Energy Policy 61 (2013) 1412–1421

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Estimating the energy use of high definition games consoles ☆

A. Webb [a,b,*], K. Mayers [a], C. France [b], J. Koomey [c]

[a] Sony Computer Entertainment Europe Ltd., 10 Great Marlborough Street, London, W1F 7LP England, United Kingdom
[b] Centre for Environmental Strategy, University of Surrey, Guildford, Surrey, GU2 7XH England, United Kingdom
[c] Steyer-Taylor Centre for Energy Policy and Finance, Stanford University, Stanford, CA 94305, USA

HIGHLIGHTS

- Estimates of games console energy use vary significantly.
- New energy use estimates calculated for high definition games consoles.
- Consoles currently on sale use 37% less energy than earlier models.
- Gaming accounts for over 50% of console energy use.
- Further research regarding console usage is needed, particularly inactive time.

ARTICLE INFO

Article history:
Received 24 January 2013
Accepted 16 May 2013
Available online 3 July 2013

Keywords:
Games consoles
Energy use
Energy efficiency

ABSTRACT

As the energy use of games consoles has risen, due to increased ownership and use and improved performance and functionality, various governments have shown an interest in ways to improve their energy efficiency. Estimates of console energy use vary widely between 32 and 500 kWh/year. Most such estimates are unreliable as they are based on incorrect assumptions and unrepresentative data.

To address the shortcomings of existing estimates of console energy use, this study collates, normalises and analyses available data for power consumption and usage. The results show that the average energy use of high definition games consoles (sold between 2005 and 2011 inclusive) can be estimated at 102 kWh/year, and 64 kWh/year for new console models on sale in early 2012. The calculations herein provide representative estimates of console energy use during this period, including a breakdown of the relative contribution of different usage modes.

These results could be used as a baseline to evaluate the potential energy savings from efficiency improvements in games consoles, and also to assess the potential effectiveness of any proposed energy efficiency standards. Use of accurate data will help ensure the implementation of the most effective efficiency policies and standards.

1. Introduction

Policy concerning the energy use of appliances[1] now forms an important part of governments' environmental strategies to reduce carbon emissions associated with domestic energy use. The Information and Communication Technologies and Consumer Electronics sectors are the fastest growing contributors, accounting for 15% of global residential electricity consumption (OECD/IEA, 2009). As such, government policies targeting the energy efficiency of appliances will contribute towards initiatives such as the European Union (EU) Climate and Energy package that, among other things, aims to improve the EU's energy efficiency by 20% (Europa, 2010).

Games consoles have undergone considerable technological development since their introduction 40 years ago. The first home games console (the Magnavox Odyssey) was released in 1972 and was an analogue system powered by batteries (The games console, 2011). 1976 saw the introduction of the Fairchild Channel F console, the first programmable system that had games cartridges containing Read Only Memory. Over time consoles have continued to develop rapidly offering more display colours, moving from game cartridges to CDs, until today where the current generation of consoles offer photo realistic gaming and a wide variety of secondary functionalities[2],

* Corresponding author at: Sony Computer Entertainment Europe Ltd., 10 Great Marlborough Street, London, W1F 7LP England, United Kingdom.
Tel.: +44 2078595488.
E-mail address: amanda_webb@scee.net (A. Webb).

[1] In this study appliances covers home electrical and electronic goods such as washing machines, TVs and consumer electronics equipment.

[2] Secondary functionality refers to any function that is not gaming such as Internet browsing or DVD playback.

0301-4215/$ - see front matter © 2013 The Authors. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.05.056

including Internet browsing, online gaming, digital television viewing and movie playback. Games consoles available in May 2013 include the Nintendo Wii U, the Microsoft XBOX360 and the Sony PlayStation®3, all of which are High Definition[3] (HD) consoles. These consoles are each different in terms of the functionality and the level of performance they offer, for example, consider media playback; the Wii U does not offer DVD playback, the XBOX360 offers DVD playback and the PlayStation®3 offers DVD and Blu-ray playback. All of these consoles are reprogrammable; updates to the operating system are downloaded from the Internet or installed via a game disc.

Alongside improved performance and functionality, the unit power consumption of consoles has increased between successive product generations[4] , and ownership has risen. For example, the increase in active gaming power consumption between PlayStation® consoles launched in 1994 and PlayStation®3 consoles launched in 2006 is 180 W (NRDC, 2008). As such, games consoles have attracted the attention of energy efficiency initiatives as all of these factors have contributed to an increase in the aggregate energy use of games consoles over the last 40 years. In addition, some studies predict a continued increase in their energy use of up to 19% by 2020 (EnergyConsult, 2012a).

Games consoles are, or have been, addressed by various regulatory and voluntary instruments, including the EU Eco-design Directive (European Parliament and Council, 2009), the US EnergyStar® program (EnergyStar®, 2009b), the Californian Energy Commission's Appliance Efficiency Standards (Energy Resources Conservation And Development Commission, 2012) and the Australian Equipment Energy Efficiency Program (Equipment Energy Efficiency Program, 2010). These initiatives have proposed a range of measures including power caps for specific operational modes and introduction of new Auto Power Down[5] (APD) requirements.

There is, however, a lack of agreement over the actual energy use of games consoles when comparing data from the available research. Several stakeholders involved in the process of developing policies and standards for consoles, including NGOs, researchers, government authorities and console manufacturers, have calculated widely varying estimates of games console energy use (collated and normalised in Table 1 for comparison) between 32 kWh/year (Market Transformation Programme, 2009b) and 500 kWh/year (NRDC and Energy Solutions, 2011). This substantial variation between estimates does not appear to have been addressed, or even acknowledged.

