# GET SMART GUIDE

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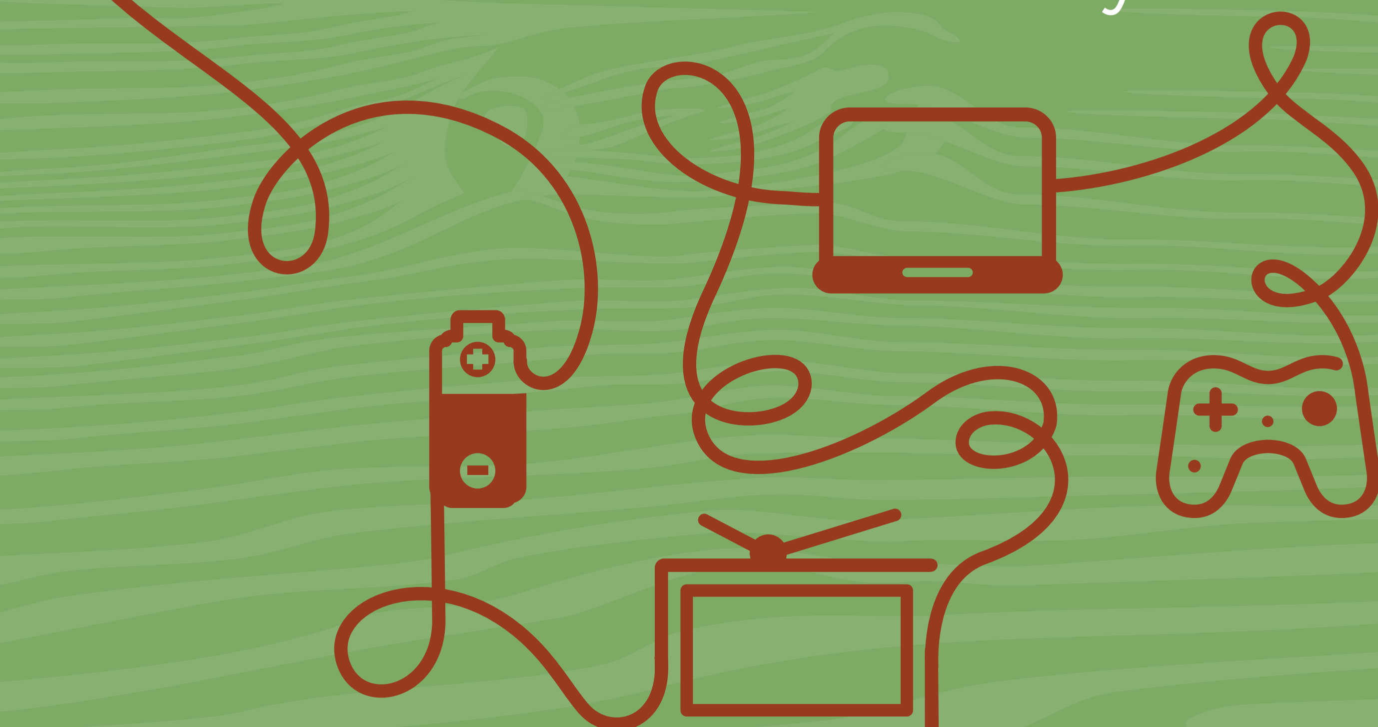
*Energy Innovation for the Consumer Electronics Industry*



smart electronics initiative

## THE SMART-ELECTRONICS INITIATIVE (SEI)

*is a unique collaborative of consumer electronics developers, manufacturers, and retailers working together with policy-makers, academia and technical analysts to develop a framework to incentivize energy efficiency integration into the consumer electronics industry. SEI is engaging industry, policy, and efficiency experts to participate in our effort to identify "smart" technologies, educate consumers and develop new policies to improve energy efficiency in consumer electronics. Early leaders for the initiative include: ARM Holdings, Belkin, Marvell, ON Semiconductor, Power Integrations, and the Lawrence Berkeley National Laboratory.*

*The "Get Smart Guide: Energy Innovation for the Consumer Electronics Industry" summarizes the major types of consumer electronics devices, their power consumption, and opportunities for energy efficient design integration. The "Get Smart Guide" also provides an analysis of the current state and federal policy landscape and how incentive programs can be designed for increased energy savings.*

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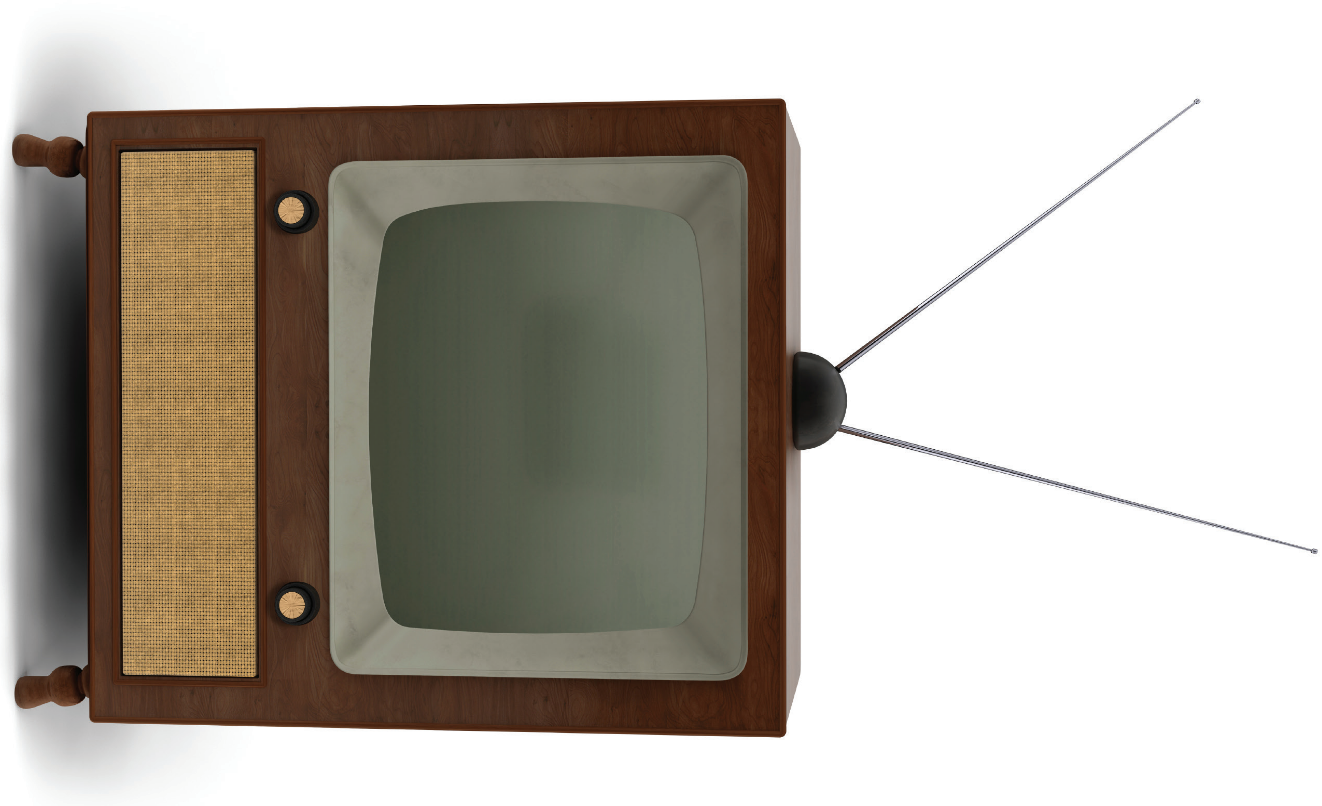
# TABLE *of* CONTENTS

The **5 million homes** owning televisions in 1950 skyrocketed to **55 million homes** by 1967 — or over 93% of U.S. households.[1]



# INTRODUCTION & BACKGROUND

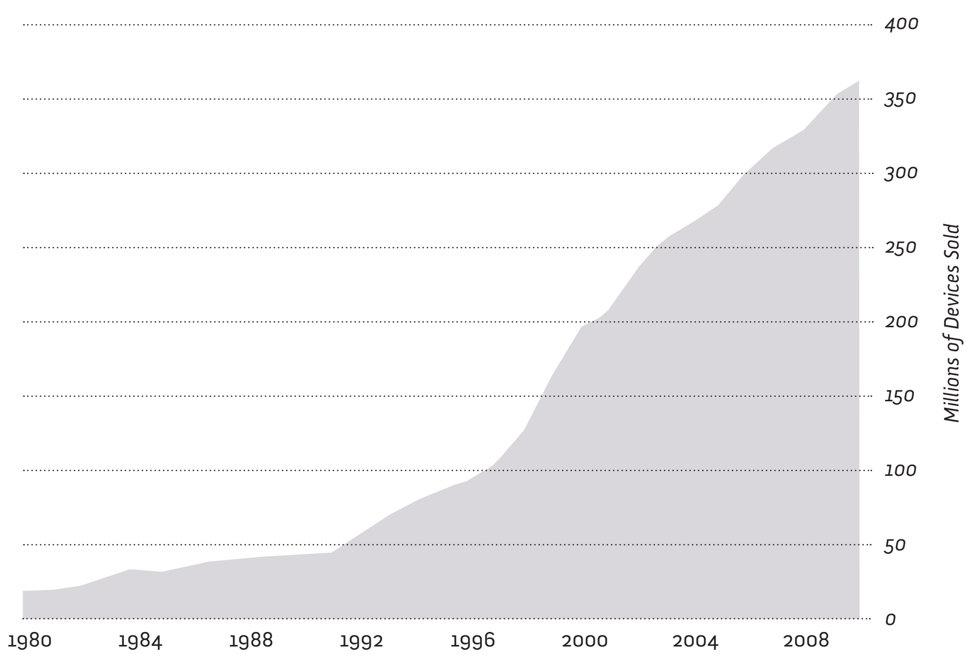
1

The allure of consumer electronics has been a part of our society since Thomas Edison's first power plant was built in the early 1880s. The idea of owning a device that took on a life of its own, when supplied with electricity, was a fascination nearly everyone shared. Even during the Great Depression, U.S. Census figures showed that over 12 million residents had new radios, 75% of which were purchased on installation payments due to the dark financial times.[2] Since then, interest in consumer electronics has only grown with the rise of televisions, computers, video games, and cellular phones.

