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The Latest-Generation Video Game Consoles

How Much Energy Do They Waste When You're Not Playing?

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EXECUTIVE SUMMARY

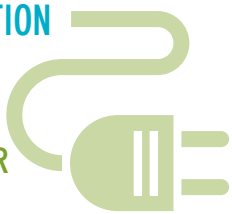
As a follow-up to NRDC's 2008 report on the energy use of video game consoles,[1] we performed extensive laboratory tests on the latest generation of the most popular consoles—the Nintendo Wii U, Sony PlayStation 4 and Microsoft Xbox One—and found they have incorporated many energy efficiency features into their designs and offer greater performance. However, the Sony PS4 and Microsoft Xbox One consume two to three times more annual energy than the most recent models of their predecessors. The Wii U consumes less energy than its predecessor the Wii, despite providing higher definition graphics and processing capabilities, in large part thanks to its very low power in connected standby mode. NRDC projects that together, these three brands of new consoles will use roughly 10 billion kilowatt-hours of electricity annually in the United States alone, once all previous-generation consoles in use have been replaced by new ones.

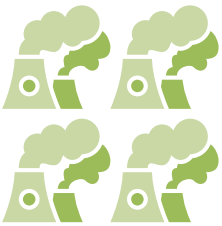
This estimate takes into account the efficiency improvements that are likely to be achieved via advances in semiconductor design in the coming years. To put this into perspective, game consoles are on track to consume as much electricity each year as all the homes in Houston, the fourth-largest city in the country, and cost consumers more than $1 billion to operate annually. Astoundingly, $400 million of that will be consumed in the middle of the night, when the console is in standby mode but still listening for voice commands like the Xbox One or using higher power than necessary to keep USB ports active like the PS4.

PROJECTED VIDEO GAME CONSOLE U.S. ENERGY CONSUMPTION

ANNUAL ELECTRICITY CONSUMPTION

10-11 BILLION KILOWATT HOURS PER YEAR





EQUIVALENT TO THE OUTPUT OF **4** LARGE POWER PLANTS*

*500 MEGAWATTS EACH

$1 ANNUAL ELECTRICITY BILLS BILLION

AS MUCH ELECTRICITY AS ALL THE HOUSEHOLDS IN THE CITY OF 4TH-LARGEST CITY IN THE U.S. **HOUSTON**

Some of our key findings:

- The new consoles consume more energy each year playing video or in standby mode than playing games.
- The Xbox One and PS4 consume two to three times more annual energy than the latest models of their predecessors, the Xbox 360 and PS3.
- While the new versions are more powerful, the two- to three-fold increase in energy use is due to higher power demand in standby and on modes and, in the case of the Xbox One, more time switched on due to its TV viewing mode. In this mode, the console is used in addition to the current set-top box to access cable or satellite TV, adding 72 watts to TV viewing.
- The Xbox One draws less power than the PS4 in on mode. However, the Xbox One consumes a lot more energy when not in use (connected standby mode).
- Nearly half of the Xbox One's annual energy is consumed in connected standby, when the console continuously draws more than 15 watts while waiting for the user to say "Xbox on," even in the middle of the night or during the workday when no one is home. If left unchanged, this one feature will be responsible for $400 million in annual electricity bills and the equivalent annual electricity output of a large, 750-megawatt power plant.
- Consoles have incorporated some good design practices, including better power scaling and well-implemented automatic power down to a low-power state after an extended period of user inactivity.
- The PS4 and Xbox One are very inefficient when playing movies, using 30 to 45 times more power to stream a movie than a dedicated Apple TV or Google Chromecast.

The results of our testing and analysis are summarized below:[2]

	Game Play Power (watts)	Video Streaming Power (watts)	Connected Standby Power (watts)	Annual Energy Consumption (kWh/y)
Wii U	34	29	0.4	37
PS4	137	89	8.5	181
Xbox One	112	74	15.7	233

Our report includes several recommendations on how console manufacturers can bring down the energy use of these consoles, and many of the suggestions are readily achievable with software updates, modifications to setup screens, or minor hardware changes. We estimate these improvements could save another 25 percent beyond natural semiconductor efficiency trends. This would save American consumers $250 million annually in electricity bills and conserve enough electricity to power all the households in San Jose, the 10th-largest city in the United States.

Several of the biggest opportunities for manufacturers are these:

1. Reducing Xbox One power draw when in connected standby with voice command enabled.
2. Reducing PS4 power draw in standby with USB ports live (when no device is charging).
3. Reducing Xbox One TV-mode power, and giving users the option to watch TV when the console is off or in a very low-power state.
4. On both the Xbox One and PS4, reducing video-streaming power to levels closer to that of a dedicated video player.
5. Allowing users to opt out of "Instant On" and voice-command features in Xbox One's out-of-the-box setup menu, so they use this high-energy-consumptive mode only if they choose to.

STUDY OBJECTIVES

There are three major platforms of home video game consoles—Microsoft's Xbox, Sony's PlayStation, and Nintendo's Wii. Between 2005 and 2013, nearly 110 million video game consoles were sold in the United States, an average of nearly one per household. Internationally, there were an additional 140 million sold. Over that period, game consoles expanded beyond pure gaming to new functions such as streaming online video and music and playing DVDs and Blu-ray discs. In fact, some industry executives have claimed that media consumption has become the primary use of their consoles. These new usages have resulted in increased time powered on, performing other activities than playing games.

This trend in increased functionality has continued with the latest generation of consoles released in 2012 and 2013. At the end of March 2014, less than five months after launch, 10 million new generation PS4 and Xbox One consoles had already been sold globally. These two consoles represent the bulk of the new generation's energy consumption. Nearly 6 million Wii U consoles were also sold globally since their launch in November 2012. The new generation of game consoles reflects major redesigns of the hardware, software, and user interfaces and features. Some of these high-performance consoles also include voice and motion recognition, which can significantly increase energy use depending on how it is implemented.

As a follow-up to our initial study on video game console energy use performed in 2008[3], NRDC has conducted in-depth testing and analysis of the power draw and annual energy use of the new models released in November 2013, the Sony PlayStation 4 and Microsoft Xbox One, along with the previously released Nintendo Wii U.

NRDC's data-gathering and analysis focused on the following tasks:

- Measuring the power demand of each of the new consoles in their various operating modes—including game play, navigation mode, media streaming, and standby when the console is turned off—and comparing these to the power draw of earlier models (measurements were made with and without camera peripherals such as the Xbox One's Kinect).
- Estimating the energy consumed annually by each of the new consoles, based on projected usage patterns.
- Estimating the national energy consumption of these devices and the associated electricity costs and carbon pollution emissions their usage causes.
- Assessing the potential energy impact of setup screens and user menus, in particular what happens when the user does and does not turn off the console after play.
- Providing recommendations on software and hardware changes and updates that manufacturers can make to reduce the energy used by these devices.
- Estimating the savings that can be achieved if these recommendations are successfully implemented.