Regulating the energy use and power consumption of games consoles is complex as they are not uniform products; as explained above each different console offers a different combination of functions and performance, and consequently different usage and power consumption. As a result, comparing the efficiency of games consoles is very difficult (in contrast to products such as televisions that provide similar functionality and easily measureable performance). For example, under the Eco-design Directive, the efficiency of televisions is determined by the size of the screen and the resolution at which they output images (European Commission, 2009). Hittinger et al. (2012) highlight characteristics of the video game market that may require unique regulatory approaches, such as console performance, which is held constant over time so that each version of a console within a product generation can perform the same tasks. At the same time, changes to the hardware, software and operating system firmware enable the power consumption of different versions of a console, within a generation, to be reduced substantially. This can be shown by the significant reduction in power consumption of both the XBOX360 and the PlayStation®3 since launch, with a reduction in active[6] power consumption of around 93 W (54%) and 110 W (58%) respectively (Intertek, 2012; NRDC, 2008). The energy use of consoles will also change as a result of updates to the operating system firmware downloaded or installed from game discs while in use. Such updates do not change the power consumption of the console in each mode, but can alter a console's functions and the way users interact with them. Constantly changing energy use patterns, such as those described above for consoles, are problematic for the development of energy efficiency policies and standards; something stated by Lee et al. (2009) as one of the primary challenges facing energy efficiency programmes. This is a particularly prevalent problem for games consoles as any policies and standards proposed to improve efficiency can quickly become obsolete as models are updated and functions are added over time.

Of the energy use estimates shown in Table 1, three particularly stand out as being high: NRDC (2008), Hittinger et al. (2012) and NRDC and Energy Solutions (2011) at between 300 kWh/year and 500 kWh/year. These estimates do not appear to account for the substantial reduction in power consumption of HD consoles since they were first launched in 2005. One thing that these studies do have in common is that they all estimate inactive time to be very high, based on the assumption that 30–50% of users always leave their consoles switched on when not in use. The power consumption while consoles are left inactive is almost the same as when consoles are in active use (see Section 3.1); therefore, these assumptions have a large impact on the resulting energy use estimates (estimates assuming between 30% and 50% of users leave their consoles on while not in use are 160–360 kWh/year higher than studies that assume all consoles are switched off after use). Section 3.2 details a discussion of inactive time estimates available for consoles.

Conversely, some studies report very low estimates for games console energy use of between 32 and 42 kWh/year (AEA, 2009; Market Transformation Programme, 2009b; Hittinger, 2011). These estimates represent an average of high and standard definition consoles that were on sale when this study was completed in 2012; until replaced by the Wii U in November 2012, the Nintendo Wii console had very low power consumption, between 14 and 18 W (Hittinger et al., 2012), and sales approaching 100 million since launch in 2006, which would skew these console energy use estimates downward. Other studies do not include standard definition consoles (NRDC and Energy Solutions, 2011) as all new consoles are expected to be HD.

The remaining estimates fall between around 60 kWh/year and 140 kWh/year (AEA, 2010, EnergyConsult, 2012a). The variability between these energy use estimates is likely to be due to variable power consumption between different versions of each console model and variations in console usage data used in each calculation.

It is not clear, therefore, what a representative estimate of HD console energy use should be. Greater certainty and more accurate information are needed to determine the impact console energy use may have on climate change, and to evaluate the likely effectiveness of any energy efficiency improvements for consoles, such as APD or more efficient processor chips.

This study evaluates data available for games consoles regarding their usage and power consumption and, by determining the

[3] High definition are those that can deliver content at a resolution of 720 p or higher.

[4] An example of different generations of consoles would be the PlayStation®, PlayStation®2 and PlayStation®3 that are differentiated by the performance and functionality they offer and the year they were launched.

[5] Auto Power Down or APD is a software function, supported by the hardware that shuts down a device after a set period of inactivity, commonly 1 hour.

[6] Active usage can be considered any state in which a function has been selected and the user is engaged and/or the function is active, for example, active gaming or watching a DVD.

Table 1
Energy use estimates published for games consoles in chronological order.

Source/region	Purpose	Energy use estimate	Normalised energy use estimate (kWh/year/console)
NRDC (2008)/**United States**	Publicising the energy use of games consoles and promoting improved efficiency	16,000 GWh/year for US consoles	300[a]
AEA (2009)/**Europe**	Developing energy efficiency measures for games consoles in the EU	41.23 kWh/year/console	41
Market Transformation Programme (2009)/United Kingdom	Briefing note for public consultation and to inform Government decisions	630 GWh/year for UK consoles in 2009	32[b]
DCCEE (2010) Australia	Home entertainment product profile report	140 kWh/year for Australian consoles	140
AEA (2010)/**Europe**	Development of energy efficiency measures for games consoles in the EU	74.8 kWh/year/console	75
Hittinger (2011)/United States	Research studying the energy use of games consoles	PlayStation®3 40 kWh/year—XBOX360S 51 kWh/year—Wii 80/19 kWh/year (with/without WiiConnect 24 enabled)	40 51 80/19
NRDC and Energy Solutions (2011)/**United States**	Promoting energy efficiency standards in California	Up to 500 kWh/year/console in California	500[c]
Console Manufacturers—Installed Base (2011)/Europe	Industry estimates for input to policy making process within the EU	101.1 kWh/year/console	101
Console Manufacturers—Currently on Sale (2011)/Europe	Industry estimates for input to policy making process within the EU	61.8 kWh/year/console	62
Hittinger et al. (2012)/**United States**	Research estimating electricity consumption of games consoles in the US	330 kWh/year/console	330
EnergyConsult (2012b)/Australia	Developing energy efficiency standards for games consoles in Australia	600 GWh/year in Australia in 2010	113[d]
EnergyConsult (2012a)/**Australia/New Zealand**	Developing energy efficiency standards for games consoles in Australia	395 GWh/year in Australia in 2010 40 GWh/year in New Zealand in 2010	66[e] 50[e]
Intertek/DEFRA (2012)/**England**	Survey of household energy consumption	42.3 kWh/year/console (average) 62.2 kWh/year/console (HD average)	42 62

[a] Total sales of consoles for 2002–2007 taken from Table 2, p.8 (NRDC, 2008).
[b] Based on stock of 20 million in 2010 taken from Table 1, p. 3 (Market Transformation Programme, 2009b).
[c] Upper bound of energy use estimate for consoles in the installed base, p.2 (NRDC and Energy Solutions, 2011).
[d] Based on stock estimate of 5.3 million, p.1 (EnergyConsult, 2012b).
[e] Based on stock estimate of 6 million and 800,000, respectively, p.9 (EnergyConsult, 2012a).

most accurate data, calculates two new energy use estimates; one for average consoles in use at the time of study (those sold between 2005 and 2011 inclusive), and one for new consoles available in early 2012. The aim of this study is to address the shortcomings and uncertainty of existing assessments of games console energy use and derive more representative estimates.

2. Method

Two approaches are available for calculating the energy use of industry sectors or products, where top-down approaches calculate the energy use at a sector level and bottom-up approaches calculate the energy use per consumer unit of equipment (Thomas et al., 2010).

