVs. The IEC could eventually adopt similar "picture optimization" procedures in future versions of the 62087 standard that would take the place of current TV setup methods. This approach provides added value to the TV industry as well, standardizing and simplifying the approaches manufacturers could take to ensure their products perform optimally.

Although this approach would likely produce active mode power measurements that are slightly lower than home measurements, it would produce a robust standard that would require little or no revision when future TV display technology arrives in the marketplace. Although the exact procedure for setup would need to be determined, the procedure could be chosen such that only minimal extra setup time would be required for this approach.

A sensitivity analysis for a variety of display types could be conducted to help determine the best approach. The sensitivity analysis would examine the following:

- How brightness/contrast and other screen settings such as color and sharpness affect active mode power consumption of a variety of TV display technologies.
- How energy use of TVs set up in the home compare to TVs set up under a performance calibration sequence.

Table 10 gives the current test methods that are available and highlights how the proposed changes that NRDC/Ecos recommends would more fully inform policy initiatives in the United States.

Table 10: Summary of Test Methods for TV Active Mode Power Measurement

	Measures black and white CRTs	Measures color CRTs	Measures all new display types	Reflects real world power consumption
DOE method	✓			
IEC 50301	✓	✓		
IEC 62087	✓	✓	✓	
Suggested method	✓	✓	✓	✓

Efficiency Metric

In order to compare the efficiency of television in a fair and consistent way, an efficiency metric must be used that meets the needs of policy-makers in the United States and helps inform utility market transformation programs. The Energy Efficiency Index (EEI) that was developed by the Europeans and may be adopted by Australia and others provides an inclusive and holistic measure of a TV's overall energy efficiency, including power use in standby and active modes; however, we believe that the EEI metric is not ideal for the United States because it does not provide information about the absolute energy use of a product in kWh of electricity. Rather, it provides an indexed number that indicates how much more energy intensive a particular TV is compared to a reference TV. This could be used to develop specifications for TV active mode power (*e.g.*, TV sets with an EEI less than 2 would receive an energy efficiency endorsement), but the number cannot be used to directly estimate energy savings. Policy makers would still need to estimate energy use and savings based on raw, measured data. Additionally, the number would mean little to consumers and utilities because it lacks information about operational costs and kWh savings.

NRDC/Ecos recommend an annual energy use metric that we feel would most directly communicate information about the operational costs and energy use of a TV. Such a metric would indicate the total kWh of estimated annual energy use. The annual energy consumption of a TV could be determined using the same approach taken in this report: measuring active and standby mode power and multiplying by the typical hours of operation in each mode. Policy makers will have to come to agreement on a standard duty cycle for TVs based on real world TV viewing data, but this development would have to take place regardless of metric in order to make informed energy savings estimates. The annual energy use metric could be combined with a comparative metric, such as a five-star scale, so that consumers would be able to compare the efficiency of TVs with similar screen sizes and resolutions and still understand the absolute energy consumption of the model they purchase in kWh.

For policy makers and consumers alike, there are numerous benefits to the annual energy use metric. The annual energy use metric simplifies the revision process for energy efficiency specifications in programs like ENERGY STAR because policy makers no longer have to deal with multiple efficiency metrics for different modes of operation. The specification could easily be updated based on power measurements of a representative sample of TVs, reducing the amount of time required to revise specifications and enabling more frequent updates than currently possible.

Consumers also benefit from annual energy use metrics because they provide more useful information about the total energy efficiency of a product. A single annual energy consumption number allows the consumer to easily compare one product to another on the basis of kWh per year (or more meaningfully, dollars per year), instead of having multiple numbers for each mode of operation. There is no longer a need to directly explain to the consumer what each mode of operation means, only that the sum total of use in all modes will amount to a certain portion of their electric bill. This may not be practical in low-power products where annual energy use might amount to less than $10; however, in high-power electronic appliances like TVs, consumers could expect to pay $20 to $40 or more per year, and several hundred dollars over the life of the TV, to operate the device. It makes customers clearly aware of the operating cost trade-offs of moving to a larger or higher resolution model as well.

