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Lowering the Cost of Play

Improving the Energy Efficiency of Video Game Consoles

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NRDC (Natural Resources Defense Council) is a national nonprofit environmental organization with more than 1.2 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, D.C., Los Angeles, San Francisco, Chicago, and Beijing. Visit us at www.nrdc.org.

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Executive Summary

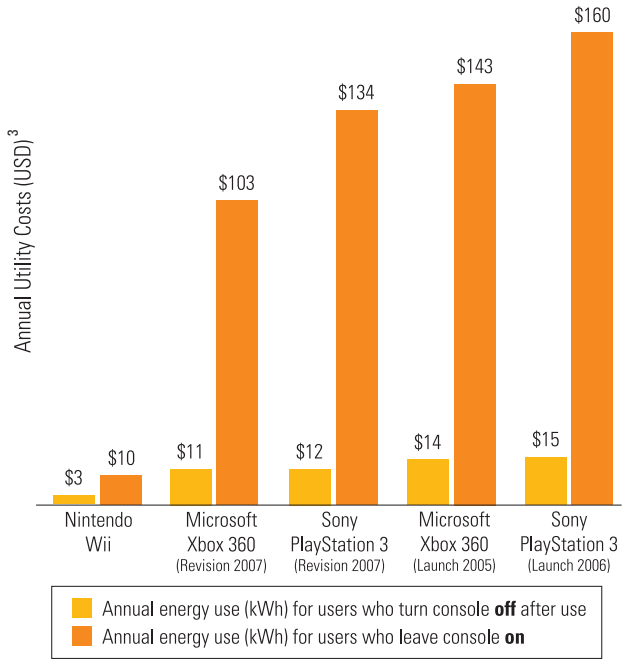
NRDC and Ecos Consulting performed the first ever comprehensive study on the energy use of video game consoles and found that they consumed an estimated 16 billion kilowatt-hours per year—roughly equal to the annual electricity use of the city of San Diego.[1] This dramatic figure stems from the increased number of video games installed in American homes, the higher power levels needed to operate many of the latest models, and the assumption that half of all users leave their consoles on all the time. A Sony PlayStation 3 or Microsoft Xbox 360 left on 24 hours per day, seven days per week will consume as much electricity each year as two new refrigerators. Through the incorporation of more user-friendly power management features, we could save approximately 11 billion kWh of electricity per year, cut our nation's electricity bill by more than $1 billion per year, and avoid emissions of more than 7 million tons of CO_2 each year—an amount equal to the global warming pollution from all the cars on the road in San Jose, our nation's high-tech capital. Even greater savings would be achieved worldwide.

New Gaming Systems Are Increasingly Popular and Often More Power Hungry

Today, more than 40 percent of all homes in the United States contain at least one video game console. NRDC and Ecos Consulting measured the power use of the latest and prior generation game consoles offered by Microsoft (Xbox), Nintendo (Wii), and Sony (PlayStation).[2] During game play, the Nintendo Wii uses one-seventh as much power as the Sony PlayStation 3 and one-ninth as much power as the Microsoft Xbox 360. Each console does, however, offer a different set of features and a different game play experience.

As shown in Figure 1 summarizing our video game console energy use findings, Sony and Microsoft continue to optimize their systems (PS3 and Xbox 360, respectively) after their initial launch, resulting in significant energy reductions. In addition, machines left on all the time use dramatically more energy and have much higher operating costs.

FIgure 1. The Price of Play: Annual Energy Use and Costs for Three Popular Gaming Systems



A Quick Look at the Most Popular Consoles

Nintendo Wii
Using an average of just 16 watts in Active mode, the Wii is the juice sipper of the group. Attracting buyers with novel, interactive game play rather than power hungry, high-end graphics, the Wii uses far less power to operate than its competitors.

Microsoft Xbox 360
Consuming an average of 119 watts in Active mode, the Xbox 360 sits in the middle of this widely spaced field. The Xbox does offer users a built-in auto power-down option, but the feature is disabled by default and buried deep in the system menu.

Sony PlayStation 3 (PS3)
Burning through an average of 150 watts in Active mode, the Sony PS3 draws the highest amount of power of the video game consoles on the market in 2007. In October 2008 Sony introduced a power management feature via online update, but it too is disabled by default.

Note: Wii, Xbox, and PlayStation are the respective registered trademarks of the Nintendo Corporation, the Microsoft Corporation, and Sony Computer Entertainment Inc.

Many Factors Contribute to Increasing Video Game Console Energy Consumption

Six industry and consumer trends are contributing to an increase in national video game console energy use:

1. **The overall number of video game consoles in U.S. households is increasing**, with sales growing approximately 8 percent per month over the last seven years. In 2007, approximately 17.5 million video game consoles were sold in the United States.
2. **Increases in the average power consumption of consoles** in Active and Idle modes are the trend for new generations of video game consoles.
3. **Power management features are not easily accessible** to users or do not exist on certain video game consoles, resulting in many consoles remaining on hours after the user has finished playing a game or watching a movie.
4. **Many video game consoles are left on for extended periods of time** in Idle mode. Some users simply forget to turn the video game console off when they turn off their television. Other users leave the consoles on because some games do not allow them to save their progress any other way, requiring them to leave the console on until they resume playing hours or days later. In addition, some game designs may also prevent the proper function of power management for those video game consoles that support auto power-down.
5. **Video game console manufacturers continue to offer additional entertainment features** on their consoles with each new generation. By increasing the variety of home entertainment uses of the machines, such as playing movies and connecting to the Internet, manufacturers increase their power consumption too.

6. **U.S. consumers often use their video game consoles as high-definition videodisc players**. Unfortunately, the consoles utilize anywhere from four to seven times as much power as stand-alone Blu-ray disc players and as much as 24 times the power of a stand-alone DVD player. In addition, the console will continue to draw near-full power continuously if the user forgets to turn it off after viewing a movie.

Manufacturers, Developers, and Users Can All Improve Video Game Console Efficiency

While the amount of energy consumed by gaming consoles in the United States is quite high, there is great potential for reducing their energy consumption and the associated emissions of global warming pollution. Significant savings can be realized immediately if console and game manufacturers and developers adopt simple energy-saving technologies and if users make minor changes in how they use their consoles.

Building in an automatic power-down feature that would put a gaming console into a low-power mode following a defined period of inactivity is the single power management feature that would bring the greatest savings in annual electricity consumption. Implementing a power-down feature with a one- or three-hour delay in new gaming systems—and systems already in homes via software update—would bring significant savings to the estimated 50 percent of users who probably do not turn off their machines when not actively playing. A summary of these possible savings for the best-selling gaming systems can be found in Table 1.

Table 1. Annual Energy and Utility Bill Savings Potential for Users Who Leave Console On

Video Game Console	Annual Savings Potential (kWh) With 3-Hour Power Down	Annual Utility Bill Savings (USD) With 3-Hour Power Down	Annual Savings Potential (kWh) With 1-Hour Power Down	Annual Utility Bill Savings (USD) With 1-Hour Power Down
Nintendo Wii	60	$6	66	$6
Microsoft Xbox 360 (Revision 2007)	793	$79	877	$88
Sony PlayStation 3 (Revision 2007)	1053	$105	1164	$116
Microsoft Xbox 360 (Launch 2005)	1108	$111	1225	$122
Sony PlayStation 3 (Launch 2006)	1247	$125	1378	$138

Savings projections apply to users who leave their console on as there is no power down savings to be achieved for those users who already turn off their consoles.