This study uses a bottom-up approach to consider the energy use of HD consoles sold between 2005 and 2012. This includes the XBOX360 and PlayStation®3, which have similar power requirements and functionality, but excludes the Wii U that was launched in November 2012, after the study was completed. Exclusion of the Wii U from the scope of the study will not impact the results much as only 2.25 million units were sold in 2012, versus almost 10 million XBOX360 consoles and 11.25 million PlayStation®3 consoles in the same year (VGChartz, 2013). In addition, global lifetime sales of PlayStation®3 and XBOX360 consoles are around 75 million, with total sales of Wii U around 3 million (ibid.,). Standard definition consoles are not included in the scope of this study as they have relatively low power consumption and sales of these platforms, such as the Wii, are declining more rapidly than HD platforms. Furthermore, no new standard definition models are anticipated to be launched in the future. This approach is the same as that used by NRDC and Energy Solutions (2011).

Typical Electricity Consumption (TEC) methodology is used in this study to estimate the energy use of an appliance over a defined time period (EnergyStar®, 2009a). In relation to games consoles, TEC methodology is already used in the EnergyStar® Computer Requirements (EnergyStar®, 2009a) and the European Union Ecodesign Sound and Imaging Equipment preparatory study (AEA, 2010).

TEC uses a formula that multiplies the power consumed in a specific mode by the time spent in that mode. A generic formula is shown below for calculating TEC:

$$\text{TEC (Wh)} = (P_1 * T_1) + (P_2 * T_2) + \cdots + (P_n * T_n)$$

where P is the power in Watts, T the time in hours, $_{1,\,2,\,\ldots,\,n}$ are the different modes, and $\sum T = 8760$ h/year.

The calculation of TEC should account for all time in the period being considered, commonly one year, with the modes included reflecting the usage of the appliance in question.

The modes included in this TEC calculation are defined as follows:

Standby—This is a common mode on many electrical appliances, defined as "a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following functions, which may persist for an indefinite time: reactivation function, or reactivation function and only an indication of enabled reactivation function and/or information status display" (European Commission, 2008).

Networked standby—This mode is increasingly common on appliances that use a network connection to send and receive information. It is defined as "a condition in which the equipment is able to resume a function through a remotely initiated trigger via a network connection" (European Commission, 2013). Of the games consoles considered in this study, this mode is only available on the PlayStation®3.

Gameplay—This includes the time a console spends switched on, with a game disc loaded and one or more users interacting with the console via the use of peripherals such as controllers. It also includes the time spent gaming online.

Media—Various media are able to be played on consoles including CDs, DVDs and Blu-rays. Consoles connected to the internet are also able to stream media. This mode covers all of these media functions.

Other functions—This covers messenger services, photo viewing, Internet browsing and time spent downloading additional content. These functions are grouped together as they are only used by a relatively small proportion of consumers (under 10% of consumers report using these functions with a frequency of at least once a week; GameVision, 2011a), and the power consumption reported for these functions is broadly similar, varying by just 1–2 W (AEA, 2010).

It is also important to consider the time a console spends switched on but not in use, or inactive, as this will affect estimates of console energy use and potential energy savings. While inactive use itself is not a function or mode it can be defined as "the state in which the mode has been selected but the user is not engaged and/or the function is not active" (Console Manufacturers, 2011). Other sources usually define idle mode as "the state in which the computer is not active" (EnergyStar®, 2009b). This is relevant for PCs as when inactive the device enters a state in which no processing or active functions are undertaken. However, from a device perspective, whether being used or not consoles are dissimilar as they are constantly drawing on the processing capabilities, accessing memory and generating images on screen whether or not users are inactive themselves. Although a seemingly subtle difference, these definitions have very different connotations in terms of power consumption. Computers, when they are idle, do not perform any function and as such require less power than when active. In contrast, due to the nature of their functions, consoles are always processing information and generating images, thus requiring similar power whether or not they are being actively used (AEA, 2010). Therefore, the term "inactive" is used in this paper to define the time when consoles are switched on, but not responding to user input, in each mode.

The TEC method is useful for evaluating the energy use of an appliance; however, it is only as reliable as the data used for power consumption and usage. It is also sensitive to changes in the input data, something which this study aims to address by evaluating all available data for power consumption and usage of HD consoles.

3. Results and analysis

In order to calculate representative energy use estimates for high definition consoles, available data for power consumption

Table 2
Measured power consumption data for HD games consoles (Watts).

Year sold	Source[b]	Navigation[a]	Gameplay		Media Usage		Internet browsing		Other functions		Standby (networked Standby)	Active[c]	Inactive[c]
			Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive			
2005	NRDC (XBOX360) (2008)	–	172	162	–	–	–	–	–	–	2.2	–	–
2006	NRDC (PS®3) (2008)	–	188.6	181	–	–	–	–	–	–	1.1	–	–
2007	Danish Technological Institute (2007)	179.2	192.3	–	176.8	–	178.6	–	–	–	1.8	–	–
2007	NRDC (2008) (PS®3/XBOX360)	–	153/ 127	–	129/ 85	–	–	–	–	–	1.1/3.1	150.1/ 118.8	152.9/ 117.5
2010	Electric Power Research Institute (2010) (PS®3/XBOX360)	–	84.8/ 87.9	–	–	–	–	–	–	–	–	–	–
2010	AEA (2010)	–	93.3	92.8	74.9	73.9	74.1	74.1	74.6	74.6	0.9	–	–
2010/	**2011**	EnergyConsult (2012a) (PS®3/ XBOX360)	67.6/ 76.9	76.6/ 81.3	–	73.5/ 58.9	–	–	–	–	–	0.05/ 0.67	–
2011	Console Manufacturers—installed base (2012a)	113	113	113	113	113	113	113	113	113	1.3	–	–
2011	Console Manufacturers—new consoles (2012a)	72	72	72	72	72	72	72	72	72	0.5	–	–
2010	NRDC and Energy Solutions (2011)	74.5	87.5	–	70	–	70	–	–	–	0.5 (11)	–	78.8
2012	Intertek/DEFRA (2012) (PS®3/ XBOX360)	–	–	–	–	–	–	–	–	–	1.2/3	79.6/ 79.1	–

[a] Navigation is defined as "a mode in which no other mode is engaged and the game console is displaying a menu of functions from which the user may select" (Console Manufacturers, 2012b).