Finally, there is a historical precedent for the annual energy use approach, which has been used time and time again in the energy efficiency community. National mandatory appliance efficiency standards for refrigerators, air conditioners, and other appliances have typically used annual kWh as the metric for regulation. These standards proved that manufacturers and policy makers can come to consensus on test methods and duty cycle assumptions for a variety of appliances to report annual energy consumption. All subsequent efforts to highlight differences in appliance energy use–EnergyGuide labels, consumer guides, magazine articles, utility incentive and marketing programs, government procurement efforts, and ENERGY STAR labels – have depended on this base of knowledge on annual energy use information for their success. Published data on annual energy use is essential to these groups in estimating annual operating cost, determining payback times for improved efficiency, and making lifecycle cost comparisons.

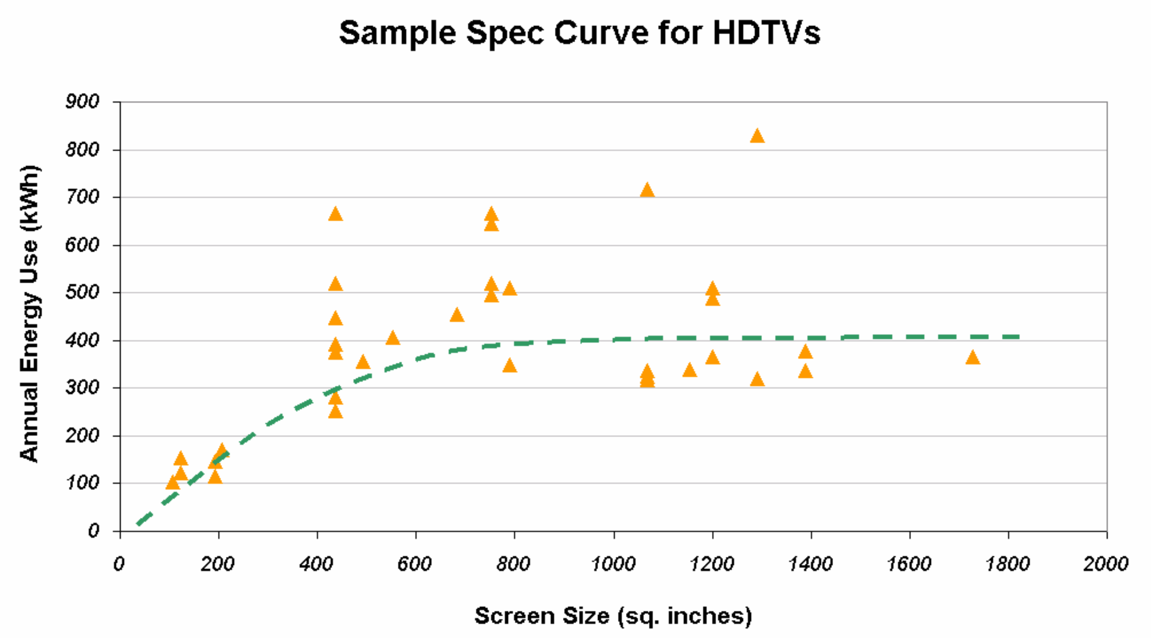
Recommendations for U.S. Policy

Voluntary Labeling

Current U.S. efforts to encourage energy efficiency in TVs, such as the ENERGY STAR program, only label products based on the amount of power they consume in standby mode (when the user believes the TV is "off") and do not limit the TV's power consumption when it is turned "on." As a result, consumers can select a TV they believe is energy-efficient, and then discover that it actually uses the same or more energy per year than a non–ENERGY STAR TV of similar size. NRDC/Ecos recommend that new and existing energy efficiency labeling programs in the United States, such as ENERGY STAR, adopt a specification for total TV energy efficiency (including all modes of operation, active and standby) in the near future that would harmonize, where possible, with international efforts currently under way in Australia, Europe, Japan, and China. As much of the rest of the industrialized world moves to encourage active mode energy efficiency in TVs, the United States can play an important leadership role.

NRDC/Ecos recommends that the new specification evaluate TV energy efficiency based on an annual energy use metric as described in the section above on TV efficiency metrics. The specification should grant allowances for additional electronic functions like CableCARDs™ that result in fixed increases in energy consumption. Having separate specifications for different screen technologies like CRTs, LCDs, plasma, DLP, etc., is not recommended, as consumers should be encouraged to buy the most efficient TV, not just the most efficient TV of a given technology type. Specification curves drawn on a graph of annual energy use vs. screen area could account for different levels of resolution, features, and performance. A hypothetical specification curve for HDTVs is illustrated in Figure 12 below.[40] TVs of similar size and comparable performance characteristics with the lowest energy consumption would receive endorsement through an efficiency label (models that fall *below* the green line in Figure 12).