MODES OF OPERATION AND TEST METHOD

NRDC measured the power consumption of the three newest consoles in the six modes in which these devices typically spend the most time:

Mode	Definition
Navigation	Use of the menu screen to navigate among different functions
Game Play	Active use of a game program
Media - Video streaming	Viewing of a high-definition (HD) Netflix movie (streamed)
Media - TV mode	Use of the console to control the TV and view programs or the program guide from a cable, satellite, or telco set-top box (currently available only on Xbox One)
Connected Standby	"Sleep" mode, in which the console remains connected to the internet and can provide limited secondary functions such as charging of USB peripherals and reactivation via voice command (for Xbox One)
Off	Lowest power mode, in which the only function available is reactivation from the console's power button or controller

Other, secondary modes such as DVD, Blu-ray disc, music streaming, and video chat were not measured because they are less frequently used and represent a small fraction of console annual energy consumption. However, these modes were still accounted for in our annual energy consumption totals, using the same power levels as for the navigation mode.

NRDC took power measurements using the test procedure defined by the U.S. Environmental Protection Agency (EPA) for its Energy Efficient Game Console Recognition program v1.0 wherever applicable. For modes that were not covered by the EPA test procedure, such as game play and connected standby, we developed our own test procedures which are documented in the Appendices.

We used the game titles indicated in the table below for our power measurements. The game sample represents a diverse selection of publishers, types of games, and native resolutions, selected out of the relatively limited set of game titles available at launch.[4]

	Title	Publisher	Native Resolution	Output Resolution
Wii U	Super Mario Bros	Nintendo	720p	1080p
	Assassin's Creed III	Ubisoft	720p	1080p
	The Legend of Zelda: The Wind Waker	Nintendo	1080p	1080p
PS4	Knack	Sony	1080p	1080p
	Assassin's Creed IV: Black Flag	Ubisoft	1080p	1080p
	Killzone: Shadow Fall	Sony	1080p	1080p
Xbox One	Just Dance 2014	Ubisoft	480p	1080p
	Call of Duty: Ghosts	Activision/ Infinity Ward	720p	1080p
	Assassin's Creed IV: Black Flag	Ubisoft	900p	1080p
	Forza Motorsport 5	Microsoft/ Turn 10 Studios	1080p	1080p

Video streaming measurements were made using the movie Gasland (2010), streamed from Netflix in "Full HD" (1080p) for all three consoles.

Notes on power measurements:

Peripherals: All consoles were tested with and without the motion-sensing and voice-recognition peripherals Xbox One Kinect, PS4 Camera, and Wii U Sensor Bar. Xbox One and Wii U are shipped with these peripherals, whereas the PS4 camera is an aftermarket accessory. However, for the sake of fairness, we compared all consoles with these peripherals connected.

Units tested: The units tested were retail launch models with system updates up to mid-April 2014. We also expect future hardware and software updates to impact consoles' energy consumption. The effects of any system updates and hardware improvements released after that date are not reflected in this report. Two PS4 units were tested and a 4 percent difference in power was found between them, indicating significant power variability between units. Power measurements in this report should therefore be taken as indicative, not as the average of all units sold.

RESULTS

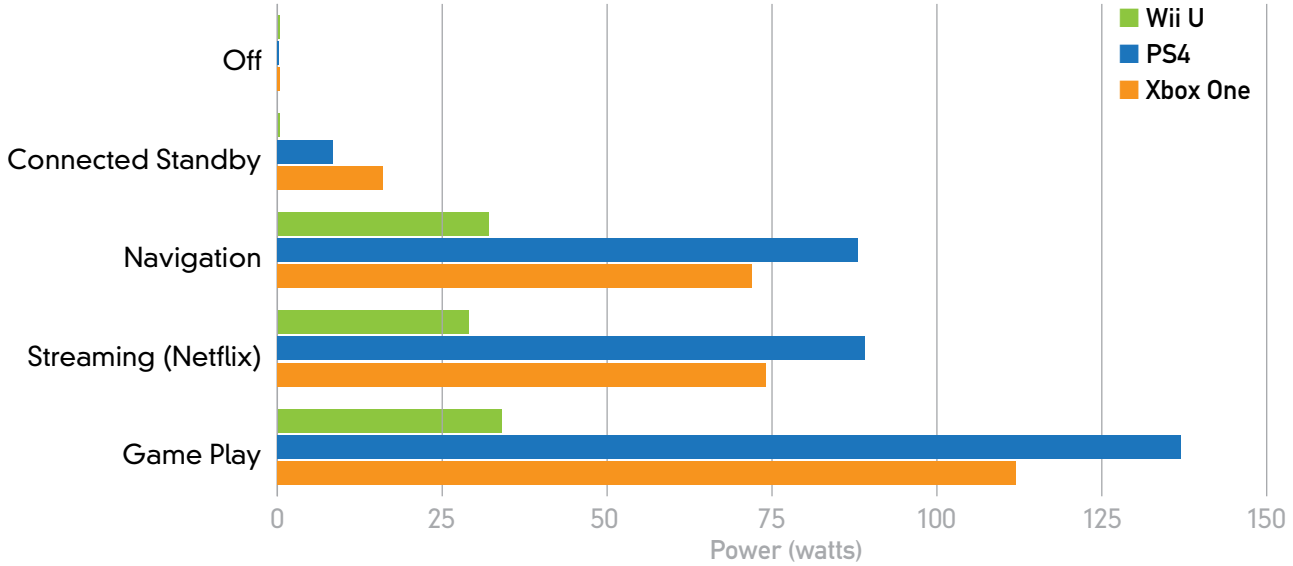
POWER DEMAND

The results of NRDC's testing are presented below in both tabular and graphic form. NRDC's testing reveals that PS4 and Xbox One consume roughly three times as much power as Wii U to play games and video, and that PS4 draws 20 to 25 percent more power than Xbox One. The game play power numbers for the Xbox One and the PS4 include usage of the Kinect and Camera accessories, respectively.

Table 1: Power consumption in the most common operating modes

Power (watts)	Wii U	PS4	Xbox One
Game Play	34	137	112
Video Streaming (Netflix)	29	89	74
Navigation/ TV mode	32	88	72
Connected Standby	0.4	8.4	15.7[5]
Off	0.4	0.3	0.4

Figure 1: Power consumption in the most common operating modes



The power consumption of game consoles depends on multiple factors, including performance capabilities, efficiency of the hardware components (such as the CPU, GPU, and power supply), hardware architecture, and power management of the components (i.e., reducing or increasing the power demand of each component in the system depending on the task being performed).