[b] Where power consumption data is available for both XBOX360 and PlayStation®3 consoles it is included in the table and separated by a forward slash (/), as indicated in the source column.

[c] The power consumption values for active and inactive are separated from the data presented per mode as they are not attributable to a specific mode; instead they are broad averages for consoles.

and usage are collated and evaluated below. New energy use estimates are calculated and a sensitivity analysis performed on the resulting estimates to identify the key determinants of console energy use.

3.1. Power consumption data

Data on the power consumption of HD games consoles varies widely (Table 2). Data for gameplay power consumption varies between 72 and 192.3 W, with media usage and inactive modes showing similar ranges, between 70 and 176.8 W and 75 and 181.5 W respectively. Values reported for standby power consumption vary between 0.05 and 3.1 W. The large variation in power measurements for HD consoles can be explained when considering the date of the measurements; the studies in Table 2 consider consoles sold between 2005 and 2012. The change in HD console power consumption is a result of changes to the hardware, operating system and software that have led to efficiency improvements, as discussed above. Some studies report very limited data that only considers active power consumption and not the power consumption of individual modes (Intertek/DEFRA, 2012), whereas other studies report detailed values for a number of modes (Danish Technological Institute, 2007; AEA, 2010).

Although the studies in Table 2 report measured power consumption data for HD games consoles, the data have not been collected using a common methodology. Differences between the methods include the time span over which measurements were taken and the games or movies used to test certain functions. Despite these differences, all of the studies refer to existing test standards for other electrical products and confirm the use of a suitable power meter. The main issue with the use of different methods for testing concerns the language used to describe the modes tested; for instance, idle screen saver mode (Danish Technological Institute, 2007) versus navigation (NRDC and Energy Solutions, 2011). It is, however, possible to interpret the various terms for the same mode and collate them accordingly, as has been done in Table 2. Recently, to overcome the lack of a common test methodology and mode definitions, the NRDC and console manufacturers have agreed on a method (Console Manufacturers, 2012b), a version of which is included in the adopted EnergyStar® requirements for consoles (USEPA, 2013). The use of different testing methodologies is, therefore, likely to have a minimal effect.

Four studies report power consumption data for multiple modes and functions (NRDC, 2008; Danish Technological Institute, 2007; AEA, 2010; Console Manufacturers, 2012b). AEA (2010) and NRDC/Energy Solutions (2011) report measurements of more recent HD console models while the Danish Technological Institute (2007) reports power measurements of an early PlayStation®3. None of these studies report representative power consumption data for all HD consoles sold between 2005 and 2012; however, they do give an accurate picture of the variation in power consumption between modes. Console Manufacturers (2012a) report an average navigation mode power consumption for HD consoles sold between 2005 and 2011 inclusive (113 W), and the navigation mode power consumption of HD consoles on sale in early 2012 (72 W). It is important to note that the average power consumption value for consoles sold between 2005 and 2011 inclusive is are not weighted according to sales of each model; consoles are unusual in that sales usually peak between 3 and 5 years after launch (VGChartz, 2012a), and as such sales of lower power models are likely to be higher than the launch models. Console manufacturers do not report data for other active modes in this particular proposal. Such data is important; Table 2 shows that other studies report a difference in power consumption of between 17 and 42 W for active modes (NRDC, 2008; NRDC and Energy Solutions, 2011; AEA, 2010; Danish Technological Institute, 2007). Unfortunately, none of the available power consumption data are therefore complete. It is essential that any estimate of console energy use considers the difference in power consumption between modes, while also considering the power consumption of HD consoles sold between 2005 and 2011 (i.e. those currently in use).

To account for shortcomings in the available power data for HD consoles, this study calculates the ratio between the power consumption values in navigation and other active modes as reported by AEA (2010) and NRDC and Energy Solutions (2011) (Table 3). The data reported by the Danish Technological Institute (2007) is not included as it only considers one model of PlayStation®3 console, whereas the other studies report averages for HD consoles on sale at that time. The following generic equation is used to calculate the ratios for each mode using the AEA (2010) and NRDC/Energy Solutions (2011) data:

$$\text{Ratio} = \text{Powerconsumptionmode}^n\ (\text{W})/\ \text{powerconsumptioninnavigation}\ (W)$$

where n=gameplay, media or other functions.

For example, the equation to calculate the ratio for active gaming using the NRDC and Energy Solutions (2011) data would be as follows:

$$87.5/74.5 = 1.17$$

The manufacturer power consumption data (Table 2) is then multiplied by the median of the AEA and NRDC and Energy Solutions ratios to calculate power consumption estimates per mode. For example, to calculate the active gaming power consumption for consoles sold between 2005 and 2011 inclusive, the console manufacturer average navigation power consumption is multiplied by the median ratio: $1.21*113 = 136.7$ W

Standby power consumption values are taken directly from the console manufacturer data (Console Manufacturers, 2012a) as these data are averages for HD consoles sold between 2005 and 2011, whereas the other studies only consider HD consoles on sale at that time. Networked standby power consumption is taken from the NRDC and Energy Solutions report (2011), the only study to report this.

Table 3
Ratios, and resulting power consumption values, for use in calculating the energy use of HD consoles.

Mode	AEA ratios	NRDC ratios	Median ratio	Power consumption (W)	
				In use	New consoles
Gameplay	1.25	1.17	1.21	137.1	87.4
Gameplay inactive	1.25	1.17	1.21	137.1	87.4
Media	1.01	0.94	0.97	109.9	70.0
Media inactive	1.01	0.94	0.97	109.9	70.0
Internet browsing active	0.99	0.94	0.97	109.3	69.6
Internet browsing inactive	0.99	0.94	0.97	109.3	69.6
Other functions active	1.00	0.94	0.97	109.7	69.9
Other functions inactive	1.00	0.94	0.97	109.7	69.9
Navigation	1.00	1.00	1.00	113.0	72.0
Standby	–	–	–	1.3	0.5
Networked standby	–	–	–	11.0	11

3.2. Usage data

Data available on console usage, on a per console basis, is summarised in Table 4. The total time consoles are reported to be switched on ranges between 1.1 and 2.64 h/day, with the time spent in standby mode ranging between 4.7 and 22 h/day.