Saving Energy When Gaming in Your Own Home

The single most effective way to save energy is to power down your system—after saving your game if necessary—when not actively playing. If you own a console with a power-saving feature such as auto power-off after a preset time, use it. To learn more about how to set up this feature, visit **www.nrdc.org/energy/consoles/contents.asp**

Conclusion and Recommendations

The increased power consumption of many of the latest models of video game consoles has resulted in a significant rise in the total amount of electricity consumed by these devices each year. We must ensure that the next generations of consoles use less power than their predecessors, even while offering more features. In order to significantly reduce video game console energy consumption and the associated emissions of global warming pollution, extensive collaboration among the video game console manufacturers, the component suppliers, and software companies that design the games will be required. NRDC makes the following recommendations for increasing the efficiency and reducing overall power consumption of gaming consoles:

- Console manufacturers, game designers, retailers, gaming websites, and efficiency advocates should work together to develop and roll out a campaign to encourage users to turn off their video game consoles after use and to take advantage of the auto power-down feature on their console when available.
- The next generation of game consoles should be shipped with an auto power down feature that would go into effect after one to three hours of inactivity. These settings should be the default when shipped and should not require the user to "opt in" as is currently required.
- Game publishers and video game console manufacturers should cooperate to develop standard auto-save features in games similar to those used in computer software, so that the user experience is not disrupted when a power-down occurs. Under the new system, a user's place in a game would automatically be saved regardless of the user's progress within that game. Upon return to the console, the user would also be able to resume playing in a reasonable amount of time following a power-down.
- Video game console designers are encouraged to include a "sleep button" on the controller that the user can push to automatically save progress in a game, along with current game play settings, and to place the console into a low-power sleep mode.
- New video game console designs should be optimized to dramatically lower the amount of power consumed during movie playback. Also, a one-hour auto power-down that initiates from the end of a movie, rather than the beginning, should be enabled.
- Video game console manufacturers should equip their products with the most efficient power supplies available.
- Manufacturers should take advantage of processor voltage and frequency scaling capabilities to reduce the Idle power consumption of future generations of video game consoles.
- Video game console manufacturers should collaborate on developing a standard test procedure for video game console power use by identifying the basic definitions, test sequences, and potentially standard test media (such as multiplatform video games or high-definition video content) that will be necessary to make the clearest "apples to apples" comparisons of power use across platforms.
- The video game industry should share known console usage market studies or help to fund additional research in order to better understand user usage cycles and, ultimately, energy consumption.

CHAPTER 1

The State of Gaming

Video game consoles are becoming increasingly popular in U.S. households.[4] Between 2002 and 2007 more than 62 million video game consoles were sold in the United States alone. Today, more than four out of every ten U.S. households own a video game console, and 14 percent of those households are reported to have more than one functioning console. Highly anticipated games and new video game consoles bring millions of consumers to stores every year. The latest video game consoles and games offer superior gaming experiences and often include other features, such as online gaming and the ability to play DVDs or downloaded movies. In 2007, approximately 17.5 million video game consoles were sold in the United States, and sales of consoles and games added up to the video game industry bringing in $17.9 billion.[5] By way of comparison, that is approximately the same amount of money that Americans spend on DVDs each year.

The Highest-Selling and Most-Played Gaming Consoles

Four video game consoles make up the majority of sales and installed systems (those already in homes) in the country: the Nintendo Wii, the Sony PlayStation 2, the Sony PlayStation 3, and the Microsoft Xbox 360. Despite the release of newer consoles, the PlayStation 2 remains the most-played console in the country and represents the largest percentage (40 percent) of consoles in use in U.S. homes. The sales totals for 2002 to 2007 are shown in Table 2 for the top four consoles.

Table 2. Sales of Four Best-Selling Video Game Consoles for the Years 2002 to 2007[6]

Video Game Console	2002	2003	2004	2005	2006	2007
Sony PlayStation 2	8,420,000	6,320,000	4,630,000	5,540,000	4,694,000	3,965,817
Xbox 360	-	-	-	607,000	3,926,000	4,618,632
Sony PlayStation 3	-	-	-	-	687,000	2,555,858
Nintendo Wii	-	-	-	-	1,080,000	6,287,381
TOTAL	**8,420,000**	**6,320,000**	**4,630,000**	**6,147,000**	**10,387,000**	**17,427,688**

The Wii, PS3, and Xbox 360 Compared

Nintendo Wii – Despite its relatively low-end graphics, the Wii has attracted buyers with its novel interface, motion-sensitive controller, and game play that can include physical activity on the part of the player. Wii is the smallest of the latest generation consoles and performs the fewest supplemental functions for the user. It is not capable of playing movies and utilizes less powerful graphics processors.

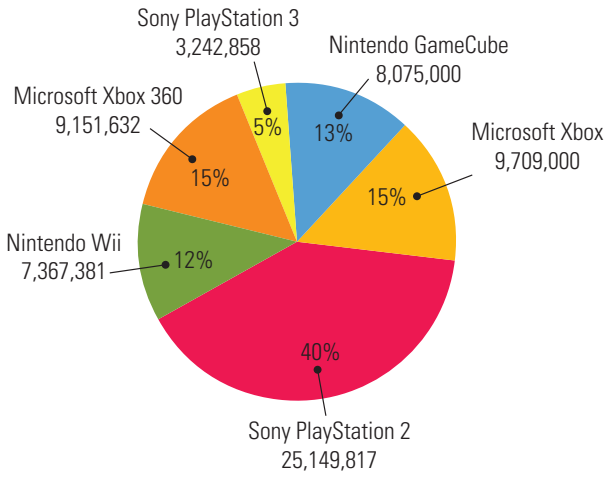
Sony PlayStation 3 – The PS3 is equipped to play video games as well as videodiscs with its internal Blu-ray player. The console contains high-speed central and graphics processors similar to those found in gaming computers and offers the user many features such as Internet connectivity, multiplayer online gaming, media server and networking capabilities, and a wide variety of games.

Microsoft Xbox 360 – The Xbox 360 is also equipped to play video games as well as videodiscs and contains an array of high-end processors similar to the competing PS3. Currently, the internal drive can play regular DVDs.The Xbox 360 offers the user many features such as Internet connectivity, multiplayer online gaming, media server/networking capabilities, and many different types of games.

It is estimated that video game consoles have a five-year life cycle, based on the fact that manufacturers have historically released new console designs about every five years. Within the next three years, manufacturers are expected to introduce new versions of their consoles to the market, spurring another cycle of hardware and software sales. Despite the consistent stream of hardware upgrades, many older consoles continue to be used after the release of a next-generation console. Figure 2 shows the share of all installed models in the United States, including earlier models such as the initial Xbox from Microsoft and the Nintendo Game Cube.

All of the latest consoles offer at least some of the following features: enhanced 3D graphics capabilities, built-in hard drives, Internet connectivity, backward compatibility with earlier console versions, and the ability to play high-definition video content. Future designs for consoles will likely continue to improve upon these features as well as begin to cater to a user base that wants to centralize more of its home entertainment needs. It is already estimated that many of the consumers who purchase a video game console plan to use it as their primary move-watching and entertainment device.[8] In addition to giving users the ability to play games and watch movies, future consoles may allow Web surfing, email access, digital video recording, and home media server functionality. One can also expect the future consoles to be used as part of a home network, which has additional power use implications.

Figure 2. Video Game Consoles in U.S. Homes



The Nielsen Group found that, on average, users who account for close to 75 percent of all playing time have their consoles on for an average of 5 hours and 45 minutes on the days they play.[7]

CHAPTER 2

Gaming System Usage and Energy Consumption

NRDC and Ecos Consulting conducted this study—the first of its kind—to analyze the power use of video game consoles. After measuring the power use of the various consoles in each of their operating modes, we then determined the annual energy use and operating cost of each device, modeled overall national video game console energy use, and determined potential energy savings that could be achieved by the video game console industry. Our findings show that the increased power consumption by the latest generation of Xbox and PlayStation consoles, added to the power consumption of older consoles already in homes, has resulted in a continuous climb in overall console energy use. Changes in the design of video game consoles and the accompanying games are needed to halt this trend and ensure that the next generation of video games consume less power than today's models rather than more.

What We Measured, and How?

In the absence of an industry consensus on how to define operating modes and how to measure the power use in each of these modes, NRDC and Ecos Consulting developed our own test method to perform this study. Our research and energy assumptions focus on the current stock of consoles and present technology rather than what they may become. If consoles become central hubs for home entertainment beyond video game play, energy efficiency and power management will be even more important.

In order to test the power use of consoles while playing games, we defined the operating modes as:[9]

Active/On: The device is on, a disc is loaded in the console, and the user is actively playing a game. Power measurements in this mode were averaged over three to five minutes.

