Power Consumption of Video Game Consoles Under Realistic Usage Patterns

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Summary

Video game consoles are becoming increasingly common in living rooms around America and can consume large amounts of electricity when in use. There have been a few studies in recent years examining the energy consumption of video game consoles, but bottom line figures rely strongly on assumptions about how the game consoles are used, and many of the assumptions used in earlier work are not in agreement with recently published usage patterns. This study merges the power consumption data from earlier work with newer video game console usage information to produce more accurate figures describing the overall energy use of video game consoles. By using more accurate data, this study comes to notably different conclusions than previous investigations.

Previous work has overlooked both the effect of the WiiConnect24 service and the fact that the average Wii is used three times less than an average Xbox 360 or PS3. Taking these into account, the electricity consumption per hour of active use of the Nintendo Wii console is actually much higher than previously assumed and is higher than both the PS3 and the Xbox 360 under most reasonable scenarios.

The WiiConnect24 service, which is active by default for a Wii console connected to the Internet, greatly increases the standby power of the Wii from 2 Watts to 9 Watts. Since most Wii consoles have been connected to the Internet, it is possible that the majority of Wii consoles have this service enabled. Taking the usage of the consoles into account, it is shown that the average Wii (with WiiConnect24 enabled) uses 550 Wh of electricity for each hour of use, which is significantly higher than the figures for the currently-available Xbox 360 (125 Wh per hour of use) and PS3 (107 Wh per hour of use) consoles. Additionally, the average Wii (with WiiConnect24 enabled) consumes 97% of its electricity when it is in standby mode, versus 10 - 30% for the other consoles. Even with WiiConnect24 disabled, the average Wii consumes approximately the same amount of electricity for each hour of use as currently available models of PS3 and Xbox 360.

Of most importance for consumers, it is shown that the total energy consumption of any of the video game consoles is small compared to the average residential electricity load, as long as the console is powered down when not in use. Even the console with highest annual electricity consumption, a launch-model Xbox 360, accounts for only 1% of average residential electricity consumption under average usage patterns (or 2% if a 150W HDTV is also included). But if left on continuously, the same console would account for 15% of the average electricity load (25% with an HDTV left on as well). Additionally, the cost of electricity to operate a console is shown to be negligibly small compared with the cost of the system, games, and peripheral devices.

Even though the current-generation consoles differ in their services and energy use, their effect on total electricity use is quite small as long as they are powered down after use. Thus, gamers interested in reducing their energy use should concern themselves with more prominent energy use (such as transportation, heating/AC, or lighting), rather than fret over which video game console to purchase.

Introduction

Approximately 185 million current-generation video game consoles (Nintendo Wii, Microsoft Xbox 360, and Sony Playstation 3) have been sold worldwide through 2010, with US console sales accounting for 90 million units (VGChartz, 2010). The power consumption of a single console can be more than 100 W when in operation and there have been several studies looking at the consequences of this electrical load, both for an individual consumer of electricity and for the nation as a whole (Natural Resources Defense Council, 2008) (Electric Power Research Institute, 2010). An Electric Power Research Institute (EPRI) analysis concluded that the Nintendo Wii was by far the most efficient current-generation console. A Natural Resources Defense Council (NRDC) study, which assumed that half of all game consoles were left on 24 hours a day, calculated that gaming consoles in the US consumed 16 billion kWh of electricity annually - roughly the same consumption as the city of San Diego.

But energy consumption calculations for game consoles are highly sensitive to assumptions made regarding the modes and amount of console usage. Recent console usage data from The Nielson Company, coupled with more realistic assumptions regarding console settings, allow for a clarified picture of energy consumption of video game consoles which challenges some of the conclusions of previous studies.

The power consumption of video game consoles differs greatly across the three current-generation consoles. But even for a single console, there are variations across hardware revisions, console tasks, and due to manufacturing variability of individual consoles. For example, an EPRI report states that the newest revision of the PS3 hardware consumes 85 W of power when in use, down from 150 W for the original hardware (Electric Power Research Institute, 2010). A study performed by the Natural Resources Defense Council found that the power consumption of an Xbox 360 was 30% lower when playing a DVD versus a video game, and that power consumption was found to vary by 10% across different games played on the same game console (Natural Resources Defense Council, 2008). All three systems have standby modes that consume power when not in use. This power consumption, also known as "vampire power" or "phantom load", can account for a large fraction of the energy used by consumer electronics under some usage patterns.