The reality, too often overshadowed by the shiny products, is the increasing and ongoing cost of powering these devices. Consumer electronics currently account for approximately 15% of total residential electricity consumption, or about 200 TWh.[3] To be sure, there is a growing trend of new efficient, battery-powered devices that offer opportunities for reducing home and business energy usage. But these portable devices, combined with increasing use of always-on and always-connected devices, generate higher demand for energy usage outside the home in the "cloud", where data storage is located in centralized servers in large commercial facilities.

Recent trends suggest that the use of consumer electronics will continue to grow at record pace. Between 1980 and 2010, annual sales of electronic devices increased by a factor of about twenty *(Figure 1)*. By 2011, there were roughly three billion consumer electronic devices in the U.S., and the average household owned about 25 products. Manufacturers introduced an estimated 20,000 new products at the annual Consumer Electronics Show in 2012. Today, global spending for consumer electronics is on track to hit an all-time high of $1 trillion. Business is booming.

FIGURE 1. *Three decades of increasing sales in consumer electronics in the U.S.*[4]



This report reviews some of the major consumer electronics devices we use in our homes, how they work, and what we can do to move towards **a more efficient future.**

Recent innovations have given rise to an array of technologies capable of making these devices considerably more efficient. However, scaling-up the use of these technologies has proved challenging. Competitive markets force producers to cut input costs wherever possible and consumers see little value in demanding more efficient devices, since each one constitutes less than 1% of their home's electricity bill.

A situation like this calls for policies and programs to bridge the gap between the need to reduce energy consumption and the lack of incentives to integrate new, more efficient technologies. Energy and environmental agencies tend to share the responsibility for creating policies that encourage the adoption of energy efficient practices and products. Federally, the Environmental Protection Agency (EPA) and the Department of Energy (DOE) work to implement policies based on both regulatory and market solutions. Thanks to programs such as minimum efficiency mandates on manufacturers, Energy Star ratings, and incentive programs such as those administered by many utlity companies, U.S. annual energy consumption was roughly 3.5% lower in 2010 than it would have been in the absence of these programs.[6]

FIGURE 2. *Major devices and their estimated annual energy usage in American households*[5]

| Major Devices | U.S. Energy Use 2010 *(TWh)* |
|---|---|
| *Televisions* | 65 |
| *Audio-Video* | 43 |
| *Computers* | 31 |
| *Set-top Boxes* | 26 |
| *Battery Chargers* | 18 |
| *Monitors* | 13 |
| *Power Supplies* | 12 |
| *Network Equipment* | 6 |
| *Telephones* | 3 |

This report reviews some of the major consumer electronics devices we use in our homes, how they work, and what we can do to move towards a more efficient future. The first section provides an overview of current energy use trends in seven of the most widely used types of consumer electronic devices: televisions, audio-video equipment, set-top boxes, computers, monitors, and network equipment. Together these devices represent over 6% of U.S. energy usage[7] and over 15% of household energy usage. We focus on these devices because they also hold great potential for future energy savings.

The second section outlines a new approach to energy efficiency in consumer electronics by grouping together like functions and discussing technologies available to make each function more efficient. In the ever-changing consumer electronics market, handheld phones and tablets now serve computing needs, computer monitors serve as televisions, and data used on all devices is increasingly accessed from common cloud-based storage and services. Current trends indicate that each type of device will only continue to multiply their functions.  In short, regulating or incentivizing energy use in a single type of device is complicated, since there are likely other types of devices that serve similar purposes.  Instead, by grouping together like *functions*—displays, data processing, power supply and sound amplification,—this section provides a framework through which  policy-makers can develop solutions to energy efficiency problems in electronic devices. Current policy approaches to power supply (battery chargers) equipment at the state and federal level exemplify this approach.

The final section outlines three core recommendations for reducing energy use in consumer electronic products. The first recommendation is for state and federal authorities to adopt a function-specific approach to encourage production of a new wave of energy efficient devices. The second recommendation encourages product manufacturers to begin using widely available energy savings technologies in their products to instantly reduce energy use. The third recommendation is for consumers, in some cases working in concert with their utilities, to choose smart devices, broadly defined to include an array of technologies capable of managing energy usage, and home automation systems that can instantly cut back energy use.

## 2

# MAJOR HOUSEHOLD DEVICES

Electronic devices most commonly used by U.S. consumers include televisions, audio-video equipment and game consoles, set-top boxes, telephones, computers, monitors, network equipment, and imaging equipment *(Figure 3)*.

Though these various types of devices are typically used in different areas of the home, many of them contain technologies and functions that are similar across devices. Home entertainment in the family room makes use of the television for display, audio video equipment for local content, and set-top boxes for access to remote content. Home office needs are met using monitors for display, computers and associated equipment for local content, and network equipment and telephones for access to remote content.

Televisions and monitors already are identical in their functionality. This leads to the presumption that the devices connected to them might also become indistinguishable from each other: computers, audio, video and gaming will continue to morph and merge, as will networking devices and set-top boxes. However, for simplicity and consistency with current policy, these six categories of devices are listed individually in this report.

The following sections consider the largest of these categories—televisions, audio-video, computers, set-top boxes, monitors, network equipment and servers—in greater detail.

FIGURE 3. *Major devices and their contributions to national household energy consumption.*[3]

| Functional Category | Major Devices | U.S. Energy Use 2010 *(TWh)* |
|---|---|---|
| *Display* | *Televisions*<br>*Monitors* | 78 |
| *Data Processing* | *Audio-Video*<br>*Computers* | 74 |
| *Networking* | *Set-Top Boxes*<br>*Network Equipment* | 36 |
| *Power Supply* | *Battery Chargers*<br>*External Power Supplies* | 6 |

## TELEVISIONS

Commercial televisions began playing a part in U.S. society in the 1930s. At that time, a television consisted of a signal receiver that displayed broadcast programs on a black and white cathode ray tube (CRT). What began as a novel luxury item has now become ensconced as a universal electronic necessity on par with refrigerators and washing machines. While most U.S. households owned just one television in 1978, by 2010 the average household owned more than three.[3] Uses for television sets have proliferated, from watching broadcast programming in the 1950s, to playing video games, tapes, and DVDs several decades later. Today, they are used for downloading music, programming and on-demand internet-based video. In the near future, one might expect televisions to be commonly used for daily communications.

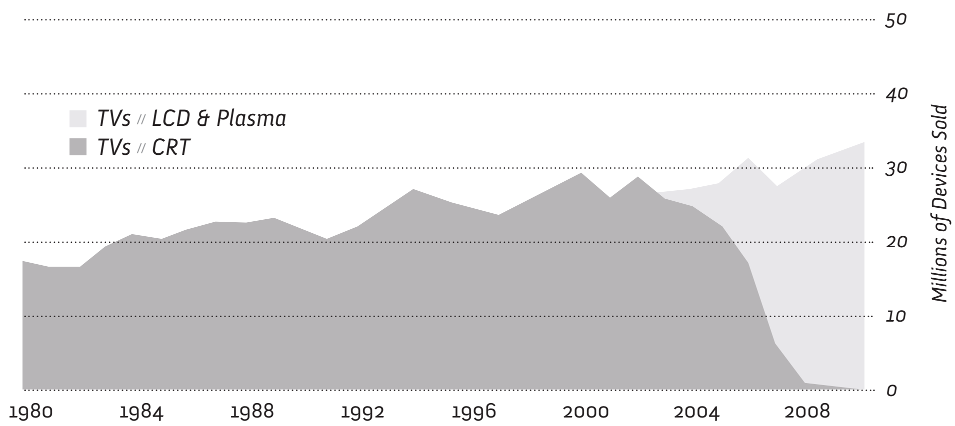
### *Televisions*[3]

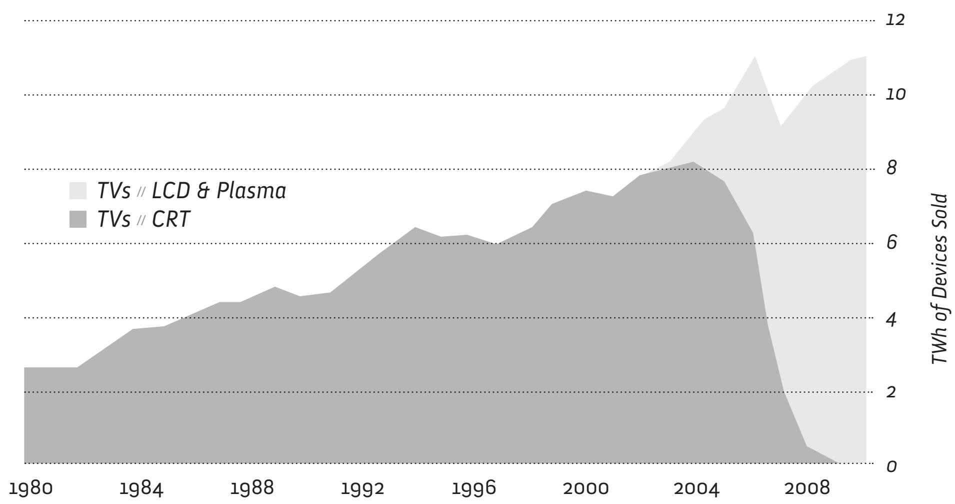
| | |
|---|---|
| 2010 Energy Use | *65 TWh* |
| Main Efficiency Opportunity | *Display* |
| Other Opportunities | *Power management*<br>*Data processing*<br>*Power supply* |

Currently, more than 5% of global residential power consumption is attributed to televisions alone. While improvements in display technologies work to reduce this energy share, more units per home, larger screen sizes and expanded applications work in the opposite direction *(Figure 4)*. In 2010, only one in five American households still used a CRT display as their primary television, a status quickly being usurped by newer technologies like Liquid Crystal Displays (LCD) and Plasma Display Panels (PDP).[3]

Increased use of LCDs, in particular, has improved the efficiency of televisions sold over the past few years; however, overall TV energy use continues to grow *(Figure 4)*. The largest opportunity for future energy efficiency improvements are likely to come from new display technologies, as manufacturers work to produce television displays made with organic light emitting diodes, or OLEDs, which have the potential to cut television energy use by 50-90% without sacrificing picture quality. Other substantial opportunities for reducing energy use in televisions lie in the power supply and data processing functions.