The completeness of the power consumption data varies with three studies considering only specific modes such as gameplay and active (Interactive Software Federation of Europe, 2010; Market Transformation Programme, 2009b; Intertek/DEFRA, 2012) and two simply reporting the total on-time (Nielsen, 2009, 2010).

Numerous studies collected usage data through the use of meters that measure consumer usage of consoles rather than relying on reported use from surveys (Nielsen, 2009, 2010; Intertek/DEFRA, 2012). This is the most accurate way to measure usage; however, it is not possible to measure the time a console is left on but inactive as current metering technology simply records the function selected. The remaining two studies in Table 4 report usage based on surveys of console users, one of which includes unspecified expert assumptions (Market Transformation Programme, 2009a). Such data are less reliable as it is not clear what assumptions this data may be based upon and they are dependent on consumers accurately reporting their usage; failures of recall and social desirability effects are known to affect the reliability of survey data (Crockett et al., 1987). There is, however, no clear indication of whether surveying console users leads to higher or lower estimates for usage time; as shown in Table 4, even the use of the same collection method at different times leads to different estimates of usage time (Nielsen, 2009, 2010). This could be caused by a number of factors including when the data were collected, which users were covered by the study, the region/s covered by the study and whether a new game or platform has recently been launched. Further research could establish the effect of these factors on the time users spend gaming and using other functions on their consoles. Considering the studies that give an estimate of total usage time (both active and inactive), the median and mean are calculated to be 1.9 h/day.

The studies in Table 4 do not, however, give a detailed indication of the contribution each mode makes to the total on-time. Nielsen (2013) report the contribution of each mode for HD consoles, which indicates that users spend 56% of total on-time gaming (online and offline), 18.5% streaming media, 13.5% watching DVDs and Blu-rays, 5.5% watching downloaded content and 7% using other functions including audio player and Internet browsing. The Nielsen data is only for console users in the United States, however, it is largely similar to European usage reported by console manufacturers and used in the AEA (2010) report (this data based on industry estimates, as opposed to surveyed or metered usage, and as such are not included in Table 4). Although the contribution of secondary functionalities varies between the studies, these functions have very similar power consumption so use of one study versus another is likely to have a minimal effect on the resulting energy use estimates. It is also important to consider that the Nielsen (2013) data is for gamers in the US, versus the AEA data for EU consumers; this could affect the usage patterns as different services may be available in different regions. The Nielsen (2013) data is used in this analysis as it is based on a survey of users, versus manufacturer estimates, and is therefore more reliable. Further research could establish whether significant regional variations in usage exist for console users, and the impact this could have on the total energy use estimates.

Studying the data for console usage in Table 4 shows no clear trend for change in usage over time, therefore, for the calculations below it is assumed that usage of HD consoles is constant over time. This is an area where further research is required to improve understanding of console usage, in particular whether usage increases as the number of functions increases, or if usage time is split between more functions.

In order to give as accurate a representation of HD console energy use as possible, this research will also consider the time a console spends in networked standby; only previously considered by NRDC and Energy Solutions (2011). As shown in Table 2, the power consumption in networked standby is much higher than standby, 11 W compared to between 0.5 and 1.3 W, and so could have a significant impact on console energy use. Only PlayStation®3 consoles currently offer this functionality, accounting for 55% of the high definition consoles currently in use in Europe (VGChartz, 2012b). Of the PlayStation® consoles sold, an average of 9.75% of European users report that they use this function once a week, with the rest not using it at all (GameVision Europe, 2009, 2010; GameVision, 2010, 2011b). Hence, it is estimated that 5.4% of high definition consoles have the networked standby function enabled. Any time spent in networked standby replaces time spent in standby, as such, the standby time (i.e. $24-1.9 = 22.1$ h/day) is multiplied by the proportion of users with the networked standby enabled. This

Table 4
Usage data for HD games consoles (hours per day/console).

Source/region	Data collection method	Game play	Media usage	Internet browsing	Other functions	Active	Inactive	Standby	Networked standby[a]	Total on-time
Nielsen (2009)/United States[b]	Metered usage	–	–	–	–	–	–	–	–	2.64
Nielsen (2010)/United States[c]	Metered usage	–	–	–	–	–	–	–	–	1.1
Market Transformation Programme (2009)/United Kingdom	Metered usage/survey/ expert assumptions	–	–	–	–	0.4	1	10	–	1.4
Interactive Software Federation of Europe[d] (2010)/Europe	Survey	1.72	–	–	–	–	–	–	–	–
Intertek/DEFRA, (2012)/United Kingdom[e]	Metered usage	–	–	–	–	2.3	–	4.7	–	2.3

[a] Data for the time a console spends in networked standby is not provided by any of the sources of usage data. It is, however, considered in the subsequent analysis based on the activation rate reported in GameVision studies published between 2009 and 2011 and is included in this table for completeness.

[b] This is an average estimate of usage for PlayStation®3 and XBOX360 consoles calculated using the active user % data in Fig. 1, p. 3.

[c] Average for PlayStation®3 and XBOX360 consoles taken from average metered weekly hours per user. To reflect research that reports multiple users are active on each console, the hours per user has been multiplied by 1.8, the average number of users active on each console as reported in the GameVision studies published between 2009 and 2011.

[d] This value is calculated using the data in Figure 20 of the report. The average number of XBOX360 and PlayStation®3 users in each category is calculated and multiplied by the mid-point of that category. As described above, this is also multiplied by 1.8 to reflect usage per console.

[e] This is an average for XBOX360 and PlayStation®3 consoles.

calculation results in an average networked standby time for all HD console users of 1.2 h/day, which is subtracted from the original standby time to give a total of 20.9 h in standby.

As previously stated, it is important to be able to estimate the proportion of the total time a console is switched on and active versus inactive. This allows the potential energy saving of improvements, such as Auto Power Down (APD), to be assessed. Estimating the time a console spends inactive is complex as a console can be inactive in any of the available modes. Although metering technology is the most accurate method available for gathering data on consumer usage, current technology cannot be used to discern between active and inactive console usage.

Owing to a lack of available data, various studies have assumed that between 30 and 50% of users never switch their consoles off (NRDC, 2008; NRDC & Energy Solutions 2011; Hittinger et al., 2012), which would result in an inactive time of 22.2 h/day for those users (see below for the median on-time estimate). Recent survey research, however, suggests that the proportion of PlayStation®3 consumers that leave their consoles on all the time may be as low as 3% (Webb et al., 2011). Even if this figure is as low as 3%, this would suggest annual energy use of around 960 kWh for those users; something which is likely to skew average energy use estimates significantly.