Part of the variation in power consumption among these three products appears due to differences in performance capabilities. While it is clear from technical specifications (processor cores, memory, and so on) that the PS4 and Xbox One deliver significantly higher performance than Wii U, the hierarchy is less obvious between PS4 and Xbox One. PS4 has faster memory (GDDR5 at 5500 MHz) than Xbox One (DDR3 at 2133 MHz), and a more powerful graphics processing unit, but Xbox One has a different memory architecture, with 32 MB of embedded SRAM on die, which may partly compensate for the

difference.[6] Xbox One also offers more advanced voice and gesture recognition capabilities than PS4. Xbox One is the only console to offer voice command in connected standby mode, the mode the console may go into when it is switched off or when it automatically powers down after extended inactivity. The PS4 is capable of charging controllers through its USB ports from connected standby, albeit at a hefty power penalty of 5 watts around the clock, just to be ready to charge. Xbox One can charge some USB peripherals from both connected standby and off modes, but not the Xbox One controller. Wii U does not offer any USB charging from off mode.

In the absence of a standard benchmark to compare console performance, NRDC presents results without attempting to normalize power consumption by performance capability.

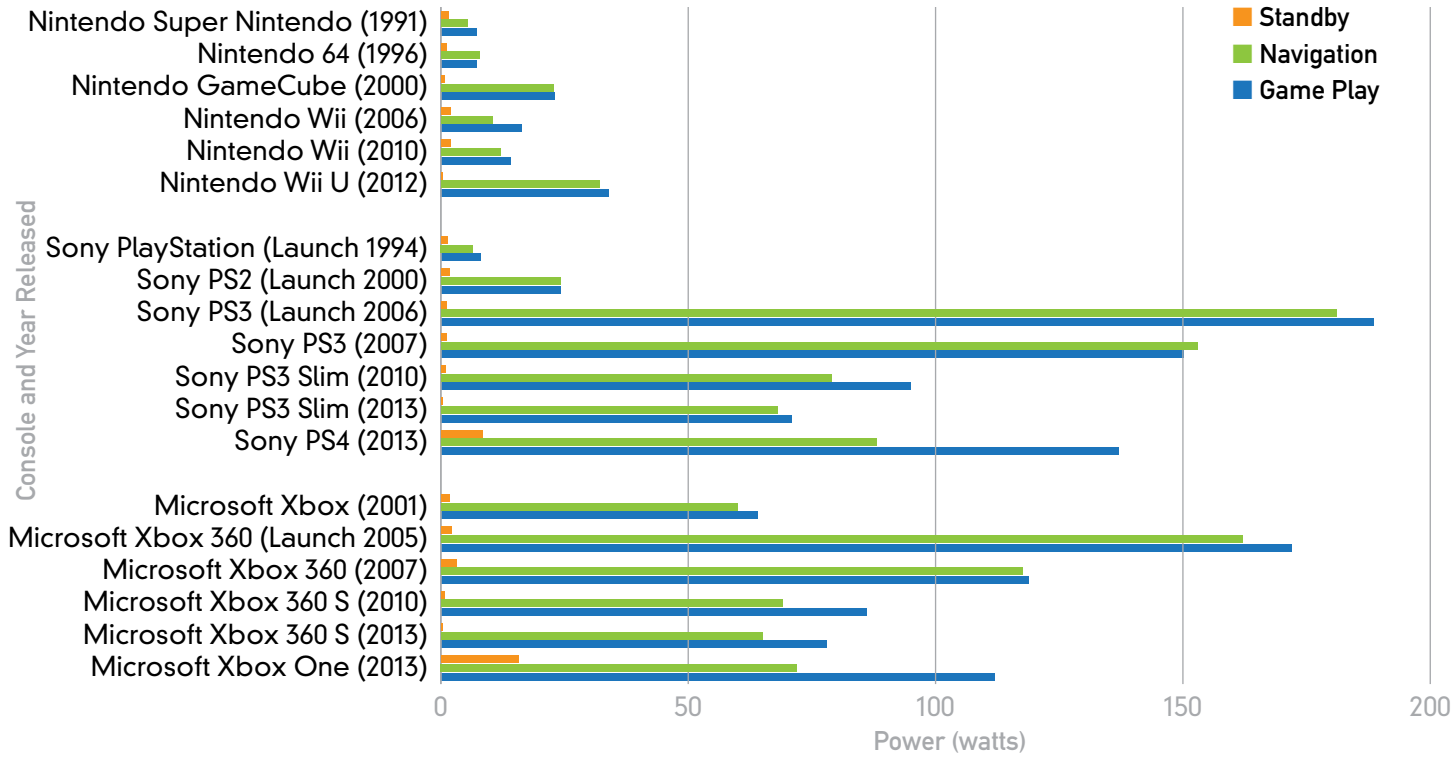
History of Game Console Power Demand

The power demand of the PS4 and Xbox One in gaming and navigation modes is lower than that of the launch models of their predecessors, the PS3 and Xbox 360, but significantly higher than that of the latest versions of their predecessors (up to 90 percent higher for PS4). Wii U power demand is higher than both the launch and latest versions of its predecessor the Wii. Two factors should be kept in perspective when comparing the launch models of the new generation with the latest versions of their predecessors:

1. The new consoles have higher processing and graphics performance than their predecessors—by a factor of roughly 10, according to one manufacturer.
2. The energy efficiency of the previous generation has been improved progressively over the six to seven years since their launch, whereas the new consoles have not yet been fully power-optimized.

For example, the data in Figure 2 show that: a) the 2013 version of the PS3 drew roughly 70 watts to play a game, whereas it takes 137 watts to play a corresponding game with the new PS4 at launch, and b) the PS3 when first launched in 2006 drew 180 watts in navigation mode, but power was reduced to 68 watts within several revision cycles.

Figure 2: History of video game console power



ANNUAL ENERGY CONSUMPTION

NRDC estimated the annual energy consumption of game consoles, expressed in kilowatt hours per year (kWh/y), by multiplying the average time spent in each mode each year (hours) by the power consumption of each mode (watts). NRDC's average usage assumptions are represented below and explained in detail in Appendix 2.3.

While devices are able to go into low-power off mode and draw less than 1 watt, in the United States they will instead spend most of their time when not in use in connected standby mode, drawing significantly more power, because this is how they are configured by default. In developing our usage (duty cycle) scenarios, we assumed that 90 percent of users would retain the default connected standby configuration and 10 percent would switch to off mode. This translates to 18–19 hours per day in connected standby and roughly 2 hours per day in off mode.