FIGURE 4. *Energy use of TVs growing faster than sales due to larger screens, despite more efficient display technology*[4]



| *Audio-Video*[3] | |
|---|---|
| 2010 Energy Use | *43 TWh* |
| Main Efficiency Opportunity | *Power management*<br>*Data processing* |
| Other Opportunities | *Power supply*<br>*Sound amplification* |

## AUDIO-VIDEO

With the proliferation of radios and televisions in the American household, it was only a matter of time before the entrepreneurial spirit expanded these sources of entertainment beyond broadcast programming—to audio and video capture, playback and interactivity. Initially captured as analog recordings on cassette tapes, audio and video content today is digitally recorded using laser disc and solid-state technologies. Popular audio-video equipment found in U.S. homes now includes radios, videocassette recorders (VCRs), compact disc players (CDs), digital videodisc players (DVDs), Blue-ray players, audio amplifiers, portable audio systems, home theater systems, MP3 amplifiers, and game consoles.

Video players and game consoles of today have increasingly similar attributes. All major game consoles utilize DVDs to load games, and most play movies as well. Sony has incorporated a Blu-ray player in its PS3 console, and other manufacturers are rumored to follow. Like many game consoles, the newest stand-alone Blu-ray players have built-in network connectivity. In 2010, nearly 40% were connected to the Internet, providing consumers with video-on-demand capabilities in addition to standard Blu-ray disc use.[8]

When confronted with the term “audio system,” many recall the stack of discrete black boxes popular in the late 1900s, or the all-in-one portable boom boxes, or mini-towers with detachable speakers. Today, MP3 docking stations and home-theater-in-a-box (HTIB) systems have largely replaced component systems.

HTIB systems commonly provide six audio channels and the capability to power as many as nine, each adding to the overall energy use of the system. As of 2010, more than 60% of households had surround sound capabilities.[9]

## SET-TOP BOXES

A set-top box is an information device that began as a solution for broadcasters that wanted to offer channels beyond what the television sets of the time would allow. The addition of a set-top box broadened the range of the television tuner, allowing access to channels outside its standard range. Newer television sets now come equipped with expanded tuner ranges to accommodate some extra channels, but set-top boxes are still needed for services like satellite feeds, premium channels, digital cable, pay-per-view, video on demand, and Internet TV.

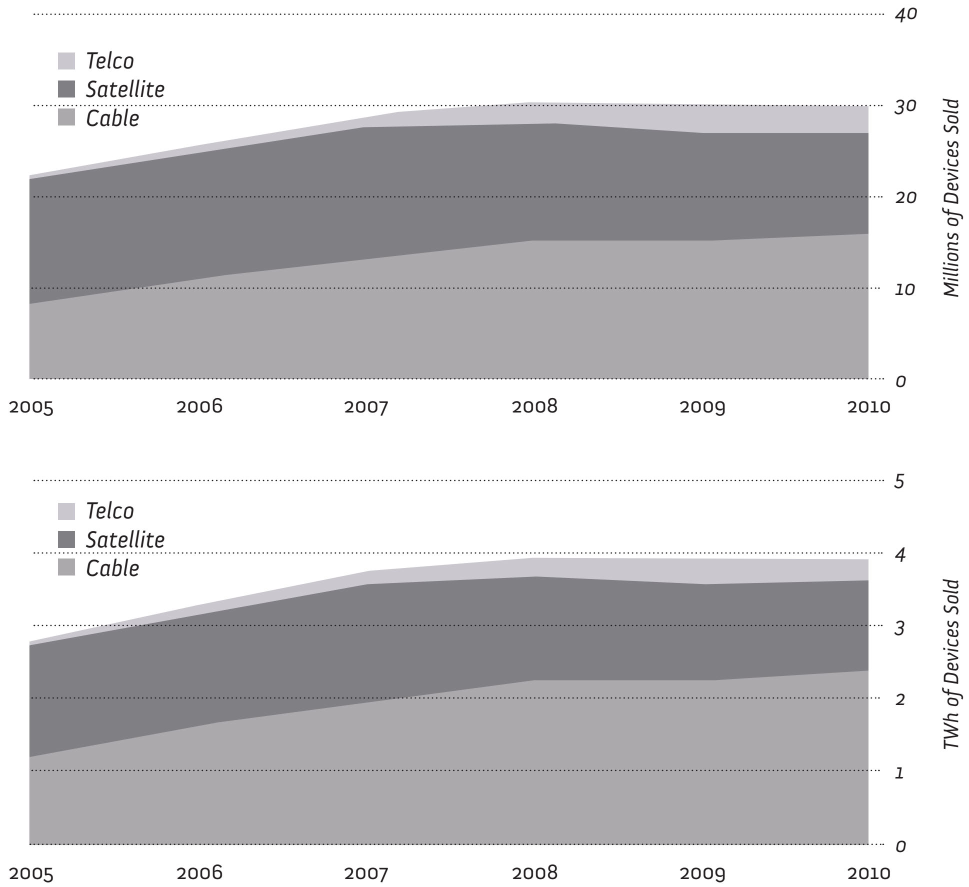
The number of U.S. consumers using set-top boxes increased dramatically in 2009 when television stations ceased analog broadcasts, forcing those with older analog television sets to purchase set-top boxes to convert the incoming digital signal to analog.

### *Set-top Boxes*[3]

| | |
|---|---|
| 2010 Energy Use | *26 TWh* |
| Key Opportunities | *Power management*<br>*Data processing* |
| Other Opportunities | *Power supply* |

In 2010, homes in the U.S. housed 160 million set-top boxes that consumed $3 billion in electricity each year—enough to power all the homes in Maryland.[10] Most of the boxes can be attributed to pay television— a service to which 80% of U.S. homes subscribe. Since contracts with the service providers generally do not allow a choice of set-top boxes, consumers must accept whatever device is provided. Commonly known as the 'principal agent' problem, the arrangement results in the installation of particularly inefficient devices. Since service providers don't pay their customers' electricity bills, they have little or no motivation to demand efficiency from the manufacturer.

FIGURE 5. *Energy use of set-top boxes increasing due to increasing number of units*[3]




British Sky Broadcasting, which provides TV content to around 30% of households in the UK and Ireland, voluntarily introduced 4 million energy efficient set-top boxes in 2007. With software that provided a simple 'auto standby' feature, they saved their customers over 18 million US dollars in one year. Today, Sky is working with industry partners to further improve set-top box energy efficiency as part of the EU European Energy End-Use Efficiency and Energy Services Directive.[11]

## *Computers*[3]

| | |
|---|---|
| 2010 Residential Energy Use | *31 TWh* |
| Key Opportunities | *Power management*<br>*Data processing* |
| Other Opportunities | *Power supply*<br>*Sound amplification* |

## COMPUTERS

In 1951, the U.S. Census Bureau purchased the first computer, which weighed 29,000 pounds, cost over $10 million, and used about 100 kW of electricity. By 1975, Intel had produced an integrated circuit sparking the personal computer revolution. For several decades after, personal computers were suitcase-sized boxes that sat on or under desks in offices and homes, using 200 to 300 watts through high-powered chips and inefficient components.

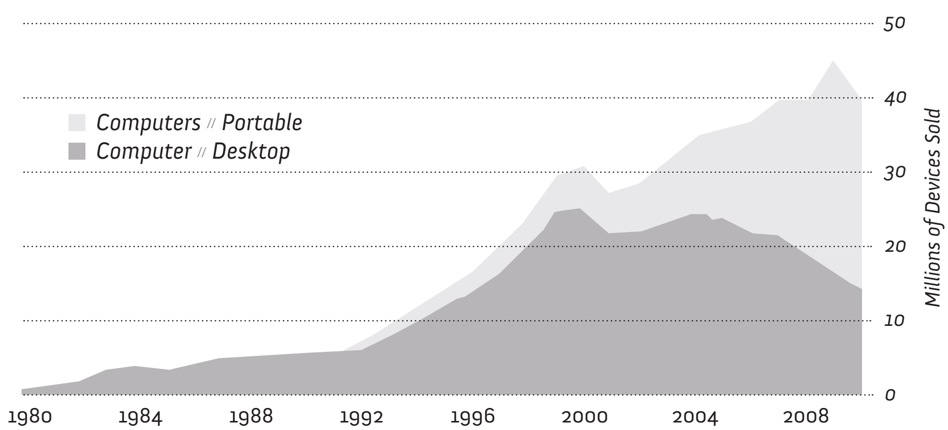
Today, increased dependency on computers for everyday tasks means that households may contain both desktop and portable "laptop" computers. However, there exists a large gulf between desktops and laptops in terms of their energy use. A 2010 side-by-side comparison showed Intel's desktop Pentium 4 processor used up to five times more power than their mobile based Atom processor. Utilizing low power ARM technology for its chipset, one nonprofit computer manufacturer is producing a laptop for third world children that uses only 2 watts of power and costs less than $200.[12,13]