Idle: The device is on, a disc is loaded in the console, but the user is not touching the controller. This can happen either when the game is paused or when it is playing, as long as the user is not interacting with the game. Power measurements in this mode were averaged over one to six minutes.

Standby/Off: Either the user has powered down the console manually through the switch on the console, or the console has powered down automatically through its power management feature. Power measurements in this mode were averaged over one to three minutes. Some prefer to call this "sleep" mode.

For several tests, the same game was available for both the Xbox 360 and the PlayStation 3, allowing us to compare power use between consoles while playing the same game. Tests were completed for several different games that were available for both of these consoles.

In order to test the power use of video game consoles when playing a movie, we defined the operating modes as:[10]

Active/On: The console is on, a disc is loaded in the console, and a movie is actively being played. Power measurements were averaged over 15 minutes.

Idle With a Disc: The console is on, a disc is loaded in the console, but the movie is stopped on the opening menu screen. Measurements were averaged over five minutes. This mode demonstrates the power use of these devices in situations where users turn off their TV when they finish viewing but do not power down the console.

Idle Without a Disc: The console is on, but there is no disc loaded. Spot measurements were taken. This mode demonstrates the power use of these devices in situations where users turn off their TV and remove the disc when finished viewing but do not power down the console.

Standby/Off: Either the user has powered down the console manually through the switch on the console, or the console has powered down automatically through its power management feature. Spot measurements were taken.

Where possible, the same video was used to test active mode power use across different devices in order to minimize variables. For example, *Spiderman 3* was used for testing many of the high-definition players and video game consoles, but because it was available only in Blu-ray format and not HD-DVD, *King Kong* was used for HD-DVD players and the Xbox 360. Tests were started on the same scene of the movie. A few stand-alone high-definition player tests were completed by the Imaging Science Foundation. Although the disc titles and scene selections for these tests are unknown, they used the same test procedure regarding intervals and modes.

Comparing Power Consumption Across Gaming Systems

Testing was performed in all modes for 11 different video game consoles representing the current three leading manufacturers and various generations of products over the past 16 years. While many of the gaming consoles found in homes today are older-generation models, extensive testing was done on versions of the Microsoft Xbox 360 and the Sony PlayStation 3 introduced in the fourth quarter of 2007, to fully understand the nuances of the latest consoles and to estimate likely energy consumption levels in the coming years as older models are phased out. The Nintendo Wii was not extensively tested because the power consumption was low relative to the other two consoles, using one-fifth to one-ninth as much power, in active and idle modes, as the more power hungry Micorosoft Xbox 360 and Sony PlayStation 3.

Given that the two latest-generation consoles (Sony PlayStation 3 and Microsoft Xbox 360) operate as both gaming devices and high-definition video players, these consoles were tested with respect to both functions so that they could easily be compared to other video game consoles and to stand-alone DVD players. In addition to these consoles, 10 stand-alone DVD and HD-DVD/Blu-ray players were tested by Ecos and the Imaging Science Foundation as a basis for comparison during high-definition video-playing operation.

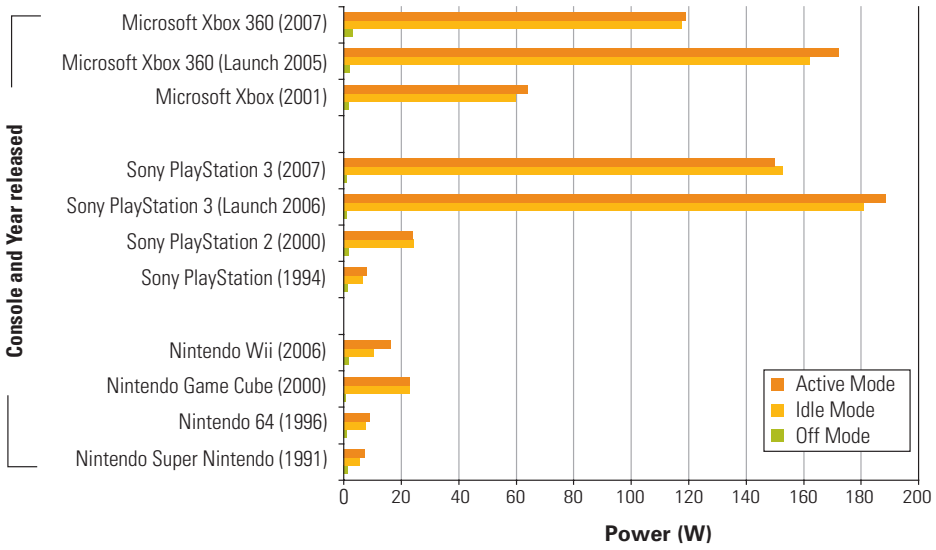
Video Game Energy Use Findings

For each video game console, we measured Standby, Idle and Active mode power use. The results are shown in Table 3 and Figure 3. These measurements are for game play only; measurements for power use when using the console to view movies are shown later.

Table 3. Average Power Measurements by Manufacturer

Console and Year Released	Off (W)	Idle (W)	Active (W)
Microsoft Xbox 360 (2007)	3.1	117.5	118.8
Microsoft Xbox 360 (Launch 2005)	2.2	162.0	172.0
Microsoft Xbox (2001)	1.7	59.9	64.0
Sony PlayStation 3 (2007)	1.1	152.9	150.1
Sony PlayStation 3 (Launch 2006)	1.1	181.0	188.6
Sony PlayStation 2 (2000)	1.7	24.2	24.2
Sony PlayStation (1994)	1.4	6.5	8.0
Nintendo Wii (2006)	1.9	10.5	16.4
Nintendo GameCube (2000)	0.7	22.7	23.0
Nintendo 64 (1996)	1.1	7.8	7.3
Nintendo Super Nintendo (1991)	1.5	5.4	7.3

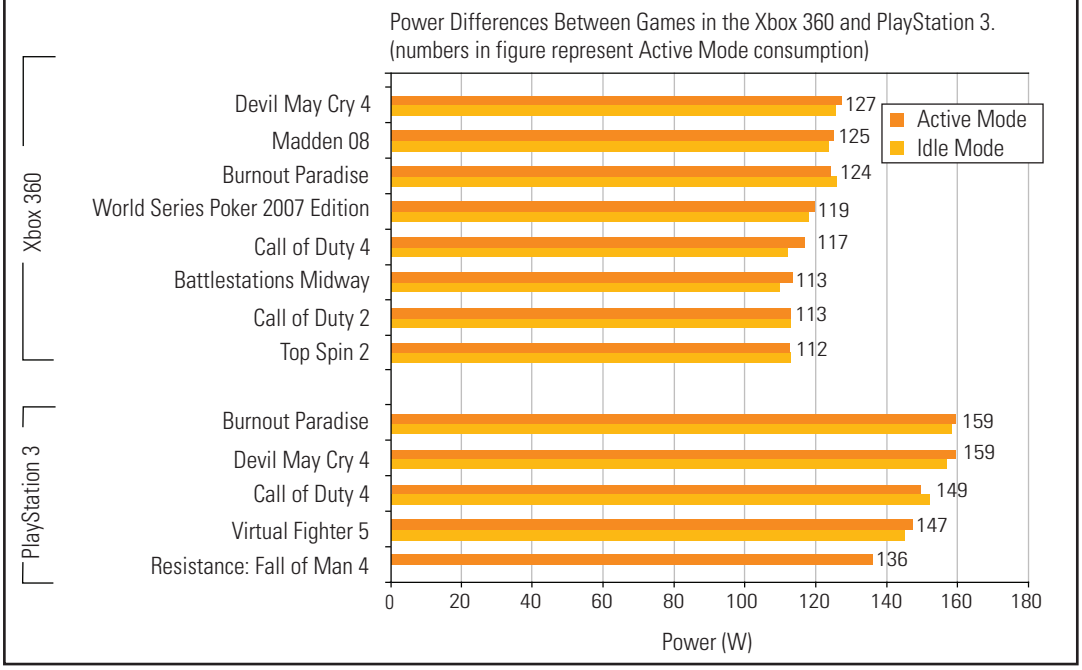
Figure 3. Console Power Consumption by Mode and Manufacturer



Our measurements show:

- **Power Use Trends –** The current Xbox 360 and PlayStation 3 use two to six times more power in active and idle modes than their predecessors. Nintendo's current Wii, however, uses less slightly less power than its predecessor, the Game Cube.
- **Comparative Power Use –** The Wii consumes dramatically less power than both the Sony and Microsoft products, due in part to its lower graphics processing requirements. In round numbers, our latest Active mode readings show the Wii drawing less than 20 watts, with the Xbox 360 and PlayStation 3 drawing approximately 120 and 150 watts respectively.