Figure 3: Usage assumptions PS4 and Wii U
(average daily usage)

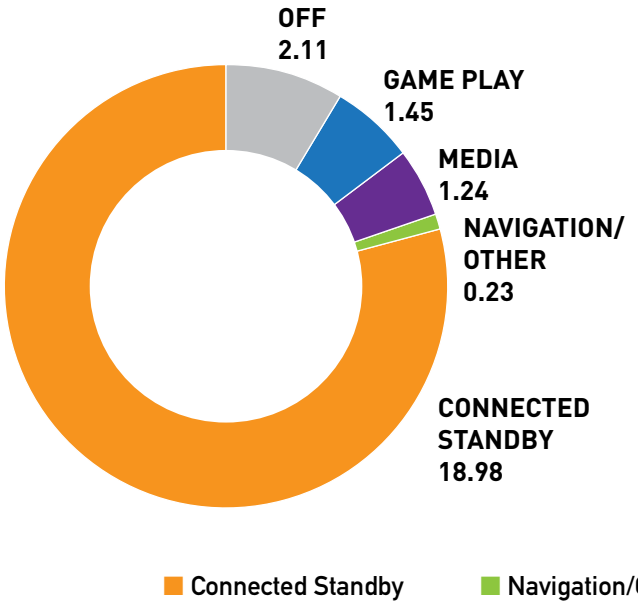
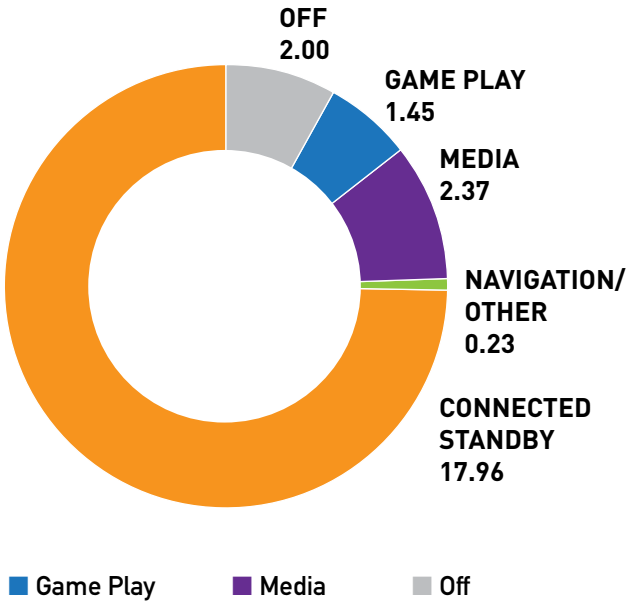
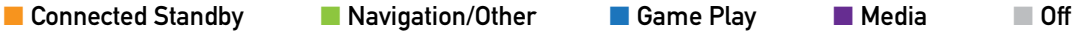


Figure 4: Usage assumptions Xbox One
(average daily usage)



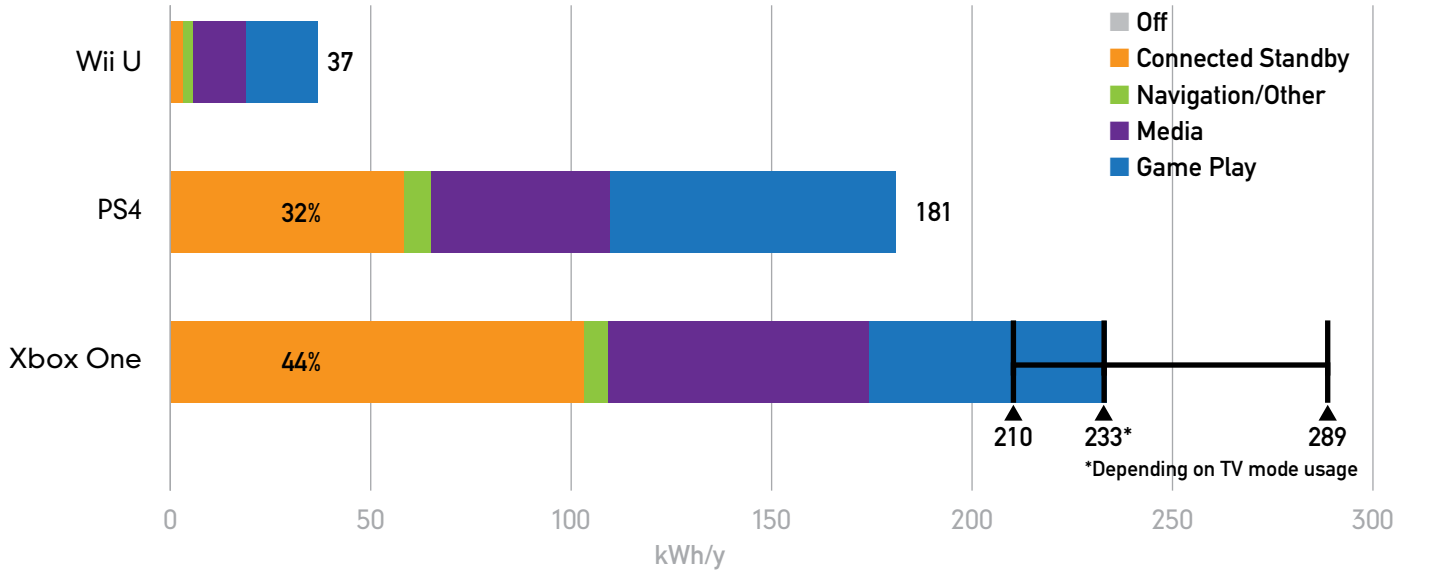


The duty cycle used for Xbox One was different from the one employed for Wii U and PS4 because of the Xbox One's TV mode. If the Xbox One is set up for TV watching, the console must remain on as long as the TV is on (as explained below), which increases the average time the console spends in media mode to five hours, the average time Americans watch TV daily. However, not all owners use this TV mode. We assumed 30 percent usage, which yields 2.4 hours media mode (video and TV) per day on average.

Putting it all together, the Xbox One consumes 233 KWh/y on average, the PS4 181 kWh/y, and the Wii U 37 kWh/y. The Xbox One's annual energy consumption is therefore roughly 30 percent higher than the PS4's, on average, and more than six times higher than the Wii U's.

While Xbox One's annual energy consumption is 210 kWh/y when the console is not configured to watch TV, it jumps to 289 kWh/y when it is so configured. And since Americans watch TV for an average of five hours per day, if 30 percent of users configure their Xbox One to view TV, the average Xbox One annual energy consumption weighted across all users is 233 kWh/y.