The three current-generation video game consoles do not offer exactly equivalent services. Each of the systems offer differing performance capabilities for games and media. The PS3 and Xbox 360 have similar technical performance and many multi-platform games offer essentially the same experience on these platforms. The Wii has a notably lower processing capability and games that run on the other systems must be modified for its more limited capabilities. In addition to games, each of the systems have multimedia capabilities such as playing DVDs (Xbox 360 and PS3), playing Blu-Ray movies

(PS3), and streaming Netflix video (all three systems). The Nintendo Wii has included motion controls since its launch in 2007 (all three systems now have a form of motion control available), though does not support high definition video. While the PS3 and Xbox 360 offer similar functionality, it is important to remember that each system is different and direct "apples to apples" comparison is not possible in all respects.

Power Consumption Model

The power consumption data used in this research are shown in Table 1. While minor hardware improvements have decreased the power consumption of all three systems over time, the PS3 and Xbox 360 have each gone through a major hardware revision, which has greatly improved the energy efficiency of the device. As a result, these consoles are divided into two categories, representing systems before and after the major hardware revision. As of 2010, the majority of PS3 and Xbox 360 consoles are of the original design, but only the newer models are available for purchase. The Nintendo Wii has a feature called WiiConnect24 which allows the console to receive messages and content updates while the system is powered down. Importantly, this feature is "on" by default for a Wii system that has been connected to the Internet and greatly increases the standby power of the device from 2 W to 9 W. Since the majority of Nintendo Wii consoles (54%) are connected to the internet, and WiiConnect24 is enabled by default, it is reasonable to assume that up to half of all Wii consoles have this service turned on (The Diffusion Group, 2010). For ease of comparison, the WiiConnect24 powered-down state is taken as the "Standby" state for that system, but it should be noted that more services are being provided than in a normal standby mode.

Table 1: Power consumption of current-generation video game consoles, for both active use and standby mode. Active mode is defined as actual use of the console (for playing a game, viewing media, etc.) while standby is the state where the console is shut down (no video output) and awaiting a signal to begin interaction with the user. The Xbox 360 and PS3 have been divided into pre- and post-hardware revision models, due to much lower power consumption. The Nintendo Wii is shown with WiiConnect24 both enabled and disabled, since the two states have very different electricity consumption in standby mode.

Console	Active Power (Watts)	Standby Power (Watts)
Original PS3	189[a]	1.1[a]
PS3 Slim	85[b]	0.5[c]
Original Xbox 360	172[a]	2.2[a]
Xbox 360 S	88[b]	0.7[c]
Nintendo Wii (WiiConnect24 Enabled)	16[a]	9[d]
Nintendo Wii (WiiConnect24 Disabled)	16[a]	1.9[a]

[a]*Source: Lowering the Cost of Play, Natural Resources Defense Council, Nov. 2008*

[b]*Source: Power Play: EPRI Analysis Reveals That Video Game Consoles Differ in Energy Consumption, Electric Power Research Institute, Dec. 2010*

[c]*Source: Green Gaming with Xbox 360/PS3, Gamespot, March 2011*

[d]*Source: XBOX 360 vs PS3 (and Wii) - Power Consumption Report, Hardcoreware.net, Feb. 2007*

A recent Nielson Company study of game console usage highlights the differences in the functionality of the three different video game consoles (Nielson Company, 2010). This study states that the average Nintendo Wii console is used about one third as much as a PS3 or Xbox 360. The console usage reported in the Nielson study and used in this paper can be found in Table 2. Nielson reports usage per console user, not per console, so an assumption about users per console must be made. This model assumes an average of two users per console, but this figure can be varied between one and four users per game console with little effect on the qualitative conclusions.

Table 2: Usage data for the three current-generation video game consoles. The Nintendo Wii is used significantly less than the Xbox 360 or PS3.