Figure 3. Power Measurements Compared Across Games Played



No published data were available about how the game being played or other variables such as Internet connection and online game play affect power consumption. Therefore, we tested a variety of games on both the PS3 and Xbox 360 platforms to see whether there are measurable differences in power use for a given console. During active mode measurements, we found there is a range of 20 to 25 watts between games on the PS3 and 10 to 15 watts on the Xbox 360. As for the impact of Internet connection and online game play, it appears that Active and Idle are minimally affected (1 to 2 watts). As long as a game disc is inserted into the device, Active mode power consumption varies by a negligible amount, whether the user has the console connected to the Internet or not and whether he or she playing online with others or playing alone (not online). Results from these tests can be seen in Figure 4 and Table 4.

Table 4. Xbox 360 Active Mode Power Measurement Comparison: Single Person Play Versus Multiplayer Online Play

Game	Single Person Offline Play (W)	Multiplayer Online Play (W)
Call of Duty 4	116.8	114.6
Battlestations Midway	113.2	112.8

When the video game consoles were connected to the Internet, this resulted mainly in a longer startup period for some games while updates were downloaded to the machine. The Xbox 360 allows users to choose a setting that will enable the console to download updates even if the machine is turned off. It is possible that when the download settings are enabled and the machine is connected to the Internet, the machine will utilize more energy overall because it will spend some of its time downloading data from the Internet when it would otherwise be in Standby mode. While the average power consumption when downloading updates is 157 watts for the PS3 and 104 watts for the Xbox 360, the downloads performed during testing typically lasted only two to five minutes,

which would result in a minimal impact on the overall energy use of the devices, assuming the box went back into Standby/Sleep mode upon completion of the download.

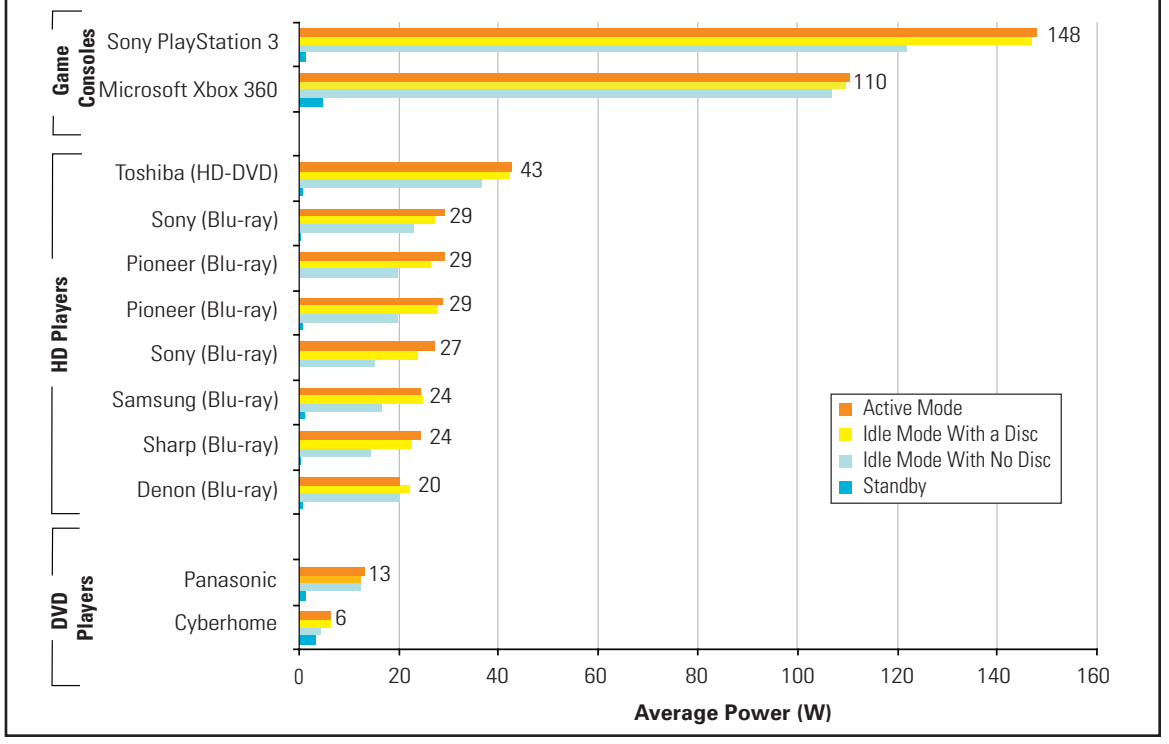
Because video game consoles now have the ability to download information and store it on a hard drive, there is a new Internet marketplace for game publishers. Users can now download games for their consoles over the Internet and play those games from the hard drive at a later time. If users download games from the Internet, some parts of the console—namely the motor in the optical drive—are not required for game play, resulting in lower power usage in Active and Idle modes. On the Xbox 360, the only console on which this test was performed, the average Active mode power was 99 watts when playing a game from the hard drive and 127 watts when playing from an optical disc. It is unclear how frequently users would take advantage of this option, as many games available for download are trial games used as advertising for game publishers. This feature should not greatly affect energy use for this generation of technology because the files would likely be too large to play most complete games in this way.

Power Consumption When Consoles Are Used as High-Definition Video Players

Video game consoles are increasingly called on to perform as high-definition DVD players. We therefore conducted separate tests to compare the power consumption of gaming consoles and stand-alone high-definition DVD players when playing movies. Gaming consoles are sometimes the preferred choice for consumers when buying Blu-ray players because they can be more affordable than stand-alone players and can serve multiple purposes. One study estimates that 75 percent of PS3 owners plan to use their console as their primary movie watching device, meaning that as many as 9.3 million PS3s and/or Xbox 360s are being used in this way.[11]

As is shown in Figure 5, video game consoles use significantly more power in all modes to play a DVD when compared to stand-alone DVD players. The Xbox 360 uses 18 times as much power in Active mode as the most

Figure 5. Power Measurements of Stand-Alone DVD Players Compared with Video Game Consoles

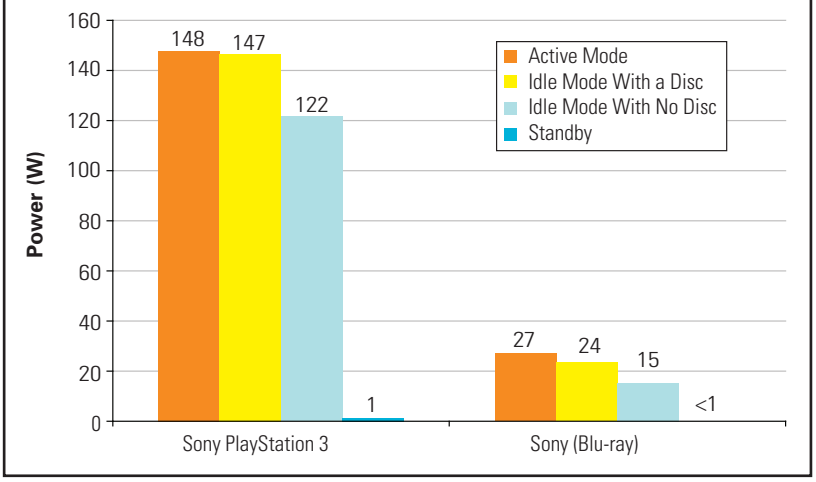


energy efficient stand-alone DVD player. The power use in video game consoles is much higher even when compared with stand-alone high-definition video players.