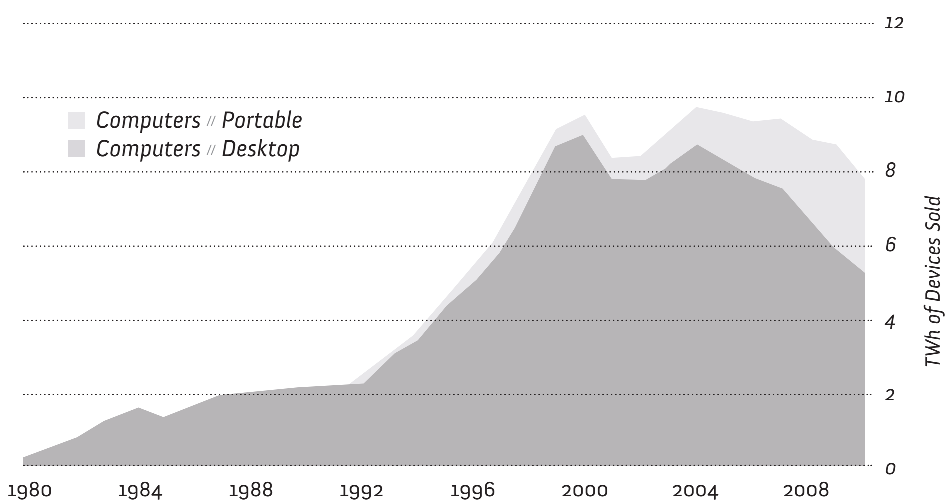
Making desktop computers more efficient represents a major savings potential. Though their market share may be declining for home use in the U.S., desktop sales are estimated to account for nearly 20% of personal computer sales in 2013. When combined with commercial use, desktop computers will continue to account for the majority of computer energy use through 2016.[14] Finding ways to make desktops more efficient therefore represents a major opportunity for energy savings.

At the same time, the increased dependency on computers for everyday tasks has raised demand for portable "laptop" computers to complement desktop computer use that could be carried to and from work, school and home. Driven by consumer preference for long battery life, lower-power laptops, netbooks and tablets are becoming more popular in the marketplace.

The rising interest in portable devices in the computer market represents a key opportunity to reduce overall energy usage from computers. However, the extent to which this reduction materializes depends on the large-scale integration of new energy-savings processors, more efficient power conversion components, more efficient displays, and intelligent power management software. Moreover, the innovation behind these feats could easily be transported to the desktop world, but at present there exist few incentives for desktop producers to do so.

FIGURE 6. *Energy use of residential computers declining due to popularity of portable units*[4]



## *Monitors*[3]

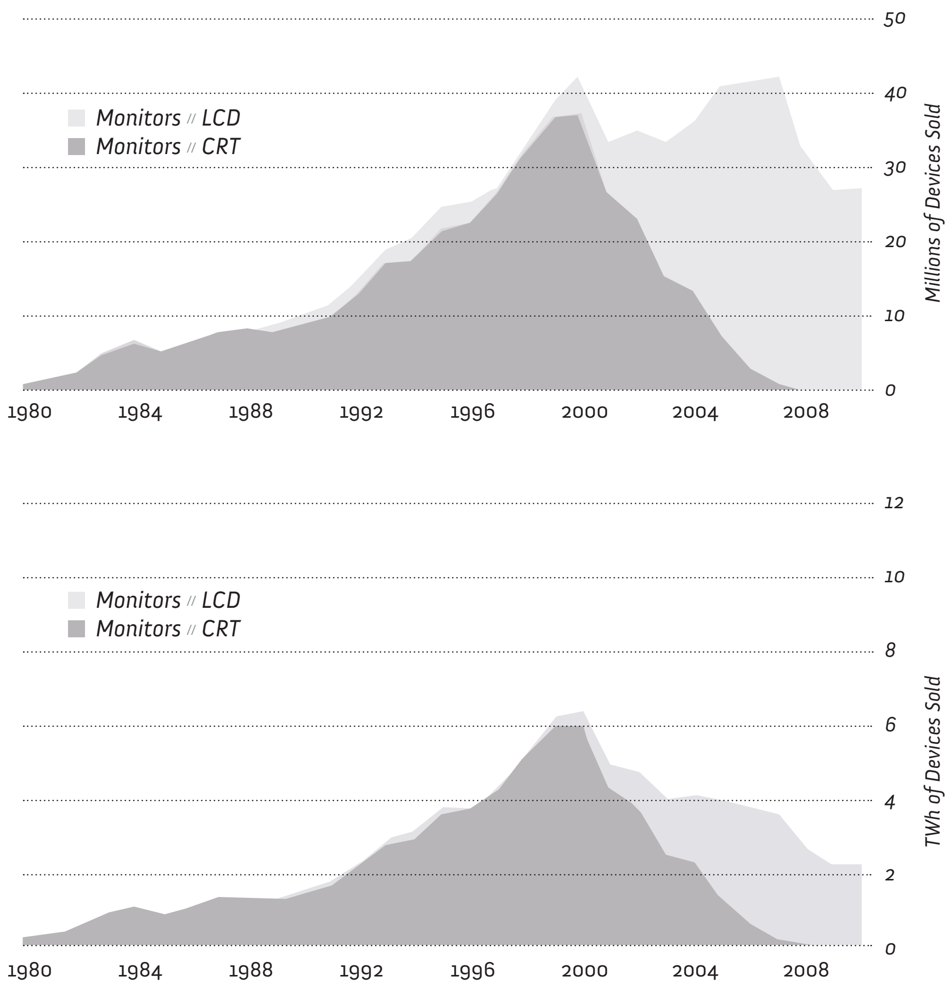
| | |
|---|---|
| 2010 Energy Use | *13 TWh* |
| Key Opportunities | *Display* |
| Other Opportunities | *Power management*<br>*Data processing*<br>*Power supply* |

## MONITORS

In the early 1960s, computer engineers realized that they could re-route the scrolling computer output, from automated typewriters (known as teletype machines) to a cathode ray tube (CRT) display. These monochromatic 'glass teletype' monitors, as they were originally known, quickly found a foothold as they displayed information instantly and paper printouts were eliminated unless desired. Because computer monitors and televisions were both based on a CRT, their power consumption was nearly identical, except that the monitor lacked sound output and the ability to tune in and process television broadcasts.

In the 1980s, computers became more graphically based and interactive, making color monitors with sound the obvious pairing. Monitors only differentiated themselves by having a higher resolution for close viewing and in lacking the variety of signal inputs available in most televisions. The trend to offload signal processing to set-top boxes, combined with the increasing media capability of the computer, has made melding monitor and television a natural evolution. In the U.S., both classes of displays have pervasively made the transition to LCD technology, making the power differences between similar size devices negligible. While a class of high-resolution computer monitors still exists for business purposes, stand-alone displays that can serve as both computer monitor and television are an increasing reality in today's households.

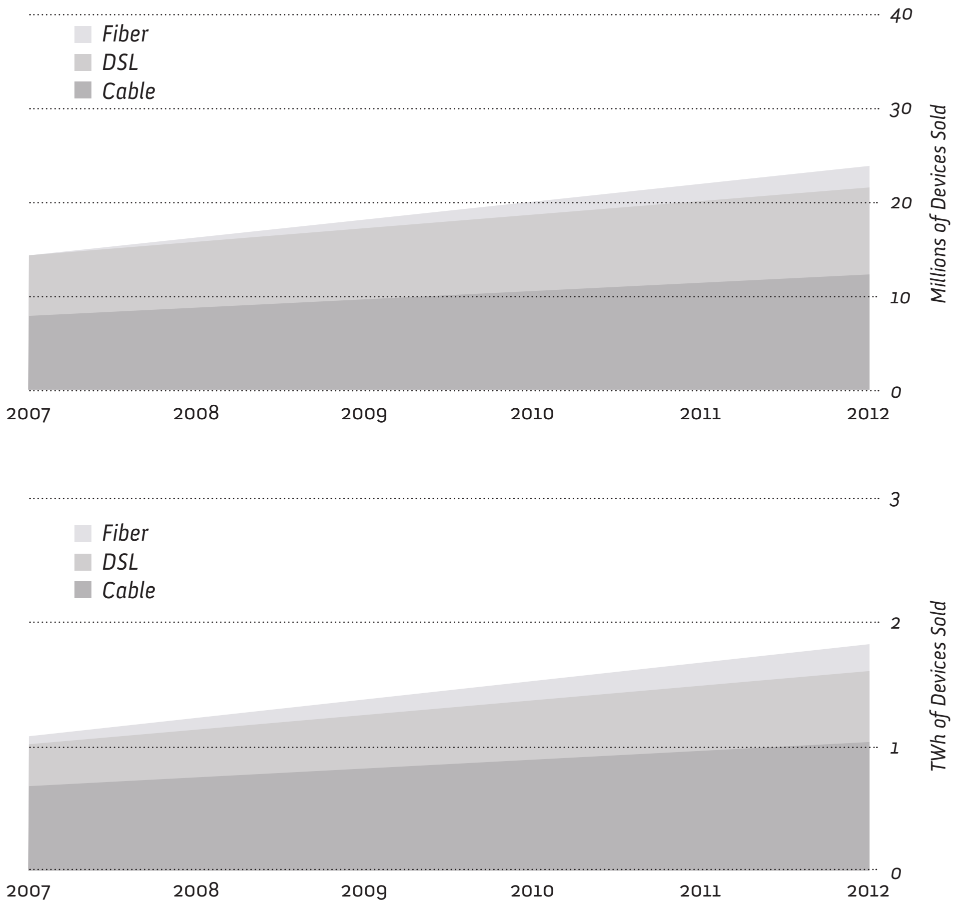
FIGURE 7. *Energy use of monitors declining due to popularity of portable computers and LCD displays*[4]



## *Residential Network Equipment*

| | |
|---|---|
| 2010 Energy Use | *6 TWh* |
| Key Opportunities | *Power management*<br>*Data processing* |
| Other Opportunities | *Power supply* |

FIGURE 8. *Residential energy use of networking equipment increasing due to increasing number of units*[3]




## NETWORK EQUIPMENT

The Internet has become an integral part of our daily lives. In 1977, the Hayes 80-103A 300-baud modem entered the market as the first residential network device, connecting a personal computer to the Internet. Originally an external device, the voice-band, dial-up modems were eventually internalized as cards or incorporated into computer motherboards. In 2004, 75% of U.S. homes had Internet access,[15] but only 14% connected to the Internet using external network equipment.[3] Since then, proprietary broadband services have once again increased the type and number of network devices, to include DSL modems, cable modems, firewalls, routers, network switches, and wireless access points.