Console	Usage (hours/week)[a]
PS3	8.2
Xbox 360	9.8
Wii	2.8

[a]*Usage is in hours/week per console, using Nielson data and assuming two users per console and non-overlapping usage for the users.*

Using the video game console consumption data in Table 1 and the console usage data in Table 2, we can calculate the overall energy consumption of an average console. For this calculation, it is assumed that there are two users per console and that their usage is non-simultaneous (no overlap in usage between users). The analysis also assumes that the console is powered down to standby mode when not in use. This assumption is supported by a recent survey conducted by ecommerce website retrevo.com, showing 84% of console owners "most of the time" turned off their console when not in use (retrevo, 2010).

Table 3: Calculated power usage for the current-generation video game consoles. These figures were calculated using the average usage data from Nielson Company in Figure 2.

	Energy consumed while active (Wh/week)	Energy consumed in standby (Wh/week)	Total Energy consumed (Wh/week)	Annual Energy consumption (kWh/year)	Energy used while in standby	Effective Power Consumption[a] (W)
Original PS3	1550	176	1726	90	10%	211
PS3 Slim	697	80	777	40	10%	95
Original Xbox 360	1686	349	2035	106	17%	208
Xbox 360 S	862	111	973	51	11%	99
Nintendo Wii (WiiConnect24 Enabled)	45	1491	1536	80	97%	549
Nintendo Wii (WiiConnect24 Disabled)	45	315	360	19	88%	128

[a]*Effective Power Consumption is defined as the total energy used by the console (in both active and standby modes) divided by the number of hours the console is in active use.*

These calculations show that the devices with the highest annual energy consumption are the original Xbox 360 and PS3 consoles. Table 3 also shows that the newer, more efficient hardware revisions of those systems reduce the overall energy consumption by around 50%. Even though it has a low active power consumption, the Nintendo Wii with WiiConnect24 enabled has a high overall energy consumption. This is due to the high standby load associated with the WiiConnect24 service and results in 97% of the console's electricity use occurring when it is not in use. The Nintendo Wii with WiiConnect24 disabled consumes the least absolute energy by far, due to its low power draw in both active and standby modes.

Importantly, total electricity usage only tells part of the story of energy consumption, due to very different usage patterns of the consoles. The total power consumption of a console could be greatly decreased if it were not used at all, but this strategy would be unhelpful because the utility of a video game console comes not from owning it but from operating it. Furthermore, it is important to understand that a device can be relatively energy efficient in all of its modes but be operated in a way that is wasteful of energy. In order to investigate both console energy efficiency and user behavior in a single metric, "effective power consumption" is used as a way to compare electricity consumption on an "hours-of-use" basis.

Energy economy is generally defined as output of a service per unit of energy input, and the service provided by game consoles is defined here as hours of active use. Thus, in this study, energy economy is defined as hours of active use per unit of electricity consumption. Examining consumption from this vantage is important because a video game console provides essentially all of its utility from active use. The "effective power consumption", the inverse of energy economy as defined above, was calculated for all consoles and is used as the primary comparative metric (Equation 1). This metric is used instead of energy economy because effective power consumption, in units of Watts, is easily comparable to other loads while energy economy, using units of hours of use per kWh, is a less intuitive metric. Functionally, the effective power consumption metric distributes the energy consumed in standby mode over the hours when the console is in active use, adding that consumption to the active use consumption. A comparison of energy use of the six consoles investigated in this paper can be found in Figure 1.

$$EPC = \frac{(hrs\ of\ active\ use \times active\ power) + (hrs\ of\ standby \times standby\ power)}{hrs\ of\ active\ use} \quad \text{(Eq. 1)}$$

By this standard, a Nintendo Wii with WiiConnect24 enabled uses the most electricity per hour of operation and even the Nintendo Wii with WiiConnect24 disabled is still approximately even with the currently available PS3 and Xbox 360 consoles (Table 3). The high effective power consumption of the Nintendo Wii console is a direct result of its low usage: the Wii with WiiConnect24 enabled uses about the same amount of electricity as an Xbox 360, but is used only one third as much. But even if the Wii were used as much as a PS3 or Xbox 360, the Wii (with WiiConnect24 enabled) consumes more annual electricity than the current PS3 and Xbox 360 models unless console usage is greater than 18 hours per week.