We also learned from our measurements that the Sony PS3 used more than five times the power of a stand-alone Sony Blu-ray player while playing the same movie (see Figure 6); the PS3 drew 148 watts while the standalone Sony Blu-ray player drew only 27 watts. In other words, two products, both made by Sony and capable of playing Blu-ray discs, used dramatically different amounts of power to accomplish the same task. This indicates that with better engineering design, future generations of the PlayStation could use one-fifth as much power to play a Blu-ray movie as do the current models.

Similarly, the Xbox 360 uses five and half times the power of an energy efficient, stand-alone high-definition video player—another opportunity for efficiency improvements. Given the market's adoption of Blu-ray as the format for future high-definition DVDs, one can easily imagine future generations of the Xbox including the capability to play Blu-ray discs.

Figure 6. Comparing Sony PlayStation 3 and Sony Stand-Alone Blu-ray Player Power Consumption

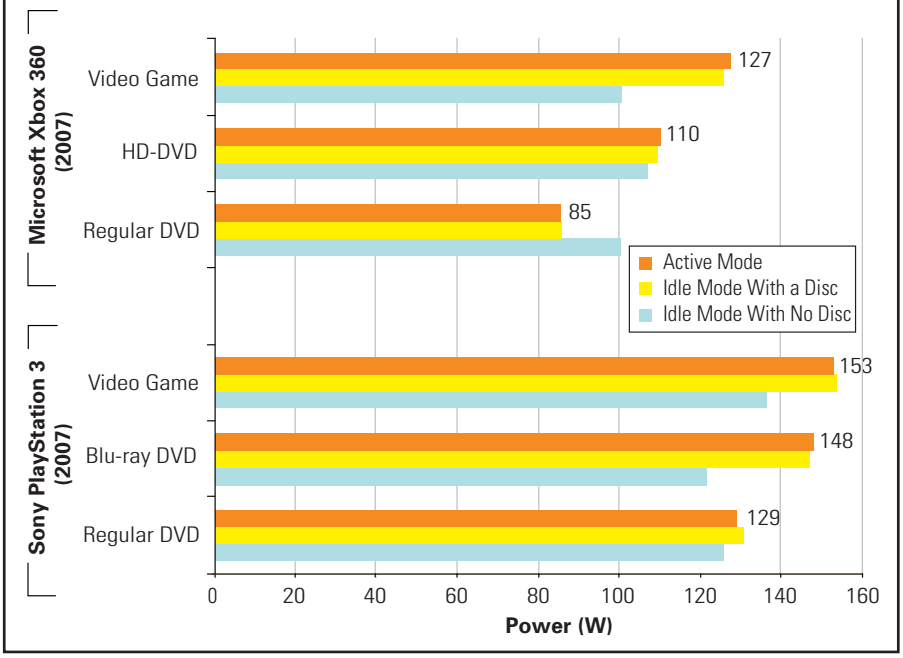


We also learned that neither the PS3 nor the Xbox 360 offers any power management features to the user related to movie play. Only one of the stand-alone players, a Pioneer Blu-ray player, offered a power management feature through a menu-selectable half-hour shutdown. Therefore, most players will continue to operate at full Idle mode power when left on after the movie is over, unless the user presses the power button. This means stand-alone players will remain in Idle mode at around 20 watts, whereas video game consoles will stay idle at well over 100 watts.

Power Consumption While Idle Is Significant in Game Play and Movie Viewing Modes

Comparing video game console energy use for the PlayStation 3 and Xbox 360 when playing video games, high-definition videos, and standard-definition videos reveals that while both units consume less energy in Idle mode than in Active mode for most applications, the difference is only slight. Figure 7 reveals the substantial energy savings that could be achieved through improved power management and power-down features that reduce video game console energy consumption when not in Active mode.

Figure 7. Power Measurement Comparison Between Game Play and Video Viewing on Consoles



CHAPTER 3

Power Management in Video Game Consoles

Most video game consoles use negligible amounts of power (3 watts or less) when turned off and dramatically higher power levels when in either Idle or Active mode. If consoles are left in Active or Idle mode for long periods of time while the user is away, large amounts of energy are unnecessarily wasted. When compared with other consumer electronics such as computers, laptops, cell phones, and monitors that can automatically enter into a power-saving mode (called sleep or standby) and quickly wake up and return to the earlier operational state, today's gaming consoles seem terribly antiquated.

Current Power Management Options Are Inadequate

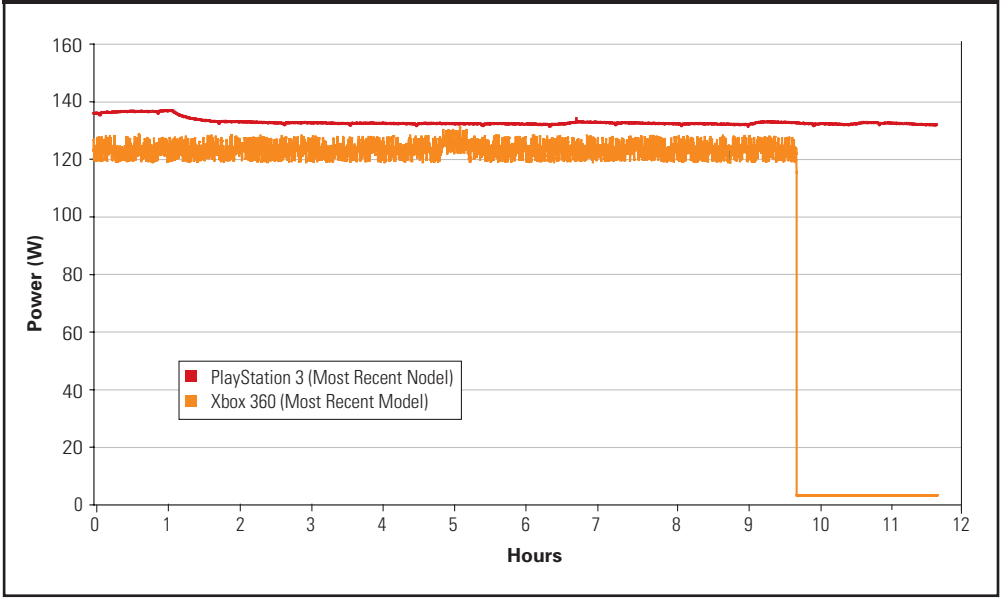
Our testing of video game consoles revealed that a console left on but not in Active mode will consume almost as much power as is consumed when a user is actively playing a game or watching a movie. Unfortunately, power management features that would automatically bring a console into a low-power state when idle are not easily accessible or well implemented—if they exist at all—on the consoles we tested.

While we are unaware of any user data revealing the percentage of users who turn off their consoles after use, we have found anecdotally that many users leave their consoles on all the time. Some turn off their televisions at the end of a session and but to turn off peripherals like the console, while others keep their consoles on in order not to lose progress in a game.

The energy consumed in the absence of an automatic power-down feature for gaming consoles is substantial, and could be reduced dramatically with better-designed machines and games. Of the consoles available on the market right now, only the Xbox 360 ships with a power-management setting available to the user (Microsoft calls this feature auto-off), but its use is likely rare because the setting is not enabled by default. The system is shipped with this important feature disabled and requires the user to "opt in" by searching through the opening menu to enable it. The Xbox 360 allows the user to select a six-hour shutdown that automatically powers-down the console to a low standby power level after six hours of inactivity. The PlayStation 3 does not have any native power-down settings available. Third-party applications such as Stanford University's Folding@home program do provide some power management features, but they are enabled only if there is no disc inside the machine. The Nintendo Wii has no power-down settings.