In 2012, an estimated 150 million home networking devices were in U.S. homes. Most are fully active and ready to use 24 hours a day, 7 days a week. In this active state, the average device draws about 6 watts without regard to use. To turn them off, most require the power to be disconnected, and only about 12% of owners indicated that they did this regularly.[16]

Power savings options for networking devices include automated standby modes (similar to those being implemented in set-top boxes), more efficient power supplies, and the ability to issue power dynamically to only the ports in use.

3

# OPPORTUNITIES *for* EFFICIENCY

As new power-saving technologies become available, some consumer electronics producers are beginning to adopt energy efficient designs. For example, the most energy efficient consumer electronics incorporate low power hardware components—power supplies, data processors, graphical displays and sound amplifiers—and use intelligent power management software to ensure that the already efficient components are powered only when needed. Applying this logic to the major electronic devices as described in the previous sections, the task of making consumer electronics more efficient is further simplified by the fact that most consumer electronics are comprised of a limited number of functional categories and corresponding components. *(Figure 9).*

Although these strategies are increasingly used in battery-operated devices to extend battery life, non-portable devices with the same functionality are much less likely to be as well designed. It could be argued that the single largest determining force in the reduction of energy required for consumer electronics has been the consumer drive for portability, as miniaturized components were optimized for efficiency to reduce overheating and enable longer battery life.

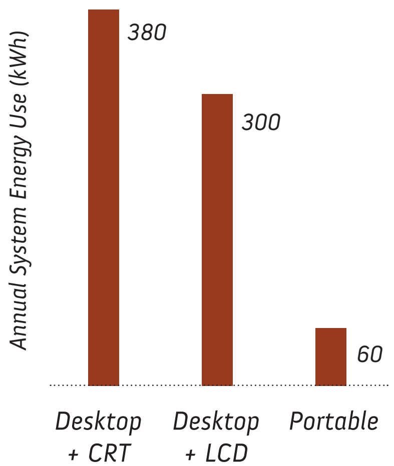
For example, standard computer systems of the 1990s, comprised of a desktop unit and a CRT monitor, used over 380 kWh per year *(Figure 10)*. By 2000, annual energy use of residential computer systems dropped to 300 kWh per year, as consumers replaced their bulky CRT monitors with lighter, smaller LCD monitors. Today, sales of portable computers—with total annual energy needs of just 60 kWh per year—have surpassed sales of desktop units. Each consumer that swaps out a desktop and LCD monitor for a laptop

FIGURE 9. *Key functions and energy efficiency opportunities for major electronic devices*

| | DEVICES | | |
|---|---|---|---|
| **Functions** | Televisions & Monitors | Audio-Video & Computers | Set-top Boxes & Network Eqpmt. |
| *Power Supply* | ⊙ | + | ⊙ |
| *Data Processing* | ⊙ | + | + |
| *Display* | + | + | |
| *Sound Amplification* | | ⊙ | |
| *Power Management* | ⊙ | + | + |

+ = *key opportunities* ⊙ = *other opportunities*

FIGURE 10. *Portable computers use 80-85% less energy than desktops*[3]



or notebook computer will save at least 80% in computer energy costs. In aggregate, energy obligations of computer systems sold in the U.S. in 2010 fell by more than 40% from the peak in 2000, despite a 25% increase in base unit sales *(Figure 9 and Figure 10)*.

As the use of portable devices rise, it is also important to ensure that the most innovative power-saving technologies are incorporated into new portable device designs. The following sections consider opportunities for efficiency in both hardware and software design of consumer electronic devices.

## DISPLAY

It is difficult to imagine a device that doesn't glow or otherwise convey some aspect of its operation with some form of visual output, whether a small alphanumeric display, an LED indicator, or a full color display screen. Even audio devices, designed with the ears in mind, commonly make use of components intended for the eyes—indicating track, channel and song title, and not uncommonly, incorporating backlighting and lighted buttons for nighttime visibility and ambiance.

From 1922 until the turn of the century, cathode ray tubes or "CRTs" were the only type of display available to consumers. CRTs tend to be large and heavy, and inefficient, owing to their physical requirements: an electron gun set in the back of a vacuum tube as large as the screen, deflection coils that move the electrons to form an image, and phosphors on the front of the tube that light up when struck by the electrons.

In 2000, color plasma displays enjoyed a brief stint of popularity, only to be quickly replaced by the current forerunner in a large flat panel display: the liquid crystal display or LCD. In their simplest form, liquid crystals are tiny gates that allow light to pass through at different angles depending on the strength of the electric field being applied. Arranged in a grid pattern and colored with filters, liquid crystals form the pixels of a display. By 2010, CRT televisions and monitors were all but extinct and the market for plasma displays dwindled as LCDs became the favored display technology. This is good news for energy efficiency, since LCDs use about half the energy of a plasma display and one-third the energy of a CRT *(Figure 11)*.

Despite the efficiency gains brought about by the transition to LCDs, there remains significant room for improvement. For example, LCD backlighting results in a relatively inefficient process for creating a lighted display: with 90% of the backlighting blocked by the LCD screen, only about 10% of the output reaches the viewer.[17] More efficient "self-emitting" display technologies are now on the horizon, with the potential to reduce large screen display energy use by 50 – 90%. Currently, Sony has a prototype 36-inch LED television unit that draws only 14 watts, while LG and Samsung are expected to begin selling 55-inch OLED units in 2012. Based on OLED's superior performance in most comparative categories, Samsung, the largest display manufacturer in the world, has predicted that OLED displays will be the mainstream display technology by 2015.[18]

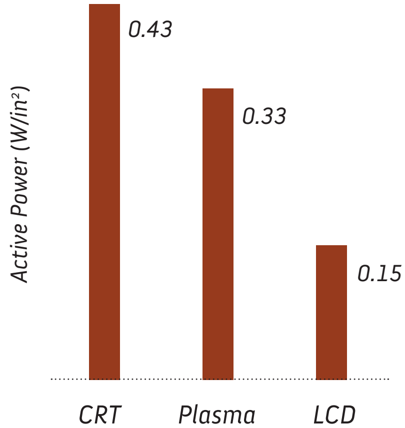
## DATA PROCESSING

### *Computers and Networking*

The basic building block of data processing and storage is the transistor. Invented in 1947, its ability to start and stop the flow of electricity allows for the translation of yes-no decisions into a language that an electronic device can further act upon. When coupled with other electronic components, such as diodes, resistors and capacitors, the circuitry found in every electronic device is born.

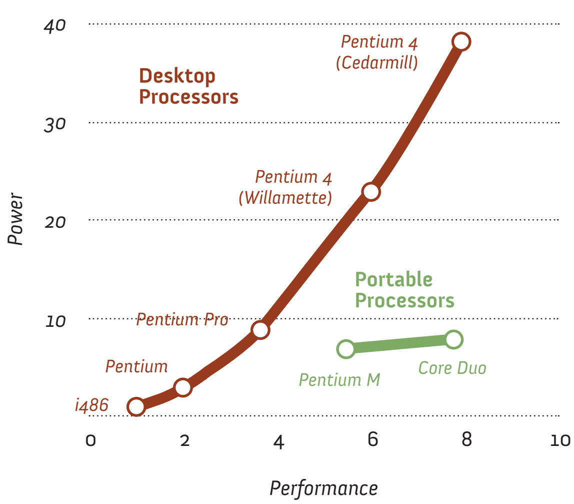
Semiconductor companies such as Marvell, ARM, and NVidia are competing to increase processing speeds while reducing battery drain. These efficient chipsets are widely used in battery-operated devices to extend battery life; however, non-portable devices with the exact same functionality are unlikely to be as well designed. For example, Intel's desktop Pentium 4 processor uses up to four to five times more power than its mobile counterparts *(Figure 12)*.

FIGURE 11. *Among common display types, LCDs are currently the most energy efficient*[3]



One product currently available is ARM's big.LITTLE processor, designed specifically to manage power usage more efficiently. The big.LITTLE processors increase efficiency by using two heterogeneous cores: the Cortex A-15, which handles high performance tasks, and the Cortex A-7, which is capable of hosting the vast majority of existing mobile tasks. The big.LITTLE switches back and forth depending on processing needs. Such processors are able to extend the benefits of dynamic voltage and frequency scaling (DVFS), while ensuring software can execute in the most power efficient manner and still offer the peak performance available today. ARM's processors are found in a wide array of mobile devices including laptops, tablets, smartphones, and digital cameras.