The metered usage estimates summarised in Table 4 include both active and inactive time and account for an unknown number of users that may have enabled APD on their console. Without knowing the proportion of users that have activated their APD function, it is not possible to accurately assess the impact of introducing an APD function that is switched on by default. In 2012 console manufacturers enabled the APD settings by default, for some console models in some regions, via software updates for both consoles in use and new consoles (in Europe this was done to comply with new regulations mandating APD from January 2013; European Commission, 2008). The impact of these changes to the total on-time has not yet been measured. Although some studies have tried to establish estimates of inactive time and the proportion of users that have activated APD, the results have shown a great deal of unreliability. For example, some users report to have activated the APD function on their console even where not available (Interactive Software Federation of Europe, 2012) while many console users appear to be largely unsure of their console's capability in terms of APD. For example, 57% of users stated that they did not know if their console powered off after a period of inactivity, while 71% of users that reported their consoles do have APD say that they use the function (Consumer Electronics Association, 2010).

Other assumptions focus on the proportion of on-time that is anticipated to be inactive, including the Market Transformation Programme (2009a) study that estimates inactive time to account for 70% of the on-time in 2008, anticipated to rise to 78% in 2020 as more downloadable content becomes available. The AEA (2010) report assumes an inactive contribution to the total on-time of 30%, split equally across all modes.

Given the uncertainty surrounding the inactive time for games consoles, this study will not consider inactive time in the analysis. Further research to establish whether console users have enabled APD on their console would allow estimates for inactive time to be improved. From the data already collected in this regard, it is clear that surveying users on this aspect of their usage returns unreliable results; therefore, it is suggested that an intrusive survey, whereby user's console settings are checked before metering usage, would be the most appropriate and accurate way to gather this information.

The total on-time (1.9 h/day) is split as reported by Nielsen (2013), which details the contribution of each mode. Table 5 summarises the usage estimates that will be used to calculate the energy use of HD consoles.

Table 5
Usage estimates for HD consoles (h/day).

Mode	Time
Gameplay	1.06
Movie/video playback	0.71
Other functions	0.13
Standby/off	20.89
Networked standby	1.20
Total	24.00

Table 6
Detailed breakdown of the energy use estimates for new HD consoles and those in use.

Mode	Energy use (kWh/year)		Percentage contribution	
	In use	New	In use (%)	New (%)
Gameplay	37.3	23.8	37	37
Gameplay inactive	16.0	10.2	16	16
Media	20.0	12.7	20	20
Media inactive	8.6	5.5	8	9
Other functions	3.7	2.4	4	4
Other functions inactive	1.6	1.0	2	2
Standby/off	9.9	3.4	10	5
Networked standby	4.8	4.8	5	8
Total	101.9	63.8	100	100

3.3. Energy use estimates

The energy use estimates calculated from the power consumption and usage values derived in Sections 3.1 and 3.2 are presented below. Energy use is estimated for HD consoles sold between 2005 and 2011 inclusive (in use at the time of study) and new HD consoles available in early 2012 (Table 6).

The energy use estimate calculated for new consoles is 37% lower than the estimate for those in use, 63.8 kWh/year versus 101.9 kWh/year. This is mainly due to advances in chip technology resulting in improvements in console efficiency between different versions of each console model. For example, the Cell processor in the PlayStation®3 now uses 45 nm technology for its transistors, which is half the size of the original 90 nm technology in the 2006 launch model (ars technica, 2008). This enables more transistors to fit on the same sized chip, lowering conductance losses and reducing power consumption. Given that the performance of a console generation is constant over time (Hittinger et al., 2012), despite hardware and software revisions, the graphics processing and central processing unit chips have decreased in size resulting in lower power consumption.

Of particular interest is the contribution standby mode makes to the overall energy use in the respective estimates. The energy use of standby for consoles in use accounts for 10% of overall power use, versus 5% for new consoles available at the time of study. This is due to a reduction in standby power consumption from 1.3 W to 0.5 W. In contrast, the contribution of networked standby to the total TEC is estimated to be 3% higher for new consoles compared to those in use. This is due to the power consumption in networked standby being the same in both energy use estimates, while all other power values have decreased. It is likely, however, that networked standby power consumption has also decreased over the product lifetime in a similar manner to other modes; research to establish if networked standby power consumption has changed over time would help to refine this aspect of console energy use estimates. The calculations also show that, in both cases, gameplay accounts for around 53% of the total energy use with the contribution of media play around 28% and other functions 6%.

3.4. Sensitivity analysis

To test the suitability of the assumptions used in this study, a sensitivity analysis has been completed. Two main parameters are considered:

1. **Power consumption data**—The ratios calculated from the AEA (2010) and NRDC and Energy Solutions (2011) power consumption data are each used to calculate power consumption value for HD consoles, using the average power consumption values published by console manufacturers (see Table 2)
2. **Usage data**—The upper and lower bounds of total on-time estimates, of 1.1 h/day (Nielsen, 2010) and 2.64 h/day (Nielsen, 2009) are considered.

Figs. 1 and 2 show the change in energy use of consoles, when varying the usage time and using the different ratios for power consumption, for consoles in use and new consoles respectively. Energy use estimates for consoles sold between 2005 and 2011 inclusive range between 64 and 146 kWh/year, with estimates for new consoles available in early 2012 ranging between 38 and 92 kWh/year. The variation caused by the use of different power consumption ratios has a very small impact on the energy use estimates, ranging between 4.6% and 6% of the total, while the different usage estimates have a much larger impact with the energy use changing by up to ±40%. This indicates good agreement between the sources of power consumption data for different functions, but significant uncertainty around usage. Figs. 1 and 2 clearly demonstrate that uncertainty around usage time is a key factor in determining console energy use, further supporting the need for additional research in this area.

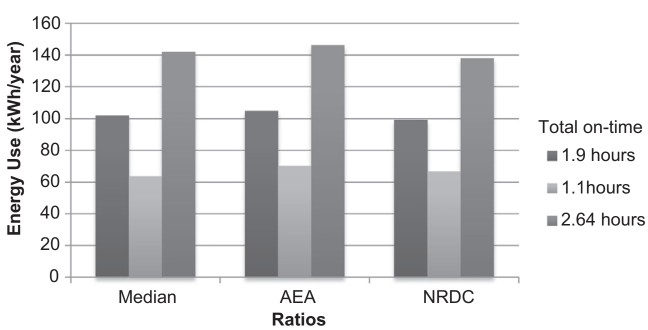

Fig. 1. Results of the sensitivity analysis for consoles currently in use.