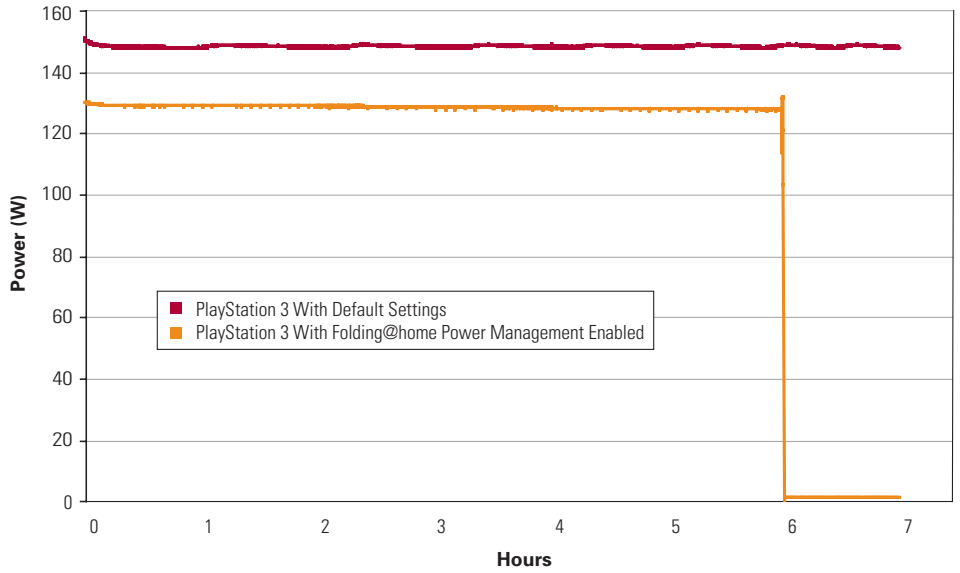
To investigate the power management settings on the Xbox 360, we left a game in the machine for six hours without any user input. The Xbox 360 successfully powered down after extended user inactivity in all of the following scenarios: when there was a game inside the machine, when there was no game in the machine, when a game was loaded (paused or playing), and when a movie was loaded (paused or playing). The resulting power-down that was observed is shown in Figure 8. The PS3, by comparison, continues in Idle mode for the entire time it is left on, never reducing its power consumption.

Figure 8. Comparing Auto Power-Down of the Xbox 360 to the PlayStation 3 (Game Idle, Not Paused)



In order to better understand the power management settings, we also performed tests on the PlayStation 3 with the Folding@home program installed.[12] With the program installed, the PlayStation 3 can power down after a time selected by the user or after a work unit is completed for the program (approximately eight hours), but only if no game or movie is loaded in the console. Given that these settings must be enabled by the users and that the Folding@home program encourages users to leave their consoles on when they are not gaming, the energy savings potential created by the power management features offered through this program is unclear. Sony estimates that close to one million users are participating in the Folding@home program now, which is nearly one-third of all PS3 owners. It is assumed that these users leave their consoles on and in an Idle mode (but without a disc in, or the program will not begin) for longer periods of time than other users. Figure 9 demonstrates the power-down behavior of the PS3 with and without Folding@home installed and enabled. The power consumption is lower overall during the Folding@home measurement because the program will operate only when no disc is loaded. Idle power use is generally lower overall in video game consoles when games are not loaded in the machine.

Figure 9. Power Consumption of PS3 with Folding@home Power-Down Settings Enabled Versus PS3 With Default Settings



Although the Folding@home program may not provide any net reduction in PS3 energy consumption, it is a useful example of a very simple, downloadable patch that enables power management in the PS3. Such a patch, if delivered by Sony as a mandatory upgrade to PS3 firmware, could dramatically improve the energy efficiency of the console without any action required of the consumer.

Industry Update: Sony Introduces Power Saving Option for PlayStation 3

In October 2008—several months after we concluded testing for this study—Sony released a firmware update for existing PS3 consoles that included a power saving feature and was automatically downloaded to PS3s connected to the Internet. This feature, similar in concept to one that already exists on the Microsoft Xbox 360, automatically powers down PS3s that are left on but are not in use and can potentially reduce a user's energy use by as much as $100 per year. Unfortunately, this feature is initially disabled and requires the user to go into the menu and turn it on. The current interface for doing so is somewhat confusing, requiring the user to select the unappealing-sounding and poorly defined "special circumstances" option in order to achieve maximum savings. We encourage the video game console manufacturers to make their auto power-down features more user friendly and to work with the game industry to ensure that the user's settings and place in the game are automatically saved before the device powers down.

The Next Step for Gaming Console Power Management

Power management is currently in an early phase of development in video game consoles, and special care needs to be taken on the parts of both manufacturers and game publishers to ensure that power management performs as designed and does not detract from the user experience, as was the case in the early days of computer power management. Game publishers want to create games that enhance the user experience as much as possible, without

interruption. Power management has the potential to interrupt the user experience if a console powers down before a game has been saved. If a console powers down before a user is able to save his or her game, the user could lose game status information and become dissatisfied with the experience. This may be one of the reasons that current console manufacturers require their users to "opt in" to the feature rather than making it a default setting. The conversation regarding consoles and power management features requires the cooperation of game publishers in creating games that can be frequently or automatically saved so that users do not lose information when their hardware goes to sleep.

Better Power Management, Step-by-Step

NRDC recommends the following options and sequence of events for implementing improved power management as part of the console player's experience:

- The user pauses the game in play, returns to the game menu, or otherwise leaves the game and console sitting idle.
- After a period of 1 to 3 hours of inactivity, the video game console automatically saves the status of the game to memory and initiates auto power-down.
- The video game console comes to rest at a low power level equivalent to Standby/Off mode power (less than 3 watts). The sleep state should be indicated through appropriate user interface elements (e.g., the color of the backlight on the power switch, a blinking indicator light, etc.).
- The user returns to the video game console after a given period of time and reawakens it by pressing the power button on the console or a button on the controller, much as he might do on a desktop computer.
- The video game console returns the user to the last saved position in the game in roughly the same amount of time it would take to boot the console from a cold start or no longer than 30 seconds.

One large challenge facing video game console manufacturers is the willingness of game publishers to cooperate in the power management effort. Game publishers will more than likely be concerned about a power-down feature any shorter than the current six-hour power down available on the Xbox 360. Game publishers use Idle mode, as we have defined it (with the game disc loaded), as an opportunity to advertise their game and draw users back to the console and are therefore less interested in seeing the console power down after a certain period of time.

Additionally, there is concern about the ability to save a game if the console goes into a default power-down when the user has not manually saved the game prior to power-down. Some games do not allow users to save in the middle of play, could potentially create a conflict during auto power down. Game publishers possess the ultimate control over the user experience, and if a designer feels that a power down event might disrupt that experience, they are likely to deny a console the ability to turn itself off. Ultimately, allowing games to save the user's progress frequently and automatically before power down would prevent this problem.

Another important aspect is to ensure that the unit quickly powers back up and restores the user to her previous position in a game in a minimal amount of time. When the user returns to the console, she should be able to return to her last saved position in a game and actually begin playing within a few seconds. If powering up from sleep takes much longer, there is the risk that users will become impatient and simply disable the feature.

CHAPTER 4

National Video Game Console Energy Savings Potential

There is great potential for improving the energy efficiency of future gaming consoles as well as those already in American homes. In order to determine the potential savings from adoption of power management and other energy saving technologies, we looked to the best available research on current video game console usage and then made careful assumptions about how those statistics relate to a model of national console usage (see Appendix A). We found that the energy consumed by gaming consoles in the United States is staggeringly high and that there are many practical ways to reduce that consumption and the associated emissions of global warming pollution. Significant savings can be realized very quickly if game and console manufacturers and developers adopt relatively simple technologies and if users make minor changes in how they use their consoles.

Estimating Average Energy Consumption and Cost

The lack of concrete information on usage cycles for video game consoles, and particularly consoles that can also function as DVD players, led us to develop usage scenarios in which 50 percent of users turn off their consoles when they are done playing a game or watching a movie, and 50 percent of users leave the device on continuously. Since we know the power use of the consoles by mode, we are able to estimate the annual energy use and operational costs to consumers for each of the major consoles on the market today. Table 5 on page 21 shows the annual energy use and utility costs per unit for the Nintendo Wii, Microsoft Xbox 360, and Sony PlayStation 3 for both usage scenarios.