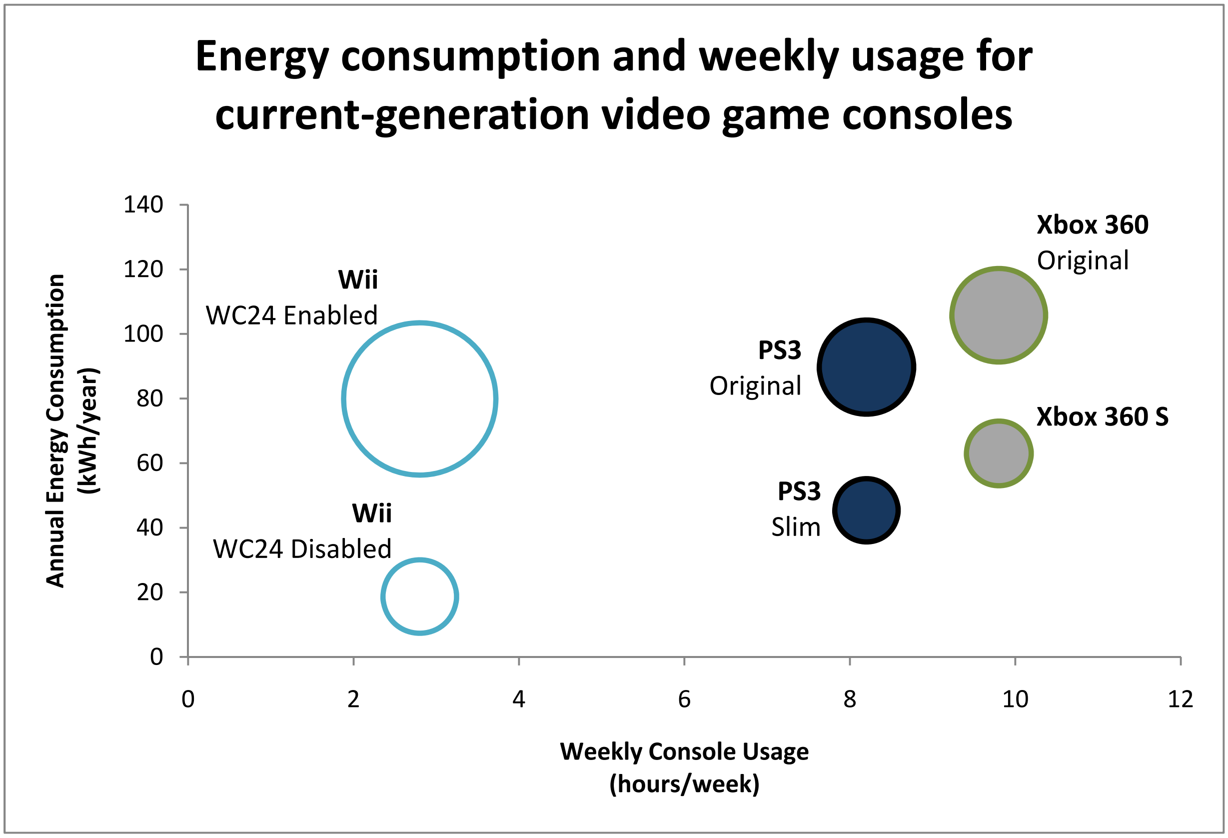

Figure 1: Energy consumption and weekly usage of the six video game consoles investigated in this paper. The area of the circle indicates the Effective Power Consumption of that system. Consoles that are lower and further right on the figure are preferred, as that indicates lower energy consumption and increased output in the form of hours of use.

Discussion

A few studies have praised the Nintendo Wii for its low power consumption, such as EPRI's "Power Play" News Release, which states in the subtitle that "Nintendo Wii Uses One-Sixth the Power of Sony PlayStation 3 or Microsoft Xbox 360" (Electric Power Research Institute, 2010). These studies have been profiled by many news outlets touting the Nintendo Wii as a greener, more efficient device than the PS3 or Xbox 360. Yet the calculations above show that, under the most common usage scenarios, the Nintendo Wii (with WiiConnect24 enabled) uses significantly more electricity per hour of active use than any version of the Xbox 360 or PS3 and more energy overall than the currently available versions of these consoles. With WiiConnect24 disabled, the Wii has the lowest annual power consumption but still has an effective power consumption roughly equivalent to the currently available versions of the Xbox 360 and PS3.