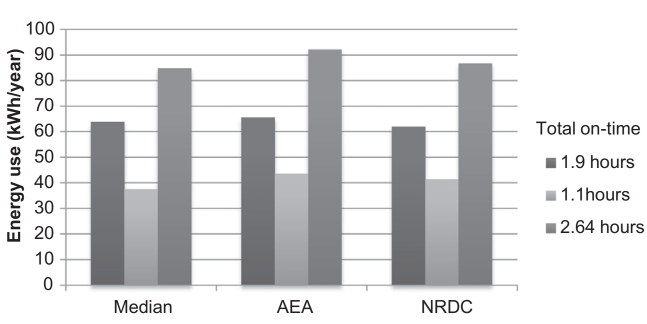

Fig. 2. Results of the sensitivity analysis for new consoles.

4. Discussion

This study details a critical review of available data for the power consumption, usage and energy use of high definition games consoles. The analysis has shown that there is a large variation in estimates for all three factors caused by a combination of lack of available data and divergent assumptions.

Although many existing energy use estimates are of a similar magnitude to those calculated herein, the following issues have been addressed:

- **Representative power consumption data derived for HD consoles in use and on sale**—All previous estimates of games console energy use have used power consumption data for HD consoles on sale at a certain time between 2005 and 2012. As explained, models within each generation of games console are subject to revisions over time that result in efficiency improvements and falling power consumption. Existing estimates of games console energy use either fail to take account of these reductions, or ignore earlier, higher power versions of games consoles already in use. Particularly when considering energy efficiency improvements that can affect the consoles already in use in consumers' homes, such as enabling APD, it is important to account for all console models sold previously. This study uses power consumption data that accounts for the falling power consumption of HD consoles over time and also the difference in power consumption between modes.
- **Usage estimates derived from relevant studies**—Existing estimates of games console usage have tended to focus on the results of one study. Usage of consoles can be affected by many factors such as when the data were collected, how it is collected and which users are covered. The estimate of HD console usage derived in this research considers all studies that report an estimate of the total on-time, gathered using metering technology, and uses a median to calculate the average energy use. Data from Nielsen (2013) regarding the contribution of each mode to the total on-time are also used, compared to previous studies that used assumptions to estimate this (NRDC, 2008) or do not consider it at all (Market Transformation Programme, 2009a, EnergyConsult, 2012a). Sensitivity analysis has shown that the range of estimates for total on-time used in this study have a significant effect on the energy use estimates, highlighting usage data as a key area of uncertainty and meriting further study.
- **Inactive time is unknown**—Previous estimates of games console energy use have either assumed the contribution of inactive time to total on-time (AEA, 2010; Market Transformation Programme, 2009a) or assumed the proportion of users that leave their consoles on all of the time (NRDC, 2008; Hittinger et al., 2012). Available data regarding users' switch off behaviour and the proportion of users that have enabled APD appear highly uncertain and so it is not possible to estimate the time consoles spend inactive. Survey results suggest that users are unsure as to whether they have an APD function available on their console or whether it is enabled (Consumer Electronics Association, 2010; Interactive Software Federation of Europe, 2012). When considering the potential impact of efficiency measures, such as APD, it is essential to know how long consoles spend

inactive (see below). Further research is needed to establish the proportion of users that have APD enabled and hence the time HD consoles spend inactive.

The energy use estimates calculated in this study detail the contribution of different modes to the total energy use. This analysis has shown that gaming makes the largest contribution to console energy use, around 53%, with media use accounting for around 28%. This level of detail is essential in determining the relative impact of console energy use compared to other products and in determining the effectiveness of possible energy efficiency improvements. Ultimately, these estimates can be used to develop baselines and improvement scenarios for the evaluation of energy efficiency policies and standards for games consoles.

The use of representative and reliable data to calculate the energy use of games consoles is extremely important when evaluating the potential impact of various efficiency improvements. For example, the NRDC (2008) estimate that the introduction of an APD feature that powers the console down after 1 h of inactivity will save 1164 kWh per user per year for users that leave their consoles on, or an average of 582 kWh per user per year. Considering that survey data suggests as few as 3% of HD console users leave their console on all of the time, these savings would be reduced to 36 kWh/user/year, 94% lower than anticipated based on the NRDC energy use estimate. If inactive time contributed 30% to the total on-time and APD were to reduce this by 50% for each console, using the energy use estimate for HD consoles in use (102 kWh/year), a reduction of 13 kWh/year per console could be expected. Considering that some studies estimate inactive usage to account for 70% of the on-time, the energy saving from APD could be as high as 30 kWh/year per console.

It has also been suggested that the introduction of power scaling technology, i.e. where a product dynamically and proportionately varies its power consumption as its workload changes, could reduce the power consumption across all modes (ECOS, 2011). Assuming a reduction in power consumption of 10% across all modes, for example, would result in a reduction of approximately 10 kWh/year per console for those consoles in use, and 6 kWh/year per console for new HD consoles available.

These examples emphasise the importance of a representative energy use estimate when evaluating possible options for manufacturers to improve the energy efficiency of consoles.

5. Conclusions

This research has calculated estimates of the energy use of HD consoles in use (sold between 2005 and 2011 inclusive) and new HD consoles on sale at the beginning of 2012 at 102 kWh/year and 64 kWh/year respectively. These figures narrow down the range of existing estimates substantially (between 64 and 146 kWh/year for consoles in use) providing more accurate and representative data. The new estimates also provide a more detailed and transparent estimate of HD games console energy use, with the contribution of each mode to the total energy use reported. The analysis also demonstrates that uncertainty around console usage has a large impact on resulting energy use estimates.

These estimates could be used to evaluate the effectiveness of different approaches and technologies to reduce the energy use of consoles, and ultimately help to set baselines and improvement scenarios for use in energy efficiency and standards development.