Table 6. Per-Unit Annual Energy Use and Utility Costs for Popular Video Game Consoles

Video Game Console	Annual Energy Use (kWh) for Users Who Turn Console Off After Use	Annual Utility Costs (USD) for Users Who Turn Console Off After Use	Annual Energy Use (kWh) for Users Who Leave Console On	Annual Utility Costs (USD) for Users Who Leave Console On
Nintendo Wii	27	$3	96	$10
Microsoft Xbox 360 (Revision 2007)	112	$11	1031	$103
Sony PlayStation 3 (Revision 2007)	118	$12	1337	$134
Microsoft Xbox 360 (Launch 2005)	144	$14	1426	$143
Sony PlayStation 3 (Launch 2006)	153	$15	1596	$160

Given the per-unit energy consumption and the assumption that half of users leave their console on all the time and the other half turn it off after 2 hours of use, the annual energy consumption and environmental impact of video game consoles in the United States total 16.3 billion kWh—roughly equal to the annual electricity use of the city of San Diego—at a cost of $1.6 billion and CO_2 emissions of 11 million tons.

Great Potential for Energy Savings

We then evaluated the savings potential that would result from the implementation of a one- or three-hour power down in video game consoles. We assume that current power management options—offered in the Xbox 360 and for some PS3 owners with the Folding@home program—are rarely utilized. Table 6 highlights the savings potential per unit if the assumed 50 percent of users who do not turn off their consoles had an "auto off" feature that would put the inactive console into a low-power sleep mode. Table 7 and Figure 10 highlight the aggregate savings potential for the entire stock of consoles if an "auto off" feature were implemented.

As clearly demonstrated in Figure 10, the incremental benefit of having an auto power-down feature kick in after one hour instead of three hours is small when compared with the energy consumed in the absence of a power-down feature. As such, care should be taken when balancing potential for maximizing energy savings with the peril of implementing too short an auto power-down period that could cause some users to disable the feature.

Table 6. Per Unit Annual Energy Savings and Utility Bill Savings Potential for Users who Leave Console On

Video Game Console	Annual Savings Potential (kWh) With 3-Hour Power Down	Annual Utility Bill Savings (USD)[a] With 3-Hour Power Down	Annual Savings Potential (kWh) With 1-Hour Power Down	Annual Utility Bill Savings (USD) With 1-Hour Power Down
Nintendo Wii	60	$6	66	$6
Microsoft Xbox 360 (Revision 2007)	793	$79	877	$88
Sony PlayStation 3 (Revision 2007)	1053	$105	1164	$116
Microsoft Xbox 360 (Launch 2005)	1108	$111	1225	$122
Sony PlayStation 3 (Launch 2006)	1247	$125	1378	$138

Savings projections apply to users who leave their console on; there is no power-down savings to be achieved for those users who already turn off their consoles.

Table 7. Annual Savings Potential Given Different Power-Down Scenarios in Consoles[13]

Annual National Energy Use (billion kWh/year)	National Utility Costs (USD)	National Savings Potential, 3-Hour Power Down (billion kWh/year)	Savings Potential, 1-Hour Power Down (billion kWh/year)	Utility Savings With 3-Hour Power Down (USD)	Utility Savings With 1-Hour Power Down (USD)
16.3	$1.6 billion	11.1	12.2	$1.1 billion	$1.2 billion

Figure 10. National Energy Use and Savings Potential With 1-Hour or 3-Hour Auto Power Down

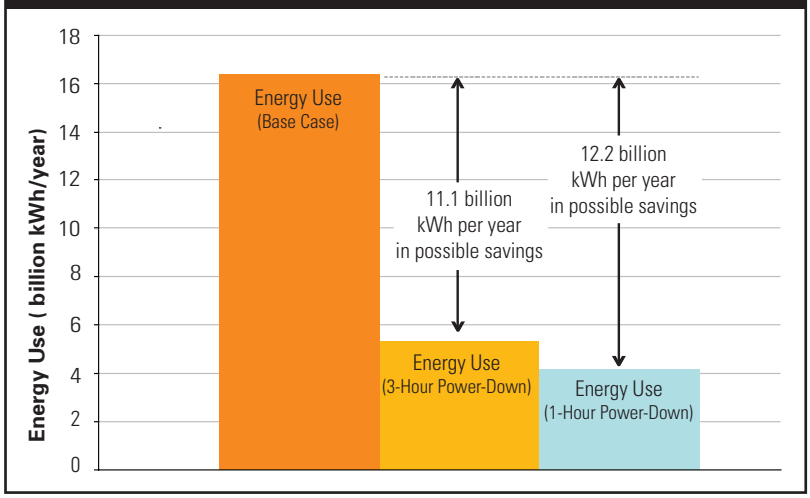
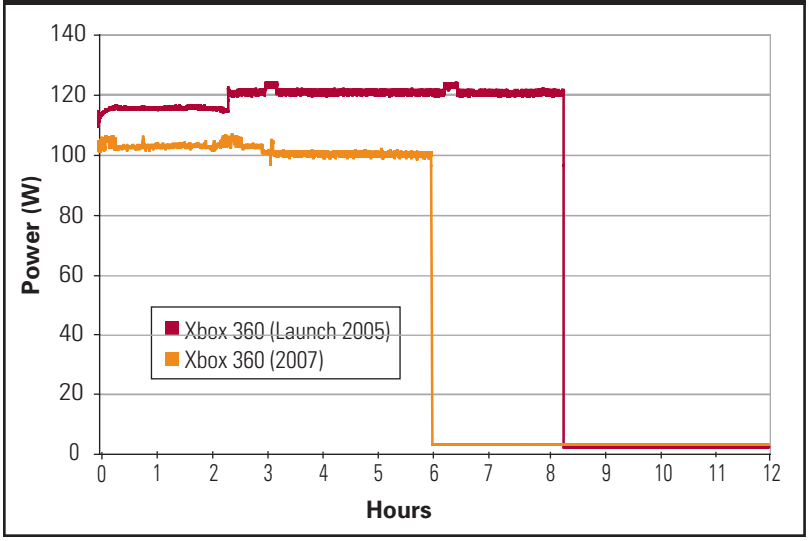


Figure 11. Power Down With a Movie in the Console



Adapting Power Management When Console Is Used as a Video Player

An additional concern is related to the power-down time frame for those consoles that also act as high-definition video players. The Xbox 360 models appear to time auto power down from different points depending on the type of media inserted into the device. For example, in the latest iteration of the Xbox 360, power down for high-definition video content is initiated six hours after the movie begins rather than six hours after the movie ends, as shown in Figure 11. The point at which the machines begin their countdown could present a problem for users if the power down occurs while they are watching a movie. Therefore, we advocate one-hour power down that would initiate at the end of a movie rather than the beginning. This requires that the software include a simple way to detect the end of a DVD movie.

CHAPTER 5

Conclusion and Recommendations for Increasing Gaming Console Efficiency

There is great potential to achieve significant energy and pollution savings by improving the efficiency of video game consoles already in homes and those currently under development. Absent a concerted effort by gaming console manufacturers and game designers, future generations of increasingly powerful consoles could only exacerbate the problem. But with collaboration between manufacturers and designers to improve the energy efficiency of their products, future generations of gaming systems can provide more immersive gaming experiences with more functions available to the user while still reducing the amount of energy required to power the systems.

If all of the current stock of consoles in the United States had better default power management settings, more efficient power supplies, and improved processor scaling, energy savings as high as 11 billion kWh annually are possible. Such reductions in energy consumption would result in savings of more than $1 billion annually in utility bills for consumers. And these savings could cut emissions of CO_2 by as much as 7 million tons—the equivalent annual emissions of three 600 megawatt power plants or the tailpipe emissions from all the cars in San Jose.

NRDC and Ecos Consulting make the following recommendations to manufacturers for improving the energy efficiency of video game consoles:

Improve Power Management

The rapid implementation of improved power management settings for gaming consoles in homes and on the shelves would not be difficult for manufacturers and would bring the most savings potential. We recommend that these settings be enabled by default when new devices are shipped, and that power down occur after one to three hours instead of the current six-hour option on the Xbox 360. In other words, users should not have to "opt in" in order to improve the energy efficiency of their consoles. The Folding@home program demonstrates how a mandatory software patch could be issued to all existing Xbox 360 and PS3 owners with an Internet connection, enabling power management across millions of existing machines without the need for user interaction or the purchase of new hardware. In addition, console manufacturers, game designers, retailers, gaming websites, and efficiency advocates should work together to develop and roll out a campaign to encourage users to turn off their video game consoles after use and to take advantage of the auto power-down feature on their console when available.