Figure 12



Mandatory Labeling

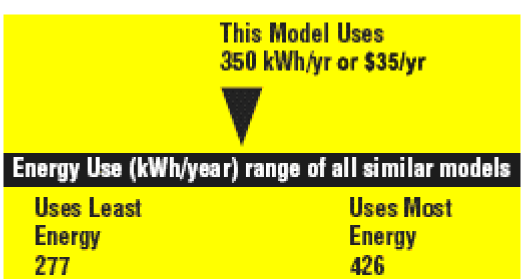
American consumers are accustomed to seeing comparative energy use information for appliances when they go shopping. That same type of information is not currently available for TVs, even though 260 million TVs are now in use, and some of the newer, larger models consume as much energy per year as a new refrigerator.

Ecos/NRDC recommend that U.S. policy makers follow the lead of countries like Australia and examine the possibility of mandatory energy efficiency labeling for TVs. Today's larger TVs can consume on the same order of energy per year as a new refrigerator, and thus it seems that these appliances should also be required to bear the DOE's EnergyGuide label. The DOE currently has the legal authority to extend EnergyGuide labeling to TVs but has never taken the necessary steps to add TVs to the current list of labeled products.

As illustrated in Figure 13, the new EnergyGuide label for TVs should provide information on:

- The amount of energy used to operate the TV annually, based on a standard duty cycle.
- The cost to operate the TV annually, based on energy use and typical electricity prices.
- The range of annual energy consumption for other TVs of comparable size and resolution. This information could be shown on a horizontal scale, as is done with the current EnergyGuide label, or more effectively, it could be shown using a five-star scale or similar comparative measure.

Figure 13



RECOMMENDATIONS FOR FUTURE WORK AND 2005 STRATEGY

Detailed Examination of Resolution

In our 2004 research, the limited time and scope of our project required that we only examine differences in TV resolution at a broad level. We examined differences between broadly defined "classes" of TVs—namely, what we defined as standard resolution TVs and ED/HD resolution TVs—and tried to compare TV energy efficiency within these categories. As we have noted, there are many smaller gradations that further separate resolution levels found in today's TVs. Table 11 outlines some of these smaller categories of TV resolution.

Table 11: Summary of Resolution Levels in 2004 TV Market

"Branded" TV Resolution Level	Typical Resolution (horizontal x vertical pixels)	Number of Pixels Displayed	Interlaced/ Progressive Scan
Analog	330 x 480	158,400	Interlaced
SDTV 480i	640 x 480	307,200	Interlaced
EDTV 480p	852 x 480 (widescreen)	408,960	Progressive
HDTV 720p	1280 x 720 (widescreen)	921,600	Progressive
1080i	1920 x 1080 (widescreen)	2,073,600	Interlaced
1080p	1920 x 1080 (widescreen)	2,073,600	Progressive

In future work, we recommend giving more consideration to the exact level of resolution displayed by a TV and learning whether small differences in resolution (*e.g.*, between EDTV and HDTV resolutions) have noticeable effects on active mode power consumption. This knowledge will be crucial for any future policy development.

Independent Data Gathering

Australia and other countries are now measuring TV energy use in the active mode in retail stores and may soon make information on TV energy efficiency available to the public through voluntary/mandatory labeling programs and publication of measured data on the Web. Because TVs are increasingly standardized for international sales with similar or identical models of TVs being sold on multiple continents, U.S. consumers could benefit from this energy efficiency research and use it to inform their purchasing decisions. NRDC/Ecos recommends cooperation with Australia, China and other governments currently measuring the active mode power of TVs with a goal of globally sharing and publishing information about TV energy efficiency to inform consumer decisions prior to policy action.

The private sector can also act to make consumers aware of the energy and environmental impacts of TV purchase decisions. While it is costly to send large, heavy televisions to independent laboratories for precise efficiency measurements, it is relatively cheap to send simple plug load meters to interested citizens. They can measure and report the approximate power use by mode and overall energy use of the products in their homes and offices. The data can then be collected and published electronically on the Web. Interested consumers could measure their TV power use under a variety of conditions and report data by model, which could then be considered by other interested TV buyers.