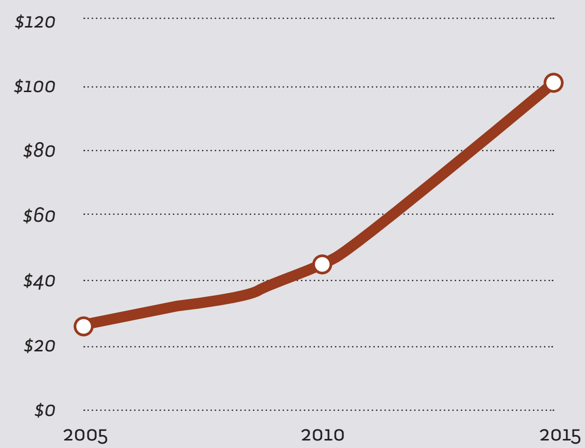
FIGURE 12. *Processors made for portable computers are far more efficient than those made for desktop computers*[19]




## *Data Storage*

*The last four years have seen a radical change in the way consumers use data, particularly with the increasing use of mobile devices to access internet content. The tremendous proliferation of always-on-and-connected devices has resulted in an explosive growth of unstructured data. These data are processed in the background (cloud) by servers residing in big data centers operated by companies like Google, Facebook, Amazon, and others. Energy consumption by data centers have garnered much recent attention, in part because their high levels of energy use go against perceptions of an energy-efficient internet-based lifestyle.*[20]

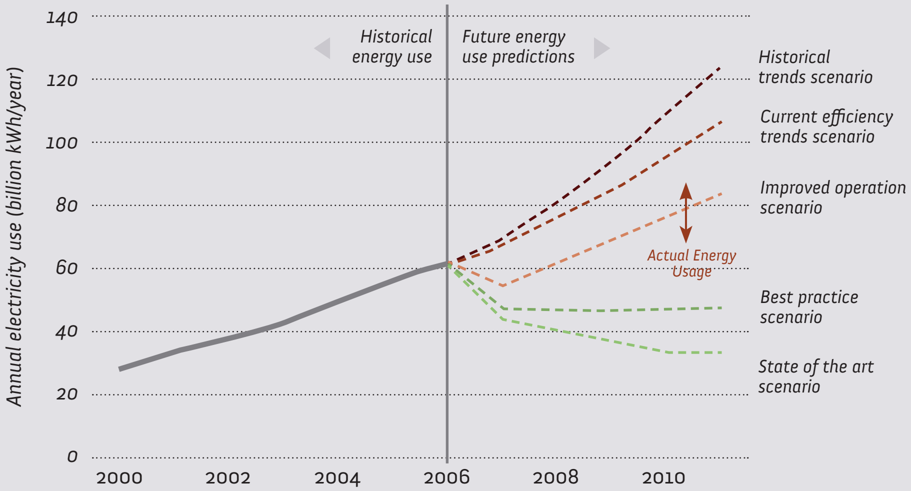
FIGURE 13. *Costs (in Billions of dollars) to power and cool servers is rising.*




*It is now widely recognized that integrating smart technologies into data storage centers could provide significant energy savings. A 2007 EPA study estimated that existing technologies and strategies could reduce typical server energy use by an estimated 25%, with even greater energy savings possible using advanced technologies.*[21] *There exist a number of readily available possibilities to reduce energy consumption of data storage facilities, even as demand for cloud-based data storage continues to grow.*

*First, some companies are developing a new generation of low power server chips that drive higher CPU utilization and offer demand-based scaling. Using a larger array of these lower performance processors enables system performance and power to be scaled with finer granularity to map to the*

FIGURE 14. *Estimated Energy Usage from Data Storage Facilities*[22]




*peaks and troughs of cloud workloads. Most data center servers are based on x86 processors that consume higher levels of power and dissipate more heat than some readily available technologies (See Box ↘). Typical annual energy consumption for data centers in the U.S. is over 75 billion kWh, with the power consumed by an individual storage unit between 3KW and12KW.*[23] *Data centers now makeup approximately 2% of total U.S. electricity use. Unlike a conventional server inside a house or business, which typically performs a significant amount of intensive mathematical calculations, the workloads run in the cloud are more sporadic and less compute intensive, thereby offering opportunities for energy savings in smart data storage technologies.*

*Second, cloud computing has evolved over the last several years from discrete processing to virtualization. Virtualization means that multiple applications are consolidated onto a small number of servers that run applications in virtual machines. Server virtualization has been extremely popular due to its ability to increase server/datacenter density by adding virtual servers without increasing physical server deployments. With such virtualization techniques CPU utilization becomes lower. Not only does lower CPU utilization translate into energy savings in itself, but it also reduces the need for additional energy-intensive cooling. Virtual consolidation can yield overall energy savings of 50% or higher.*

*Thanks in part to these new technologies, electricity used in US data centers in 2010 was considerably lower than originally projected by the EPA in their 2007 report to Congress on data centers. Current estimates set actual energy use from data centers at the "improved operation scenario" in* Figure14.[24] *At the same time, however, the U.S. Energy Information Administration estimates that demand for new generating capacity for all electrical energy uses in both businesses and homes will rise by 223 GW through 2035.*[25]

## *Advances in Data Storage Technology*

*ARM processors, such as those that power many smartphones and tablets, constitute one example of processors that could help to achieve energy savings in data storage facilities. For example, the power envelope for Marvell's quad core Armada XP is only 10W, which is 1/10th the power of an x86 processor that is used for similar applications. Servers based on ARM chipsets enable lower power, higher efficiency solutions for Data centers and enterprises resulting in significant savings in operating expenses. Additionally, complete integration of server-related I/O peripherals results in superior density and lower bill of materials. Marvell, along with ARM and its ecosystem partners are working actively on innovations that enable vast cloud deployments with a greater emphasis on efficiency, resulting in a significantly reduced total cost of ownership for operating these hyper-scale datacenters.*

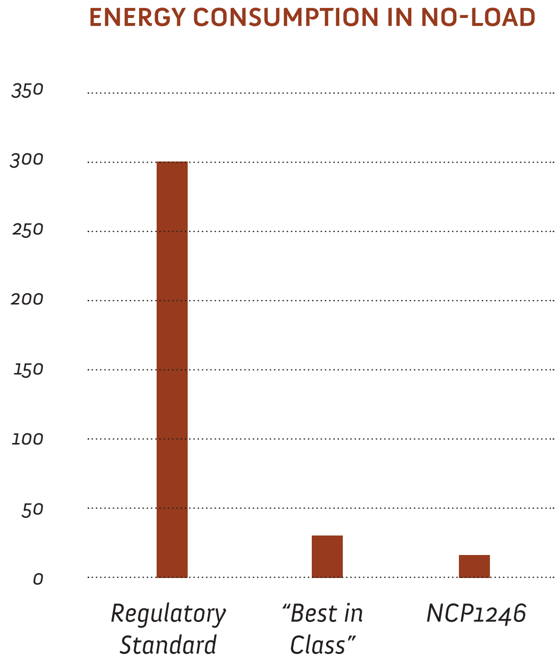
## POWER SUPPLY

Power supplies sold for use in the U.S. commonly convert from the standard 120-volt alternating current (AC) to the low-voltage direct currents (DC) required by the internal components of all electronic devices. Whether internal or external to the device they power, they are a component of every consumer electronic device available. Over 3 billion external power supplies and 1 billion battery chargers are used in the United States, contributing to a combined energy use equivalent to the output of 5 or 6 large power plants.[24,26]

Intense research and development over the past few decades has resulted in faster, more complex circuitry that can be made smaller and more energy efficient. As recently as the year 2000, bulky and inefficient magnetic or "linear" power supplies dominated the market. Early research and regulatory pressure, combined with consumer preference for smaller and lighter units, have contributed to a near complete transition by manufacturers to more efficient electronic or "switching" power supplies in just ten years. This provides hope that similar efforts applied to other opportunities in efficient display, processor, and power management technologies could bring about major changes in a relatively short period of time.

Companies such as ON Semiconductor and Power Integrations have developed companion devices for adapters, which serve as low-standby power controllers. Such devices minimize power consumption during no-load and light-load conditions. ON's NCP1246, for instance, reduces power usage by upwards of 280mW and improves on existing no-load standby power devices by 13mW *(Figure 16)*. The primary converter is switched off when a no-load condition is detected.

FIGURE 16. *ON Semiconductor's NCP1246 reduces energy usage in no-load settings over both the regulatory standard and over the current "best in class" product.*




In December 2005, the California Energy Commission adopted the first-in-the-nation energy efficiency standard for external power supplies, expected to save California $90 million annually.[27] Federal power supply standards soon followed, and later this year, the DOE is expected to rule on national standards for battery chargers that are internal or external to a device. To fully capture the energy savings opportunity, external power supply standards might be expanded to include internal power supplies, since the components differ only in their physical form and location.


FIGURE 15. *Humorists take on energy use in popular game console (reprinted with permission)*

## Battery Chargers

*Battery chargers are power supplies combined with the intelligence needed to store electrical energy to a chemical battery for later use—typically in a portable device. The most inefficient battery chargers continue to supply power to batteries after they are fully charged. More efficient design of battery chargers would make use of efficient power supplies* **and** *intelligent power management, delivering just the amount of energy required to maintain a full battery charge.*

### SOUND AMPLIFICATION

Audio amplifiers in consumer electronics perform the task of increasing low-power audio signals sufficiently to power loudspeakers. Although first developed using vacuum tubes at the onset of the 20th century, the core of today's audio amplifiers are now typically comprised of semiconductor-based transistors.

The amount of power needed by an amplifier depends on the speaker to which it sends the sound signal. A single stage of power amplification may be sufficient to power the small speakers used in headphones, but several more stages of amplification — each requiring additional power—may be needed to power a large set of floor speakers.

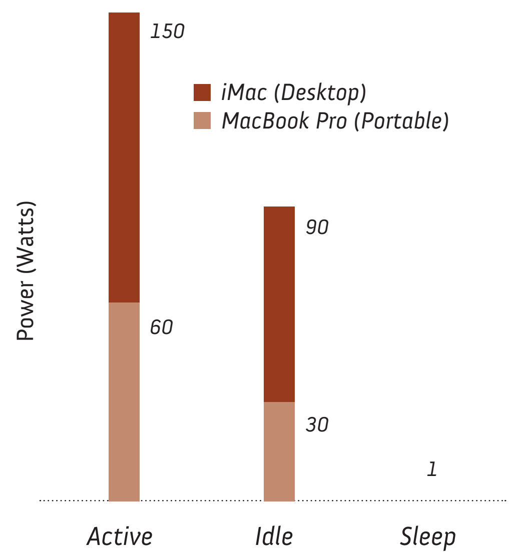
Amplifier efficiency depends on the type of construction or "Class" of the amplifier. Although there are many standard and specialized classes of amplifiers, Classes A, AB, and D are most commonly used in residential devices. Energy efficiency values range widely among these, from less than 40% for Class A amplifiers to more than 90% for Class D amplifiers.