Console designers will need to proactively reach out to game software authors to ensure that new games include the capability to automatically save the user's place in the game in the next generation of consoles before powering down to standby/sleep mode. Product designers should also evaluate methods for adding a "Sleep" button directly on the game controller itself that would quickly save the users place and put the game console into a low-power mode.

Employ Efficient Power Supplies

Video game console manufacturers should equip their future products with the most efficient power supplies available. Improved power supply efficiency is a proven cost-effective measure for saving energy. Efficient power supplies such as those already on the market operating at 90 percent efficiency can reduce power needs in all modes of operation while generating less heat in and around the console.

Enable Processor Performance Scaling

Manufacturers should take advantage of existing performance scaling capabilities in console processors that allow the processors to adjust their operating speed and energy consumption in relation to computing demand. Processor scaling can shave as much as 20 percent off power usage when processors are idling. This technology is already supported by types of processor architecture (such as IBM's Cell processor) now used in most video game consoles.[14] This technology would be particularly useful in scaling back power consumption while playing high-definition video discs as this activity does not require the full graphics rendering capabilities of the consoles. Processor scaling should be implemented in all future game console hardware designs.

Collaborate on the Development of Standard Power Consumption Test Methods

The absence of any industry accepted test procedure for measuring video game console power use in "on" modes like Active and Idle required us to develop our own in-house test procedures for evaluating the power consumption of current video game consoles and estimating their annual energy use. Our methodology provides a useful base upon which to build a more comprehensive testing procedure. We recommend that video game console manufacturers collaborate on the basic definitions, test sequences, and potentially standard test media (such as multiplatform video games or high-definition video content) that will be necessary to make the most accurate comparisons of power use across platforms.

Improve Understanding of Video Game Console Usage

The energy consumption of gaming consoles varies considerably depending on the usage patterns of their owners. Recent research by the Nielsen Group provides an important step forward in understanding console usage patterns, but there remains a general lack of definitive market research to estimate the average time spent in various modes of operation for typical users and the percentage of users who turn off their consoles after use. We encourage the video game industry to help bridge this data gap by sharing known console usage market studies or by helping to fund additional research. This improved information will ultimately lead to far more accurate estimates of console energy use and savings potential.

APPENDIX:

Building Upon Existing Gaming Console Usage Research

Although some research has been conducted on youth game play, the majority of such research is focused on active game play and its possible relationship to social behavior rather than on measuring how youth use their consoles, e.g., how often the machines are left on when the user is not playing. In order to accurately model patterns of video game console usage we began with usage cycle information from the Nielsen Group. Using the best and most current usage cycle information available, the Nielsen Group found that, on average, users who account for close to 75 percent of all playing time have their consoles on for an average of 5 hours and 45 minutes per day.[15]

Nielsen's statistics can be difficult to interpret because the time in Active mode reflects an average across only the days when the console was turned on, rather than a true daily average reflecting use across the entire time metered. It is likely, however, that many heavy users often have the console on every day. For all of these reasons, we built upon the information available and the following assumptions to complete the energy analysis.

Many users are assumed to leave their video game consoles on when they are finished with a game, even when they go to sleep at night. Much of the energy savings potential is based on the assumption that consoles are left in Idle mode for longer periods of time.

Some games do not allow users the flexibility to save their progress at any given point during play, requiring instead that users achieve certain milestones in the game in order to save their progress. An analogous situation would be a computer program like Microsoft Word allowing users to save their documents only when they had finished writing a report section. This aspect of game design can deter users from shutting down their consoles because they do not want to lose their status. As a result, many consoles are left on for hours at a time simply to preserve information that could otherwise be stored on a hard drive or flash memory card.

Some video game console manufacturers define Idle mode as a state during which there is no game disc inserted in the console. We believe that users are more likely to leave game discs in their consoles when they are left in Idle mode (a user who takes the time to eject the game disc would more likely just power down the console completely rather than leave it running) and have defined this mode accordingly.

While some users are assumed to leave software discs loaded during Idle, the Folding@home program used on the PS3 works only without a disc in the machine. With close to 1 million Folding@home users, it makes sense to apply this scenario to a percentage of PS3 users in the energy analysis.

Research on other consumer electronics products supports the above assumptions. In an after-hours plug load survey for offices, Lawrence Berkeley National Laboratory found that 60 percent of the surveyed computer users left their computers on for extended periods overnight and over the weekends.[16] Some of these behavioral trends can easily apply to increasingly computer-like devices like video game consoles. In addition, consoles can now be networked through computers and various other home electronics, contributing to more time in use.

Further, a desire to have access to entertainment quickly and easily prevents some people from powering down their devices, while others may leave the devices on because of the misconception that powering down will prevent the system downloads and updates that periodically occur. Last, manufacturers do not provide many good options for power management, and when they do, they are not readily educating consumers about these features. It is expected that large numbers of consumers leave these devices in Idle mode each day.

Endnotes

1 Many users do not turn their video game console off. A game console that is left on 24/7 will use approximately 10 times more annual energy than one that is turned off after use. Due to the absence of any studies, we based our calculations on the assumption that 50 percent of users leave their device on when they are finished playing a game or watching a movie.

2 Wii is a registered trademark of the Nintendo Corporation. Xbox is a registered trademark of the Microsoft Corporation. PlayStation is a registered trademark of Sony Computer Entertainment Inc.

3 All utility cost estimates assume typical retail electricity rates of $0.10 per kWh.

4 NPD Group, www.npd.com.

5 Ibid.

6 Ibid.

7 The Nielsen Company, "The State of the Console," Q4 2006.

8 Ben Drawbaugh, Live Coverage From BDA Press Conference, January 8, 2007, www.engadget.com/2007/01/08/live-coverage-from-bda-press-conference.

9 Ecos utilized a high-accuracy digital power meter (Yokogawa WT1600) that logged power measurements every five seconds over different time intervals depending on the operational mode. The average power reading was taken across the different time intervals in order to get a measurement for each mode.

10 Ecos utilized a digital meter (Yokogawa WT1600) for the tests on the video game consoles, which logging power measurements every five seconds over different time intervals depending on the mode. A WattsUp? Pro power meter was utilized for the tests performed on the stand-alone high-definition players, and this meter logged data every second. An average was taken across the different time intervals for the modes in order to find the average power.

11 Ben Drawbaugh, Live Coverage From BDA Press Conference, January 8, 2007, www.engadget.com/2007/01/08/live-coverage-from-bda-press-conference.

12 Folding@home is a distributed computing project designed to perform calculations and modeling for protein folding and molecular dynamics for Stanford University. The goal of the project is to better understand protein folding as it relates to medical treatments. Users can download the program from the menu on their PS3, and once it is downloaded, power-down settings can be selected by the user.

13 These estimates reflect the savings possible if all of the current stock of consoles were able to power down after one or three hours. If all consoles in the United States today could be represented as a weighted average of the Sony PlayStation 3, Microsoft Xbox 360, and Nintendo Wii, the annual national energy use would be 25.5 billion kWh/year and the national savings potential with a one- or three- hour power down would range from 17.6 to 19.5 billion kWh/year. These estimates are more likely to reflect the savings potential of consoles in the coming years as older models are replaced by these more advanced units.

14 Existing performance scaling in computer processors includes the Enhanced Intel SpeedStep® Technology and AMD's PowerNow!™ Technology.

15 The Nielsen Company, "The State of the Console," Q4 2006.

16 Roberson, Judy A., Carrie A. Webber, Marla C. McWhinney, Richard E. Brown, Margaret J. Pinckard, and John F. Busch, Energy Analysis Department, Lawrence Berkeley National Laboratory (LBNL), "After Hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment," January 2004, http://enduse.lbl.gov/info/LBNL-53729_REV.pdf.

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