Figure 5: Annual energy consumption

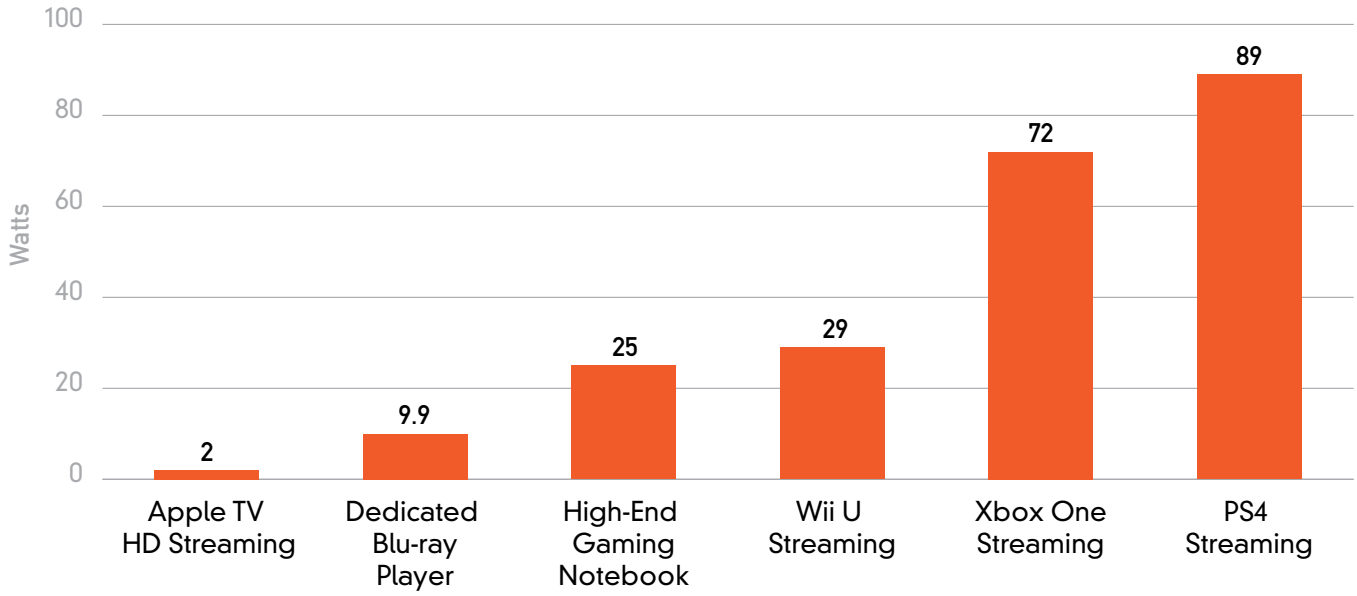


After testing these devices and analyzing the data, we made the following observations regarding the consoles' features and energy use:

1. Power Scaling: The new PS4 and Xbox One consoles are much better at power scaling than their predecessors. Power scaling represents the ability of a device to draw only as much power as the task at hand requires. This is best demonstrated by the 40 to 50 percent difference between the maximum power consumed in game play and the lowest active mode (navigation). Prior-generation consoles were able to reduce power by only about 25 percent between highest and lowest active modes. This represents good progress, but power scalability can be taken much further, as evidenced by gaming notebook computers that can scale power by as much as 80 percent.[7] Wii U only scales power by 15 percent, but draws much lower power in all active modes than PS4 and Xbox One.

2. Video Streaming: As noted previously, video streaming represents a growing share of consoles' active use time and annual energy consumption. While new consoles better adjust their power demand to the intensity of the task they perform, they still consume 30 to 45 times as much power to stream an HD movie (1080p) than the most efficient video players on the market, such as the Apple TV and the Google Chromecast, which can both play HD video at less than 2 watts. This reflects the fact that the consoles' hardware architectures, which are designed primarily for high-performance gaming, are not optimized for video streaming. Alternative approaches include implementing hybrid architectures in which a dedicated processor is used for video streaming; using add-on devices that can stream video without the console being on; or further increasing the power-scaling ability of the current consoles.

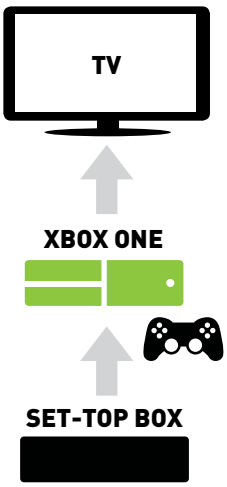
Figure 6: Power draw during HD video play (1080p)



3. TV Mode: One of the biggest factors impacting the annual energy consumption of the Xbox One is whether it is configured to watch TV. The energy impact of TV mode is determined by the setup of the console: If users set up their console to lay between their set-top box and their TV so that they can use Xbox One's TV mode, the Xbox One needs to be on any time users want to watch TV; it becomes essentially a second set-top box, adding 72 watts of power consumption to TV viewing. The only way to avoid this extra energy consumption is to set up the Xbox One on an HDMI port different from the one used by the set-top box, in which case users can never use Xbox One's TV mode. Unfortunately, Microsoft's setup instructions encourage users to configure their consoles in the high-energy TV mode without warning them of the energy impacts.

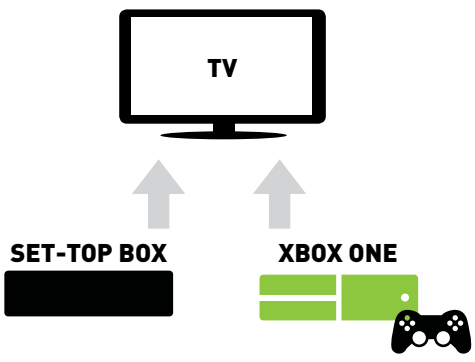
Microsoft's Recommended Setup

Allows TV viewing through Xbox One, but requires Xbox One to be on all the time you watch TV, adding 72 w to TV viewing.