### POWER MANAGEMENT FROM WITHIN DEVICES

As described in the previous sections, incorporating efficient hardware components into devices is an important first step in smart energy design. An equally important opportunity is to incorporate the software needed to allow efficient power management of those hardware components. By orchestrating power use of individual components within the device—dimming screens, putting hard drives to sleep or powering down wireless transmission when there is no activity—a device can become even more efficient.

Many devices have functionality that could be considered optional or even unwanted. For example, a digital clock display on an appliance might be a boon to some customers

FIGURE 17. *Power savings of 99% through sleep modes can be expanded beyond computers*




in certain circumstances, but the presence of several such displays in a single room can be unsightly or even annoying—particularly at the onset and ending of daylight savings time. Likewise, constantly illuminated displays on thermostats or clock radios are conveniences for some, but an uninvited sleep interruption for others. Devices should be designed to allow these "features" to be turned off, using a physical switch or a menu option.

For decades, computers have provided users with the ability to automate *low-power modes* that follow customer specified rules of non-engagement: turn off hard drives after 5 minutes of non-use—put the monitor to sleep after 10 minutes of non-use, put the entire computer to sleep after 15 minutes of non-use—with substantial additional energy savings at each step *(Figure 17)*. Other devices that could save energy through default or customer-controlled power management include televisions, set-top boxes, audio-video equipment, and game consoles. In all cases, default settings should be the lowest power settings, with the opportunity to change these defaults accessible to the consumer.

Devices designed with automated component-by-component power management, or *power scaling*, ensure that internal components use only the power needed for device functionality at any given moment. When circuit

## *Sensors*

*Sensors are the eyes, ears and skin of electronic devices, allowing them to receive signals and information from their owners and from their environment, greatly expanding the usefulness, convenience and even the energy savings of the device. Based on the success of early devices employing advanced sense-abilities, this decade is likely to be remembered as the one in which our devices became aware.*

*Being relatively small and energy efficient, sensors are unlikely to be on the receiving end of energy efficiency efforts. Instead, discussion of sensors in energy-efficiency circles tends to focus on how to best use* **more** *of these components to improve the efficiency of devices and systems. Many consumer electronics have already realized significant power savings through the use of sensors—in particular, mobile devices striving to maximize battery life—but further energy savings through implementation of sensors in non-portable devices have yet to be realized.*

elements are not needed, as indicated by internal system monitoring or external sensory cues, they are quickly powered down or off. Depending on the power and mode profile of the device, power scaling has the potential to reduce lifecycle energy costs significantly, in many cases by more than half.

An important tool for successful implementation of both low-power settings and power scaling is *device awareness,* through components that sense the elements of environment like human interaction, occupancy, light and sound. As mentioned previously, computers have long had the ability to reduce power use during periods of sensed inactivity. Newer televisions are beginning to borrow this design idea, monitoring room occupancy and powering off when nobody is watching. Displays that sense light to adjust brightness, thermostats that monitor movement and lighting levels to suggest more efficient comfort settings, and smart-grid aware devices that monitor power prices and availability to determine when and if to operate non-critical loads—all have the potential to significantly reduce the energy use of consumer electronics.

### POWER MANAGEMENT FROM EXTERNAL SOURCES

Although it's too late to implement energy efficient hardware and software design in devices already purchased and used in U.S. homes, there is a portfolio of electronic devices designed to reduce energy use from outside existing equipment. Timers, switches, specially designed power strips and other home automation gadgets can reduce the amount of time devices are active, or eliminate vampire loads after equipment is no longer in use *(Figure 18).*

A related opportunity is thermostats—the standard external control device for central heating and air-conditioning units. Through this humble electronic device lies the potential for affecting roughly 450 TWh of residential electricity use each year. Until recently, thermostats functioned as relatively simple switches and programmable timers. Newer thermostat designs incorporate advanced features that optimize heating and air-conditioning run times using advanced learning algorithms combined with motion, light, and proximity sensing. Some units also incorporate network connectivity, for remote control by consumers, utility signal reception, and additional vendor services. All of these features offer the potential for significant energy savings, yet these advanced thermostat designs are only just starting to show up in the market.

FIGURE 18. *Standby power can be eliminated with smart products such as Belkin's Wemo mobile device.*


Finally, external networking functionality for connected devices like computers and set-top boxes can impact energy consumption of devices by inhibiting sleep modes that would save energy, but might disrupt communications. This issue would benefit from industry-wide terminology and protocols for network power management.

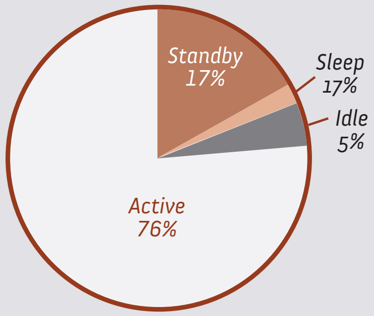
## Vampire Loads

*Nearly all consumer electronic devices consume power even when they appear to be off. This continuous energy draw—commonly referred to as "standby loss" or "vampire load"—can range from zero to as much as 25 watts per device, and accounts for about 17% of the energy use of electronic devices.[3] When multiplied by the number of electronic devices in a household, vampire loads represent about 5% of total U.S. residential electricity, adding up to more than $3 billion in annual energy costs.*

*In most cases, vampire loads are the result of powering functions that continue to operate when devices are off, like network connectivity, remote control, and time display. Not infrequently, however, device components with no standby functionality are powered unnecessarily, or inefficient power supplies waste more energy than is required, simply because the manufacturer didn't design the product with efficiency in mind.*

*The good news is that much progress has been made over the past decade. Early research on vampire loads has led to cooperative efforts by manufacturers to incorporate more efficient power supplies and better power management of components in standby and off modes. In 1999, the International Energy*

FIGURE 19. *Vampire loads account for 17% of the energy used by electronic devices[3]*




*Agency (IEA) proposed a one-watt maximum standby power level for all devices, with minor exceptions. This standard has since been adopted and shown to be feasible and effective in the U.S., Australia, South Korea and the European Union.[28] As a result, many agencies are now moving toward a 0.5-watt standard.*

# 4 CURRENT POLICY EFFORTS

State and federal energy standards policies began in the 1970s and ‘80s with a focus on the largest household appliances: refrigerators, water heaters, dishwashers, central heating and cooling, and the like. As standards were developed and expanded to smaller devices, consumer electronics entered the picture. Following existing policy, those standards focused initially on the largest categories: televisions, audio-video equipment and computers. However, as multi-function devices pervaded the market, the strategy of setting standards by device category became less and less suited to keep pace with the growing number of product types. New product categories are now emerging at a faster rate than standards can accommodate.

More recent standards have begun to reduce energy needs across device types by addressing power supplies and battery chargers, regardless of form or use of the relevant device. Efforts are also underway to set standards for internal and external power management via low power computer modes and thermostats. The most widely recognized efficiency standards are of two types: voluntary standards, administered by both government agencies and non-government organizations, and mandatory standards, administered by federal and state government agencies. In many cases, voluntary standards not only help to educate consumers, but also incentivize manufacturers and utilities to develop more energy efficient products and services.  With effective voluntary standards, market support for higher efficiency products form a pathway through which new mandatory minimum standards become more feasible.

FIGURE 20. *All of the major consumer electronics devices are addressed by a mix of voluntary and mandatory standards.*

| **Device Category** | Energy Star | Federal Standard | California Standard |
|---|---|---|---|
| ◻ *Televisions* | + | ⊙ | + |
| ◻ *Audio-Video* | + | | + |
| ◻ *Computers* | + | | ⊙ |
| ◻ *Set-top Boxes* | + | ⊙ | ⊙ |
| ◻ *Monitors* | + | | ⊙ |
| ◻ *Network Equipment* | ⊙ | ⊙ | ⊙ |
| ◻ *Servers & Data Storage* | + | ⊙ | ⊙ |
| ➤ *Battery Chargers* | + | ⊙ | + |
| ➤ *External Power Supplies* | | + | + |
| ➤ *Internal Power Supplies* | + | | |
| ∘ *HVAC Thermostats* | ⊙ | | ⊙ |
| ∘ *Low power modes* | +∘ | | ⊙ |

+ = *in place*  ⊙ = *proposed*  ∘ = *computers only*

Increasingly, public utilities play a pivotal role in programs that promote energy efficiency. In California alone, utilities administer upwards of 10 different efficiency programs, from energy audits to incentives for integrating energy efficiency measures into new construction and major renovations.[29] Utilities, moreover, are in a strategic position to encourage use of load control devices that monitor and manage energy usage for the entire household. When utilities run programs the encourage use of energy efficient devices in these ways, manufacturers are more likely to produce these devices, consumers are more likely to use them, all of this laying the groundwork for feasible and effective standards.