Similarly, the print and electronic magazines that currently review televisions could include in their standard testing protocols simple measurements of power use, the results of which could be published as a standard part of TV reviews. Furnishing these publications with NRDC/Ecos TV research through a concerted outreach effort could help raise awareness of the energy consumed by home electronics in general and potentially spark interest in energy-related stories about these devices.

TV Components

As mentioned briefly before, the TV research conducted by NRDC/Ecos in 2004 took a system-wide approach to TV energy consumption. We measured the energy use of the entire TV rather than the power drawn by its individual components. In the next phase of work, individual components of TVs could be identified that may affect the overall power consumption of the device when in use, such as CableCARDs and internal power supplies. As recommendations toward policy actions continue in 2005, it will be extremely important to understand how much power is consumed by these additional TV components so that "allowances" can be made in any proposed specifications.

TV Screen Settings Sensitivity Study

Before moving forward with any broad recommendations on revised screen settings for the IEC 62087 test procedure, NRDC/Ecos recommend investigating the effect of these settings on TV active mode power consumption through a sensitivity study. This would involve measuring the power consumed by a TV in active mode under a range of screen settings. The variation in active mode power could be recorded while altering the screen settings from absolute minimums to absolute maximums, as well as "optimal picture quality" settings. It is assumed that certain digital screen technologies like LCD and DLP will show stable power consumption over a range of screen settings, whereas plasma and CRT may be heavily affected by these settings. This work will help inform future collaboration with policy makers and the IEC committees reviewing IEC 62087 by identifying the level of priority for revising screen calibration procedures in the test method.

APPENDIX A

Summary of TVs Measured in 2004 by Ecos Consulting

Manufacturer	Model Name/Number	Technology Type	Resolution Level	Screen Size & Aspect Ratio	Average power (W)	Estimated Annual Energy Consumption (kWh)
Epson	LS57P1	LCD, rear proj.	HD	57”, 16:9	170	337
JVC	HD-52Z575	LCOS, rear proj.	HD	52”, 16:9	174	345
Mitsubishi	PD-5010	Plasma	HD	50”, 16:9	451	849
Optoma	FRRD50	DLP, rear proj.	HD	50”, 16:9	168	334
Optoma	RD50	DLP, rear proj.	HD	50”, 16:9	164	326
Panasonic	TC-32LX20	LCD	HD	32”, 16:9	198	387
Phillips	34PW862H	CRT	ED	34”, 16:9	100	209
RCA Scenium	HDLP50W151	DLP, rear proj.	HD	50”, 16:9	193	379
Samsung	HLP5063W	DLP, rear proj.	HD	50”, 16:9	156	312
Samsung	6413TE	CRT	analog	13”, 4:3	41	101
Sony	KV-30xBR910	CRT	HD	30”, 16:9	158	314
Sony	KE-42x5910	Plasma	HD	42”, 16:9	287	550
Sony	KV-24FS120	CRT	analog	24”, 4:3	59	135
Sony	KV-27FS210	CRT	analog	27”, 4:3	69	153
Sony	KV-36FS210	CRT	analog	36”, 4:3	87	185
Sony	KLV-32M1	LCD	HD	32”, 16:9	125	255
Sony	KV-32HS420	CRT	HD	32”, 4:3	167	332
Sony	KV-27FS120	CRT	analog	27”, 4:3	87	186
Sony	KE-50XS910	Plasma	HD	50”, 16:9	357	679
Toshiba	32HL83P	LCD	HD	32”, 16:9	157	314
Zenith	R57W47	CRT, rear proj.	HD	57”, 16:9	192	378
Zenith	L15V26C	LCD	HD	15”, 4:3	42	103
Zenith	L20V26C	LCD	HD	20”, 4:3	49	116
Zenith	P42W34/34H	Plasma	ED	42”, 16:9	257	496
Zenith	L17W36	LCD	HD	17”, 16:9	52	122

APPENDIX B

Assumptions for TV Stock Calculations

To estimate nationwide energy consumption by TVs, it was necessary to take stock of the number of TVs in operation in the United States today. The 2002 and 1997 Residential Energy Consumption Surveys (RECS)[41] from the DOE's Energy Information Administration (EIA), combined with current TV sales data, aided in estimating the current size of the U.S. TV stock. The RECS data provided information on the number of TVs installed in American households, and the sales data served as a check on how quickly these numbers should be rising. We estimated the size of the United States stock in 2004 at about 266 million units, assuming linear growth of the stock since 2002.