Traditional Energy Saving Setup

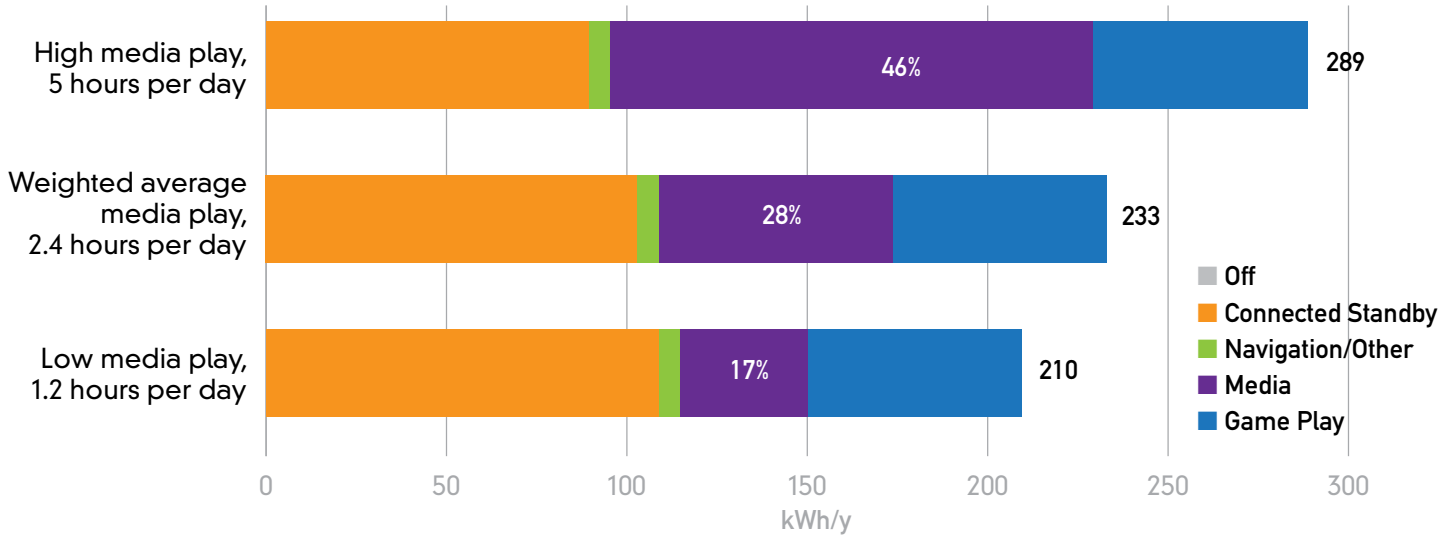
Does not require Xbox One to be on to watch TV, but does not allow use of Xbox One's TV viewing mode.



The use of Xbox One to control a TV by voice command or with the game controller—to switch it on and off, change channels, or view the program guide—can add 79 kWh to the console's annual energy consumption. TV mode and video play together represent up to 134 kWh/y, or 46 percent of annual energy consumption. This may exceed the annual energy used by the new big-screen TV to which it is connected.

The following chart illustrates three scenarios for TV watching: 1) The Xbox One is set up as a TV controller and is active in TV mode an average of five hours a day. 2) The Xbox One is set up just to watch videos, as with the PS4. 3) In a blended scenario, we assume 30 percent of console owners set up the console as a TV controller and 70 percent do not.

Figure 7: Xbox One TV mode scenarios



If all Xbox One users in the United States watched TV through their Xbox One, their consoles would consume 3 billion kWh annually in this TV mode alone, the equivalent annual output of a large, 500-megawatt power plant—enough electricity to power all the households in Boston for a year. This one feature by itself would cost American consumers an extra $300 million dollars' worth of electricity every year.

We urge Microsoft to improve its implementation of TV mode so consumers who use this feature do not need the Xbox One to stay on all the time to watch TV. This would allow users to save energy by using Xbox One's TV mode when they choose to, not all the time that the TV is on.

4. Connected Standby: Connected standby mode represents nearly half of Xbox One's annual energy consumption, and one-third of PS4's. In connected standby, the console is off but remains connected to the network, is able to wake up quickly, and provides some limited other functions such as USB charging, and voice recognition (Xbox One only). In this mode, Xbox One draws 15.7 watts and PS4 draws 8.5 watts, compared with less than 1 watt previously.

This may not seem like much compared with active power, but when multiplied by approximately 20 hours a day, it is responsible for a large share of the annual energy consumption of the Xbox One. Contrary to the previous-generation consoles, both Xbox One and PS4 are now shipped in the United States with connected standby enabled by default, and users are not even given the chance to opt out in the initial console setup. Connected standby can still be disabled in the power settings menu; however, we expect that few users do so. Interestingly enough, in Europe, because of the European Union's standby regulation, Xbox One is shipped with connected standby disabled by default; users have to opt in to enable it.

Default standby configuration of Xbox One

Standby configuration on PS4

Users can switch from connected standby (called "Instant-on" on Xbox One) to "Energy Saving" mode by clicking on the "Power Mode, Instant-on" block of text. However, the user interface on the launch model is not intuitive: There is no check box to indicate that this text is clickable, further discouraging users from choosing the energy-saving mode.

Much of Xbox One's connected high power draw may be due to the console's listening for voice commands: You can wake it up just by saying "Xbox on." But does Xbox One really need to listen for your voice command 24/7, even when you're asleep in the middle of the night, out of the house during the day, or away on vacation? Perhaps voice command could be made to power down automatically after a certain length of time, until the consumer wakes it up with the controller or power button, like Amazon's Fire TV, which offers voice command in standby for less than 3 watts. Microsoft could also allow users to program times when they want the box to be listening, or even make it "smart" so it learns when you're likely to be home and goes to sleep automatically when you're not.

PS4 also offers users the possibility to change what the console does in standby mode. By default in the United States, PS4 is configured to be connected to a network and to be able to charge USB devices from standby mode. In the European Union, PS4 is shipped with both network connection and USB charging disabled, due to the EU's standby regulations.

5. USB Charging from Standby: Is this an efficiency friend or foe? As just mentioned, PS4 offers an option to "Supply Power from USB Ports." This allows users to charge their controllers and headsets when the console is in connected standby mode. This feature can save energy because it removes a reason why users might want to leave their console on after they have finished using it (if users forget to turn off their console when they are done and the auto power down feature is disabled, the console will stay in on mode and draw 90 to 140 watts continuously). However, this feature adds 5.5 watts to connected standby (using 8.5 watts instead of 3 watts), **meaning that it is responsible for more than half of PS4 standby power**. USB charging is enabled by default and may consume more energy annually than it saves. Other products, such as some laptops, are able to keep their USB ports live and ready to charge for less than 1 watt. To deliver on its promise to save energy by allowing users to power down after they have finished playing, USB charging from off mode needs to draw no more than 1 watt additional power in standby when no USB devices are actually charging.

Xbox One has live USB ports in both off and connected standby modes. However, the Xbox One controller cannot charge in these modes. This defeats the purpose of this feature and will lead some users to keep their console on just to charge their controller, wasting a lot of energy in the process.