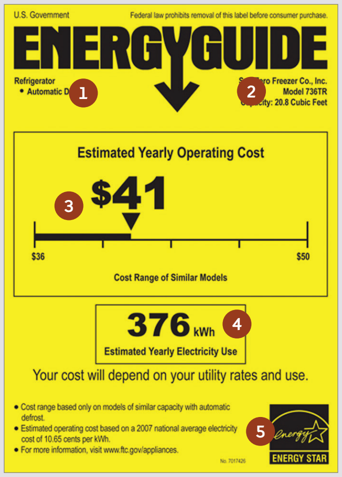
## *U.S. Energyguide Label*

*The U.S. EnergyGuide program, administered by the Federal Trade Commission (FTC), has provided consumers with comparative energy information for large household appliances since 1978. In 2007, congress further directed the FTC to develop EnergyGuide labels for major consumer electronics, including televisions, personal computers, set-top boxes, digital video disc players, and computer monitors.*

*The federal rule requires manufacturers to display a bright yellow and black EnergyGuide label (Figure 21) for each appliance model at the point of sale, showing:[32]*

1. Key features of the appliance type that contribute to operating costs
2. Make, model number, and other defining information
3. Estimated annual electricity costs under typical operating conditions, relative to other similar products
4. Estimated annual electricity consumption
5. The ENERGY STAR® logo for products that qualify

FIGURE 21. *EnergyGuide label*




### ENERGY STAR LABEL (VOLUNTARY)

ENERGY STAR is perhaps the most widely recognized energy efficiency label, with more than 80% of U.S. households correctly identifying the Energy Star label as a symbol of energy savings in their 20-year Anniversary Report. A partnership between the U.S. Environment Protection Agency (EPA) and the U.S. Department of Energy (DOE) since 1992, the program collaborates with more than 1,200 product manufacturers and 2,500 retailers to certify and promote products meeting strict energy efficiency criteria. The brand promotes energy-efficient products offering reasonable paybacks without sacrificing performance. In many cases, Energy Star ratings encourage efficiency beyond that of federal standards.[30]

The Energy Star program currently addresses more than 40 household product categories, with several more in development. Like the federal standards efforts, the ENERGY STAR program struggles to keep up with ever-changing product types and needs, resulting in a revolving process of adding standards for newly important products, and removing standards that are adopted into federal requirement or that are no longer necessary for other reasons. Despite its challenges, the ENERGY STAR program is widely considered the most successful labeling program in the world, with estimates of bill savings through ENERGY STAR products exceeding $50 million through 2015.[31]

In response to Congressional action, ENERGY STAR has also developed reports and product specifications addressing energy efficiency in U.S. commercial computer centers and data storage facilities.[33] The August 2007 report not only identifies the vast potential for energy savings, but outlines

FIGURE 22. *Schedule of Federal standards for electronic devices*

| DEVICE CATEGORY | YEAR OF STANDARD |
|---|---|
| *External Power Supplies* | *2007* |
| *Battery Chargers* | *2012* |
| *Televisions* | *2012* |
| *Set-Top Boxes and Network Equipment* | *2013* |

specific steps that federal, state, and local governments can take to realize these savings. One of the report's suggestions to improve power management at data centers, which would require opening the market to a broader range of data processors, such as those that reduce unnecessary energy use.

## STATE APPLIANCE STANDARDS (MANDATORY)

California uses less electricity per capita than any other state in the nation, and continually strives to have the most aggressive appliance standards. Every two years since its inception in 1974, the California Energy Commission (CEC) has updated the California Appliance Efficiency Regulations, codified in Title 20 of the California Code, which apply to appliances sold or offered for sale in California. Some recent regulations address power supplies, televisions, consumer audio and video equipment, and battery chargers. Efforts are also now underway for the next round of standards starting in 2012 through 2015 in three phases. The technologies and the CEC's proposed timing for developing regulations are below.

| **Phase 1** // **2012-2013** | **Phase 2** // **2013-14** | **Phase 3** // **2014-15** |
|---|---|---|
| *Displays, Game Consoles, computers, set-top boxes* | *Servers, imaging equipment* | *low power modes, power factor* |

## FEDERAL APPLIANCE STANDARDS (MANDATORY)

Federal standards for appliances have been in place in the United States since 1987. The current standards developed and administered by the U.S. DOE address more than 50 device categories and saved an estimated 7% of annual energy use in 2010. By 2035, annual energy savings is expected to reach 14%, with cumulative cost savings of more than $1 trillion (U.S. dollars).[6]

Most federal standards cover large appliances used for heating, cooling, lighting, refrigeration and cooking. To address the growing use of electronic components in these devices, the U.S. Energy Independence and Security Act of 2007 required that all future standards begin to address energy use in standby and off modes, and kicked off the process by setting the first standards for external power supplies.

Current and planned federal appliance standards address four additional device categories. The DOE set the first new energy guidelines for computers in 2011, followed by battery chargers and televisions in 2012. In 2013, the DOE is expected to set standards for set-top boxes and network equipment.

5

# RECOMMENDATIONS

The world of consumer electronics is neither a static nor clearly defined target for policymakers. Complicating energy efficiency policies is the constant evolution of device categories, as product functions are merged and morphed to create new devices with lower prices and broader appeal. To support the development of smart, efficient consumer electronic devices, policymakers must take a flexible and innovative approach. The following are recommendations for pursuing this goal.

## PROMOTE EFFICIENCY STANDARDS

Though time-consuming, the development of new standards and testing procedures is necessary as new products, or hybrids of existing devices come to market. An emerging trend that constitutes a possible solution to this problem is a revised method of categorization. No matter how simple or complex, each consumer electronic device sold is a conglomerate of a relatively finite set of components: power source, data processing, audio and visual output, and sensors.[34] It follows then, that a power rating might be assigned to each of these component categories —rather than to device categories as is currently done— making any device readily defined by the sum of its parts.

Movement toward this approach is evidenced by the recent standards for power supplies and battery chargers. Since the components have no purpose until paired with a consumer device, one could argue that the CEC and DOE have taken the first step toward creating mandatory standards that regulate specific *functions* or *components* of devices.

A more concrete example of this strategy is the ENERGY STAR specification for set-top boxes *(Figure 23)*. Note how many of the functions listed as Additional Functionality could be translated directly to other electronic devices.

## ENCOURAGE SMART DESIGN

Approaches for encouraging efficiency at the manufacturing level are well known and have been used for decades to enhance the energy efficiency of our residential appliances. Standards and labeling already go a long way toward promoting the manufacture of efficient consumer electronics. Other common strategies include manufacturer incentives, bulk purchasing, and government-funded research and development. Another, less common approach

FIGURE 23. *Energy standard based on functional allowances: Energy Star Set-top Boxes*[35]

| BASE FUNCTIONALITY | ALLOWANCE (KWH/YR) |
|---|---|
| *Cable* | *60* |
| *Satellite* | *70* |
| *Cable DTA* | *35* |
| *Internet Protocol (IP)* | *50* |
| *Terrestrial* | *22* |
| *Thin-client / Remote* | *35* |
| **ADDITIONAL FUNCTIONALITY** | **ALLOWANCE (KWH/YR)** |
| *Advanced Video Processing* | *12* |
| *CableCARD* | *15* |
| *Digital Video Recorder (DVR)* | *45* |
| *DOCSIS®* | *20* |
| *High Definition (HD)* | *25* |
| *Home Network Interface* | *10* |
| *Multi-room* | *40* |
| *Multi-stream – Cable/Satellite* | *16* |
| *Multi-stream – Terrestrial/IP* | *8* |
| *Removable Media Player* | *8* |
| *Removable Media Recorder* | *10* |

for encouraging the manufacture of efficient devices, is through competition, such as those sponsored by the X Prize Foundation and the Western Cooling Efficiency Center.[36]

With the possible exception of government-funded research, efficiency efforts tend to focus on devices, with little regard to the individual components that contribute to device energy use. Recent standards for power supplies and battery chargers have opened the door to efforts focusing on other important internal components known to be responsible for consumer electronics energy use, such as displays, data processors, and sound amplifiers. Steering efforts toward the promotion of efficient instances of these components could affect a much broader set of devices. For example, promotion of OLED displays, which use 50-90% less energy than today's most efficient displays, could improve the energy efficiency of everything from the smallest clock radio displays to the largest flat-screen television sets.

## ENCOURAGE "SMART" HOUSEHOLDS AND BUSINESSES

Standards, rebates, and consumer education already go a long way toward promoting the purchase of efficient consumer electronics and the use of power management, but more can be done. In the realm of consumer electronics, one of the greatest factors in energy efficiency gains is the trend toward mobile devices—a trend not initiated or promoted by standards. Promotion of laptop computers instead of desktop systems, mobile phones instead of cordless ones, and other battery- or solar-powered gadgets is certain to reduce the overall energy footprint of electronic devices.

Promoting greater use of automation and power management at home is another potential opportunity. Although power management at the computer level is well established, the expansion of power management to other devices and to the home system has yet to occur. Enhancements in existing automation and expansion to other appropriate devices can begin to reduce the amount of time that electronic equipment is left in high power modes, thereby reducing overall energy consumption.

### *Example: Standards Foiled by Device Categories*

*Audio systems can still be purchased as individual components, but are becoming increasingly popular as home theater-in-a-box (HTIB) packages. Of the estimated 129 million units installed in 2010, 30 million were HTIBs. This is relevant to efficiency policy since HTIBs are often excluded from audio product analysis because they include a DVD or Blu-ray disc player—a distinction that disqualifies them from the audio system category. With the introduction of functional allowances, the addition of these video components would not affect the ability to determine an efficient power level for the system.*

Featured in futuristic shows and literature, and a staple of Worlds'Fair exhibits since 1934, our fascination with automating common household tasks persists. Some appliances already do this to some extent: air conditioning, video recorders, and bread makers all have programmable features that automate tasks without constant human interaction. The ideal concept defines home automation and power management as the integration of efficient electrical devices on a home area network such that they can interact with each other, with their environment, and, from a central control panel, with the homeowner. In this way, the system efficiencies of the devices in the home, paralleling the components in a system, can be as or more important than individual efficiencies. Consumers might adjust household operations based on electric utility rate changes, maximum demand thresholds, solar power production, or the proximity of the occupant to the home.

The technologies needed to make the Smart Home a reality have been commercially available for decades, but broad implementation has been hampered by expense, competing standards, complexity of implementation and functionality that is often underwhelming. Recent advancements in pricing, user-friendliness, and utility rate structures now have the potential to make these technologies more valuable to the consumer.

6

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