APPENDIX C

Assumptions for TV Duty Cycle

Because Americans are now likely to have multiple TVs in their home—the second, third and fourth TVs that might be located in bedrooms, workshops, etc.—it was necessary to alter our duty cycle assumptions when examining TV energy use on a nationwide scale to account for these supplementary TVs that might not be viewed as often.

The 2000 U.S. Census reports average TV viewing times of about five hours.[42] Based on this information, we assume that a home's primary TV—the center of a home entertainment system, for example—is in active mode five hours per day and in standby mode for the remaining 19 hours of the day. We assume that supplementary TVs are not watched as much, on average, as the home's primary TV. The table below outlines our assumptions about the duty cycles of these supplementary TV sets. We used a weighted average to account for the viewing that occurs on a household's extra sets, which provides an average duty cycle and indicates about how much time is spent viewing any given TV in the United States. The weighting is based on the percentage of the total TV stock represented by primary TVs, secondary TVs, and so on, which was distilled from Residential Energy Consumption Surveys (RECS) from the Energy Information Administration (EIA).[43] Our duty cycle is conservative and is suitable only for macroscale energy calculations.

Duty Cycle Assumptions for American TV Viewing

	Number of Hours per Day in Active Mode	***Number of Hours per Day in Standby Mode***
Primary TV	5	19
Secondary TV	3	21
Tertiary TV	2	22
Quaternary TV	1	23
Above	1	23
Average	**3.5**	**20.5**

ENDNOTES

[1] "ENERGY STAR® Requirements for TVs, VCRs, DCR TVs with POD Slots, Combination Units, Television Monitors, and Component Television Units," ENERGY STAR web site, January 26, 2005, www.energystar.gov/ia/partners/product_specs/eligibility/tv_vcr_elig.pdf.
[2] "U.S. Consumer Electronics Sales & Forecasts: 1999–2004," Consumer Electronics Association (CEA), Arlington, VA, 2003.

[3] *Statistical Abstract of the United States,* 2001, U.S. Census Bureau,Washington, DC, 2001.
[4]"Residential Energy Consumption Surveys: 2001 Housing Characteristics Table," U.S. Department of Energy, Energy Information Administration, www.eia.doe.gov/emeu/consumption.
[5] "Washington Insider Series: The HDTV Transition," Consumer Electronics Association (CEA), Arlington, VA, 2003.
[6] Personal communication with Sean Wargo, senior industry analyst, Consumer Electronics Association (CEA). November 3, 2004.
[7] "Washington.…," Consumer Electronics Association (CEA).
[8] Personal communication with Sean Wargo of the Consumer Electronics Association, October 11, 2004.
[9] "Washington…," Consumer Electronics Association (CEA).
[10] Personal communication with Sean Wargo, Consumer Electronics Association senior industry analyst, November 3, 2004.
[11] Donovan, Paul, "Consumer Displays: New Technologies, New Opportunities," presented at the 2005 International Consumer Electronics Show, January 6, 2005.
[12] "No. 1125. Media Usage and Consumer Spending 1995 to 2004," *Statistical Abstract of the United States: 2001.* U.S. Census Bureau, Washington DC, 2001.
[13] Utility program evaluators and policy makers should be careful to distinguish between the hours of use of the main TV which will likely be found in the living room or family room, and that of the second or third TV that is in the bedroom, kitchen, etc. These secondary TVs are often smaller, operated fewer hours per day, and as a result normally consume less annual energy than the primary or main TV.
[14] "BNCE3: Standards Relevant to the Testing and Conformance of Domestic Electronic Equipment." U.K. Market Transformation Programme, September 2004. www.mtprog.com/approved briefingnotes/StandardsRelevanttotheTestingandConformanceofDomesticElectronicEquipment.aspx?kintUniqueID=300.
[15] Personal communication with Bob Harrison of the U.K. Market Transformation Programme, September 29, 2004.
[16] "BNCE3…," U.K. Market Transformation Programme.
[17] Rosen, K. and Meier, A. "Energy Use of Televisions and Videocassette Recorders in the U.S.", Lawrence Berkeley National Lab., Berkeley, CA, March 1999.
[18] Personal communication with Joel Silver of the Imaging Science Foundation, October 21, 2004.
[19] An analysis of variance (ANOVA) was performed using MINITAB statistical analysis software. The ANOVA analysis is an attempt to statistically isolate the effects of individual variables–screen area, resolution, display technology, etc.–on another primary variable. In this case, we used ANOVA to determine which of these variables had the greatest effect on active mode power use.
[20] This 200 watt ceiling means that NRDC/Ecos has observed few analog CRT TVs that draw more than 200 watts of power on average. This is not to say that this kind of power use in analog TVs is impossible.
[21] Note: this line was hand-drawn and is not the result of a regression analysis. It represents analog TVs and does not include CRTs that can display high resolution images.
[22] The cold cathode backlights of LCD direct view displays begin to draw so much power at larger sizes that they lose their energy efficiency advantage.
[23] Itoh, S. and Tanaka, M. "Current Status of Field-Emission Displays." *Proceedings of the IEEE*. Volume 90, Number 4, April 2002.
[24] Note: For the purpose of simplifying our analysis, we have chosen not to further subdivide HDTVs into the resolution levels of 720p, 1080i, and 1080p.