The Wii U demands less than 1 watt in connected standby. In this mode, it is able to wake up, check for software updates, download and install any updates, and go back to standby. This is best practice and is achievable on the other two consoles.

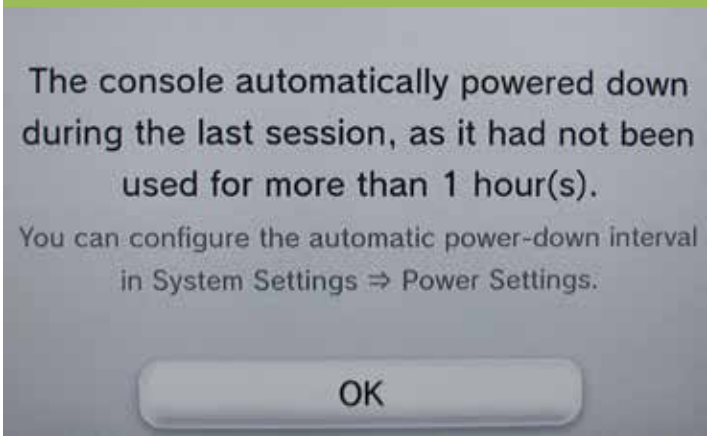
6. Off: Both the PS4 and Xbox One have real off modes that consume less than 1 watt, but unless users disable the connected standby mode in the settings menu, the consoles will never enter real "off" mode. For modeling purposes, we assumed that 10 percent of users disable connected standby, which corresponds to consoles spending approximately 2 hours per day in off mode on average.

7. Auto Power Down (APD): All three consoles are shipped configured to power down automatically after an extended period of user inactivity. If users forget to switch off their console after they have finished using it, the console will go to standby rather than continue to gulp energy all night or even for days. We welcome this feature, which can save large amounts of energy as long as users don't disable it. The Xbox 360 launch model was shipped with this feature disabled, the PS3 did not have this feature at launch but implemented it partially later on, and the Wii never had it.

We noticed two improvement opportunities regarding auto power down:

- On the PS4, the default two-hour setpoint for inactivity is longer than necessary. One hour would be a good compromise between energy savings and user convenience.
- The Wii U implementation keeps displaying annoying messages reminding the user that APD is enabled, which could lead many users to disable it in order to avoid the messages. It does not display similar messages to remind users that APD is disabled!

Wii U: Auto power down notification



NATIONAL IMPACT

The PS4 and Xbox One individually may cost consumers roughly $150 in electricity bills over a five-year life, depending on usage. Once new consoles have replaced the 110 million units currently installed in the United States—and even taking into account potential efficiency gains of up to 50 percent over the life of this generation of console, as was the case for the previous generation—the energy consumption of America's game consoles will cost consumers $1 billion in electricity bills, topping 10 billion kWh annually. This is equivalent to the annual output of four medium-size (500-megawatt) power plants, enough to power all the households in Houston, the fourth-largest city in the nation.

NRDC RECOMMENDATIONS AND PRIORITIES FOR ENERGY SAVINGS

Sony and Microsoft have made significant progress on game console energy. The new generation consoles were designed to be more efficient than the launch models of the previous generation, and the new hardware and software include many features that limit the increase of energy consumption despite offering much higher performance than their predecessors.

What They Got Right			
	Wii U	**PS4**	**Xbox One**
Connected standby power	✔ Connected standby mode draws less than 1 watt	✔ Connected standby draws only 3 watts (with USB charging disabled) ✔ USB charging from connected standby mode: removes reason to leave console on just to charge peripherals	✔ Quick game resume (Beta): removes reason to leave console on to avoid longer game-resume times
Active mode power	✔ Active modes draw less than 35 watts	✔ Better power scalability (reduction from highest to lowest active power): roughly 50% versus 25% for PS3 ✔ Navigation inactive: PS4 sheds 12 watts after 10 min. inactivity in navigation mode	✔ Better power scalability (reduction from highest to lowest active power): roughly 40% versus 25% for Xbox 360 ✔ Power in active modes not much higher than most recent Xbox 36 ✔ TV dimming: dims TV after 10 min. inactivity, saving roughly 50% of TV power
Auto-power down	✔ Auto power down in all active modes	✔ Auto power down in all active modes	✔ Auto power down in all active modes

Still, much more can be done to dramatically reduce console energy consumption. Manufacturers understandably focused most of their launch efforts on getting the consoles working, not on optimizing energy efficiency. There are many opportunities left to dramatically reduce the consoles' energy consumption and the earlier the better, so consumers who buy these consoles over the next year or two can benefit from these improvements.

We expect the energy consumption of the new generation of game consoles to go down progressively over time due to the natural trend in semiconductor "die shrink," the reduction in size and corresponding increase in efficiency of semiconductor circuits. However, semiconductor efficiency is only one factor in the efficiency of the overall device: Hardware architecture, system on chip optimization, software optimization, and power management of components are other major opportunities to cut energy waste. They are the main reasons why mobile devices such as phones, tablets, and even laptop computers are so much more energy efficient than stationary devices.

Game console manufacturers can leverage the same design best practices to reduce console energy consumption beyond natural die size reduction. They should do so as soon as possible, before too many units of the current models are sold and lock in high energy consumption for consumers for the next five years. As of January 18, 2014, just two months after their release, 8 million PS4 and Xbox One consoles had already been sold globally. Just these two months' worth of sales will consume 8,000 gigawatt-hours of electricity and be responsible for the emissions of 3 million metric tons of CO_2 over the life of the consoles. **Much of that energy will be consumed when no one is using the console but it is still listening for a voice command in the middle of the night and using higher power than necessary to keep USB ports active.**

Here are NRDC's priorities for manufacturers to optimize the efficiency of their consoles:

Energy Efficiency Improvement Opportunities			
	Wii U	**PS4**	**Xbox One**
Connected standby power	Enable USB ports in standby mode so users don't disable APD to charge their devices	Reduce incremental power for USB charging in standby modes to 1 watt or less (when no device is charging)	Reduce energy consumption of connected standby with voice command Allow USB charging of controller from connected standby and off modes so users don't disable APD to charge their devices
Active mode power		Reduce video streaming power to levels closer to those of efficient video players	Significantly reduce TV mode power Allow passive HDMI pass-through, so that TV mode users can watch TV without requiring console to be on
Auto-power down	Eliminate user notifications on auto power down so users aren't encouraged to disable that feature	Change default APD settings for U.S. to 1 hour for gaming/general and 10 minutes for controller	
Setup			Provide opt-out for "instant on" and voice command features in initial setup menu Improve user interface on settings screen to facilitate opt-out from connected standby

Some of these recommendations only require settings or user interface changes; they can be implemented rapidly on new products and even on existing products via software updates. Others require hardware design changes and will require more time, but work should start on them as soon as possible.