There are several factors not considered in this analysis. For example, an active console must be linked to a television or monitor as a display. The Nintendo Wii is unable to display in high definition (HD), while the PS3 is marketed as an all-in-one multimedia HD platform. Because of the different capabilities and marketing of the consoles, it is reasonable to assume that they may be connected to different types of televisions. The power consumption of an HDTV can range from fifty to several hundred watts, but this consumption was not included in the calculations above. Additionally, this study did not examine the energy consumption of consoles that are left in active (or idle) mode when not in use, which is important because the consoles do not have a low-power idle state or effective auto-power-down options. Clearly, the Nintendo Wii, with the lowest active power consumption by far, would use the least electricity if a user chose to leave the console on all the time. It is unlikely, though, that consumers who never power down their video game consoles would be interested in a paper about console efficiency. Finally, this paper does not address potential methods for reducing the energy consumption of video game consoles, a subject which has already been examined in the Natural Resources Defense Council (NRDC) study "Lowering the Cost of Play" (Natural Resources Defense Council, 2008) and is currently being addressed by the Energy Star program as part of their proposed game console requirements (Energy Star, 2009).

While video game consoles collectively draw a large amount of power and represent a potential target for efficiency improvements, it is important to view their power consumption in proper perspective with other residential energy use. The average American home uses 11,500 kWh of electricity per year (Energy Information Administration, 2009). Applying the baseline usage pattern discussed in this paper, the highest energy consuming console in Table 3 was an original design Xbox 360, using 106 kWh of electricity per year, which would cost around $13/year at average US residential electricity prices of $0.12/kWh (Energy Information Administration, 2010). This represents less than 1% of the average household electricity usage, and is still less than 2% (approximately $25/year) when a 150 Watt HDTV is included in the calculation. An alternate way to frame this cost is to compare the cost of purchasing a game to the cost of the electricity required to play a game. For a game offering 30 hours of gameplay, played over the course of 6 weeks on an original PS3, the total electricity used (attributing all standby consumption to this game) would be 6.7 kWh. At average electricity prices this would cost $0.80, which is trivial compared with the cost of games, which normally launch at a $60 price point. The original PS3 is actually the most expensive case, and this comparison has neglected the cost of the system and other peripherals, which would again dwarf the electricity consumption.

Even heavy use of video game consoles does not greatly increase the cost of console electricity use. A gamer that operates the highest active power consumption console (an original design PS3) for 41 hours per week (ten times the average, and equivalent to hours spent at a full-time job) will consume 410 kWh ($50) of electricity annually in the PS3 and an additional 320 kWh ($40) in a 150 Watt HDTV. This would still be only 7% of the electricity consumed by the average home. But if a rarely-used PS3 is never powered down, its electricity consumption would be 15% ($200/year) of average residential electricity use for the PS3 alone and 25% ($350/year) if an HDTV was kept on as well. This example is representative of the other consoles and shows that even very heavy console usage has a smaller effect than leaving the console on continuously.

For video game players that are responsible enough to power down their console when not in use, the electricity consumption of their console is less significant than other electrical loads in an average home, and an even smaller fraction of their overall energy use. Thus, gamers interested in reducing their household energy consumption should look to other improvements with a greater potential impact, like insulating their house. There are many sources, such as the energysavers.gov website, that can provide advice on effective energy saving improvements.

Conclusion

This paper was written with the intention of performing a calculation of electricity consumption of the three current generation video game consoles, using the most recent usage and power consumption data. There are two important conclusions to draw from this analysis. First, despite much reporting to the contrary, the Nintendo Wii is not especially "green" versus the other consoles when the existence of WiiConnect24 and actual usage patterns are considered. Second, as long as a video game console is powered down after use, its electricity consumption and energy efficiency potential are low compared to more prominent household energy use such as heating/cooling, laundry, and refrigeration.

About the Author

Eric Hittinger is a PhD student in the Department of Engineering and Public Policy at Carnegie Mellon University. He spends most of his time researching grid-level energy storage as part of the Carnegie Mellon Electricity Industry Center. Eric is also an avid gamer and owns all three of the current generation video game consoles, which he keeps unplugged when not in use.

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