[25] Note: Ecos has been unable to locate and test an SDTV, and the CEA claims that there are essentially no models on the market. Our conversations with Sean Wargo, senior industry analyst at the CEA, indicate that the SDTV category is merely a legacy of low-end CRT display technologies. As CRTs begin to be displaced by newer display technologies, SDTV will cease to exist.
[26] "No. 1125. Media Usage and Consumer Spending 1995 to 2004," *Statistical Abstract of the United States: 2001,* U.S. Census Bureau, Washington DC, 2001.
[27] The distribution of standby power was found to be highly skewed and did not in any way represent a normal distribution. It did not seem appropriate to represent the central tendency with a mean, and therefore, the median was used to represent the general behavior of standby power.
[28] "U.S. Consumer Electronics Sales & Forecasts: 1999–2004," Consumer Electronics Association. Arlington, VA, 2003.
[29] Note: some of this variation could be amplified by differences in screen settings or other factors that need to be accounted for in a standardized test procedure.
[30] Some small amount of energy is consumed when the television is in standby.
[31] 25 percent reduction in active mode power consumption and 1 watt standby mode power consumption.
[32] "ENERGY STAR® Program Requirements for Computer Monitors," ENERGY STAR web site, January 25, 2005, www.energystar.gov/ia/partners/product_specs/program_reqs/MonitorSpecV40Final.pdf.
[33] "ENERGY STAR® Program Requirements for Single Voltage External AC-DC and AC-AC Power Supplies," ENERGY STAR web site, January 25, 2005, www.energystar.gov/ia/partners/product_specs/program_reqs/EPS%20Eligibility%20Criteria.pdf.
[34] Hershberg, C., Hiller, D., and Calwell, C., "Forging Ahead with Desktop PC Power Supply Efficiency Improvements," a presentation given at the Intel Technology Symposium, September 8, 2004.
[35] Siderius, H., and Wajer, H., "Analysis of Energy Consumption and Efficiency Potential for TVs in on-mode." European Commission and EACEM, November 1998.
[36]"Analysis of the Potential Policy Options for Energy Efficiency Improvements to Televisions," Australian Greenhouse Office, Report no. 2004/11, October 2004.
[37] "Analysis of the Potential Policy…," p. 54.
[38] Personal communication with Jiang Lin of Lawrence Berkeley National Laboratory, October 28, 2004.
[39] L. Weber, "Do LCD TVs Really Last Longer Than PDP TVs?" *Information Display,* August 2004, Note: Mr. Weber claims in this article that most TV signals exhibit an average pixel level of about 20 percent.
[40] Note: This specification curve is not a recommendation, but merely serves to illustrate how such a specification curve would look and function.
[41] "Residential Energy Consumption Surveys: 2001 Housing Characteristics Table." U.S. Department of Energy, Energy Information Administration, www.eia.doe.gov/emeu/consumption.
[42] "United States…," U.S. Census Bureau.
[43] "Residential…," U.S. Department of Energy, Energy Information Administration.