APPENDIX

Mode Definition and Test Method		
Mode	**Definition**	**Test Method**
Game Play	Active playing of games	Natural game play over a period of 20 minutes for each game, average power over three of the most popular game titles for each console[8]
Media - Video Streaming	Viewing of a high-definition Netflix movie	Average over 5 minutes; same HD movie for all three platforms
Media – TV mode	Watching pay-TV through Xbox One	Average over 5 minutes
Navigation	Menu screen	Average over 5 minutes
Connected Standby	Standby (sleep) mode, in which console remains connected to internet and has other functions active per default settings, such as voice command recognition for Xbox One and USB charging for PS4	Average over 5 minutes
Off	Mode in which the only function available is reactivation via the power button or the controller	Average over 5 minutes

Performance and Feature Comparison			
	Wii U	**PS4**	**Xbox One**
System Memory Bandwidth[9] (Proxy for Performance)	12.8	176	102
Resolution	1080p	1080p (specified as 4K through upscaling, but not verified)	1080p (specified as 4K through upscaling, but not verified)
Voice Recognition	No	Yes, in active mode	Yes, in active and connected standby modes
Gesture Recognition	Through "Wii motes" and Wii U Sensor Bar	No	Advanced gesture recognition via Kinect
USB Charging in Connected Standby	No	Partial, connected standby mode, not off mode	Yes, connected standby mode and off mode, but not for the controller.

USAGE ASSUMPTIONS

There is little publicly available data on the average usage of game consoles across all users in the United States. Manufacturers collect some usage data via their online services; however, they do not generally make it publicly available.

A recent paper (Webb, 2013)[10] estimates an average of 1.9 hours of use per day, based on four studies. Each of the four studies was partially metered, but only one of them, Intertek/DEFRA 2012, gives the size of the metered sample and makes the results available. We do not know the metered sample size for the others and are unable to check the data to ensure they are appropriate for the intended purpose (such as type and vintage of consoles). The Intertek study finds an average of 2.3 hours of active use per day. A U.S.-based study (Bensch et al., 2010)[11] also provides the size of the metered sample and the results, and finds an average active use of 2.3 hours per day.

While both of these studies have small sample sizes, they are the only verifiable sources of metered data that NRDC is aware of at this time and were therefore used for NRDC's energy estimates of Generation 7 consoles (PS3, Wii, and Xbox 360).

No usage data are available for Generation 8 consoles (PS4, Xbox One, Wii U), so NRDC estimated an active usage 25 percent higher than in the previous generation (outside of TV mode), to account for new functionality available on the new consoles. For Xbox One's TV mode, NRDC assumed that 30 percent of consumers would use their Xbox One to control their TV. Based on an average of five hours of TV watching per day in the United States, we increased Xbox One active time to account for 30 percent of users watching TV and video for five hours per day, and the remaining 70 percent watching only video for the same length of time as PS4. This may be an underestimate, because setup instructions encourage users to set up the console in TV mode. However, anecdotal feedback suggests that a significant number of users don't, perhaps because they don't want to have the Xbox One on every time they watch TV. To err on the side of caution, we assumed less than half of users set up their Xbox One for TV mode.

It is important to note that there is a high level of uncertainty around console usage; it probably varies by console and over time as new applications, game titles, and video programming become available. NRDC's usage assumptions are meant to be a reasonable estimate, not a definitive representation.

GAME PLAY TEST PROCEDURE

This test procedure complements the test procedure in EPA's Energy Efficient Game Console Recognition program v1.0. It specifies how to measure console power in game play mode, which is not covered by the EPA test method in the v1.0 program.

Preparation: The test technician should be familiar enough with each game title to be able to advance in the game at a reasonable pace (so that he/she does not have to learn the game while testing). In case the test technician is not familiar enough with the game, he/she shall train by playing for one hour in order to be sufficiently familiar with it before starting the test.

Game title selection: Select three of the most popular games for each game console.

Test Procedure

A. Load a game title.

B. Let console warm up/cool down in navigation mode for 10 minutes.

C. Launch game.

D. Start metering after game loading and initial cut scenes are finished. Set the meter to begin accumulating true power values at intervals of one reading per second.

E. Play game normally (with the objective of advancing in the game). Do not pause game or leave it inactive during measurement period.

F. Accumulate power values for a minimum of 20 minutes, and record the average (arithmetic mean) value along with game title.

G. Repeat for each of the 3 game titles selected.

H. Calculate and record the arithmetic average of results for the three game titles.

CONNECTED STANDBY TEST PROCEDURE

This test procedure complements the test procedure in the EPA's Energy Efficient Game Console Recognition program v1.0. It specifies how to measure console power in the connected standby mode, which is not covered by the EPA test method in the v1.0 program.

Test Procedure

A. Place the console in network-connected standby mode with all other options as configured by default as the console is shipped.

B. Set the meter to begin accumulating true power values at intervals of one reading per second.

C. Accumulate power values for a minimum of five minutes, and record the average (arithmetic mean) value along with mode name and description.

Endnotes

1 Noah Horowitz, *Lowering the Cost of Play*, NRDC Issue Paper, November 2008, http://www.nrdc.org/energy/consoles/files/consoles.pdf.

2 Measurements include the consoles' motion and voice sensing devices, Kinect, PS Camera and Wii U Sensor Bar.

3 Noah Horowitz, *Lowering the Cost of Play*.

4 Native resolution is the resolution a game is rendered at before any potential upscaling.

5 Measurement was 17 watts at launch. This lower figure reflects improvements made by Microsoft in its March 2014 system update.

6 Anand Lal Shimpi, *The Xbox One: Hardware Analysis & Comparison to PlayStation 4*, Anandtech, May 22, 2013, www.anandtech.com/show/6972/xbox-one-hardware-compared-to-playstation-4/3.

7 Intertek, *Building on the Eco-design Directive, EuP Group Analysis (1), ENTR Lot 3 Sound and Imaging Equipment*, Report to the European Commission DG ENTR – AEA/ED45386, Issue 1, November 2010, Table 69.

8 They were different games on each platform because there is no common game available across all platforms.

9 Rate at which data can be transferred between the processor and the system memory. Product of the memory clock frequency (in gigahertz) and memory bus width (in bytes).

10 Amanda Webb et al., "Estimating the Energy Use of High Definition Games Consoles," *Energy Policy* 61 (2013): 1412-1421.

11 Ingo Bensch et al., *Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes*, Energy Center of Wisconsin, May 2010.

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