Further research could significantly improve the analysis, including

- measured power consumption data for all models of HD console sold since launch in 2005;
- sales data for each model of HD console to allow the average power consumption for consoles in use to be weighted accordingly; and
- collection of further data to establish if usage is changing, whether users in different regions use their consoles differently, whether usage time is increasing as more functions and services become available on consoles and the proportion of users that have APD enabled. Usage is also shown to have the greatest effect on console energy use in the sensitivity analysis.

Furthermore, as data become available on the usage and power consumption of the Wii U, the results of this study can be updated so that all HD consoles currently on sale are considered in the analysis.

Acknowledgements

This work is supported by the UK Engineering and Physical Sciences Research Council through funding the Industrial Doctorate Centre in Sustainability for Engineering and Energy Systems at the University of Surrey. We would also like to thank the sponsor organisation, Sony Computer Entertainment Europe Limited, for their funding and support.

References

AEA, 2009. Building on the Eco-design Directive, EuP Group Analysis (I) ENTR Lot 3 Sound and Imaging Equipment Draft Task 1-5 Report.
AEA, 2010. Building on the Eco-design Directive, EuP Group Analysis (I) ENTR Lot 3 Sound and Imaging Equipment Task 1-7 Report.
ARS Technica, 2008. IBM shrinks cell to 45 nm. Cheaper PS3s will follow [Online]. Available from: 〈http:/arstechnica.com/gaming/2008/02/ibm-shrinks-cell-to-45nm-cheaper-ps3s-will-follow/〉 (accessed 15.08.12).
Console Manufacturers, 2011. Energy Efficiency of Games Consoles: Draft Ouline Proposal to Further Improve the Energy Consumption of Games Consoles.
Console Manufacturers, 2012a. Energy Savings of the Console Manufacturer Industry Proposal.
Console Manufacturers, 2012b. Proposal to further improve the energy consumption of games consoles.
Consumer Electronics Association, 2010. Consumer Electronics Association Gaming and Energy Study.
Crockett, L.J., Schulenberg, J.E., Peterson, A.C., 1987. Congruence between objective and self-report data in a sample of young adolescents. Journal of Adolescent Research 2, 383–392.
Danish Technological Institute 2007. Final Test Report Sony PlayStation®3.
ECOS, 2011. Power Scaling in Proportion to Data Processing.
Energy Resources Conservation and Development Commission, 2012. Order Instituting Rulemaking Proceeding. In: State of California (ed.).
EnergyConsult, 2012a. Video Game Consoles: Energy Efficiency Options.
EnergyConsult, 2012b. Video Game Consoles: Energy Efficiency Options—DRAFT.
EnergyStar®, 2009a. EnergyStar® Program Requirements for Computers Version 5.0.
EnergyStar®, 2009b. EnergyStar®,Program Requirements for Computers, Version 5.1 Game Console Requirements—Draft Final.
Equipment Energy Efficiency Program, 2010. Home Entertainment Products: Product Profile.
Europa, 2010. The EU Climate and Energy Package [Online]. Available from: 〈http:/ec.europa.eu/clima/policies/package/index_en.htm〉 (accessed 04.05.11).
European Commission, 2008. Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European parliament and of the Council with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment. Official Journal of the European Union, L339/45.
European Commission, 2009. Commission Regulation (EC) No 642/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for televisions. Official Journal of the European Union, L191.
European Commission, 2013. Commission Regulation (EU) No../.. of XXX amending Commission Regulation (EC) No 1275/2008 with regard to ecodesign requirements for standby, off mode electric power consumption of electrical and electronic household and office equipment and amending Commission Regulation (EC) No 642/2009 with regard to ecodesign requirements for televisions.
European Parliament and Council 2009. Directive 2009/125/EC of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast). Official Journal of the European Union, L285/10.
GameVision, 2010. Spring 2010 European Consumer Intelligence Report.
GameVision, 2011a. Autumn 2011 Compass European Consumer Intelligence Report.

GameVision, 2011b. Spring 2011 Compass European Consumer Intelligence Report.
GameVision Europe, 2009. Autumn 2009 European Consumer Intelligence Report.
GameVision Europe, 2010. Autumn 2010 European Consumer Intelligence Report.
Hittinger, E. 2011. Power Consumption of Video Game Consoles Under Realistic Usage Patterns.
Hittinger, E., Mullins, K.A., Azevedo, I.L., 2012. Electricity consumption and energy savings potential of video game consoles in the United States. Energy Efficiency 5, 531–545.
Interactive Software Federation of Europe, 2010. Video gamers in Europe 2010.
Interactive Software Federation of Europe, 2012. Video Games in Europe: Consumer Study Power Consumption Extract.
Intertek, 2012. Impact Assessment Study for Sustainable Product Measures: Lot 3 Sound and Imaging Equipment, Extract of Task 4 (Draft content) Identification of Policy Options for Video Game Consoles.
Intertek/Defra, 2012. Household Electricity Survey: A Study of Domestic Electrical Product Usage.
Lee, L., Westerlind, L., Schauer, L., 2009. Stay ahead of the curve! Responding to shifting baselines. In: Energy Program Evaluation Conference, Portland, pp. 352–360.
Market Transformation Programme, 2009a. BNCE GC01: Game Consoles (GCs) Government Standards Evdience Base 2009: Key Inputs.
Market Transformation Programme, 2009b. BNCE GC02: Game Consoles (GCs) Government Standards Evidence Base 2009: Reference Scenario. In: DEFRA (ed.).
Nielsen, 2009. The State of the Video Gamer: PC Game and Video Game Console User Fourth Quarter 2008.
Nielsen, 2010. Game Consoles Edge Closer to Serving as Entertainment Hubs [Online]. Available from: 〈http:/blog.nielsen.com/nielsenwire/online_mobile/game-consoles-edge-closer-to-serving-as-entertainment-hubs/〉 (accessed 09.05.12).
Nielsen. 2013. Play Vs. Stream: The Modern Gaming Console [Online]. Available from: 〈http:/www.nielsen.com/us/en/newswire/2013/play-vs–stream–the-modern-gaming-console.html〉 (accessed 28.03.13).
NRDC, 2008. Lowering the Cost of Play: Improving the Energy Efficiency of Video Game Consoles.
NRDC & ENERGY SOLUTIONS, 2011. Proposal Information Template-Game Consoles 2011 Appliance Efficiency Standards.
OECD/IEA, 2009. Gadgets and Gigawatts: Policies for Energy Efficient Electronics. International Energy Agency.
The games console. 2011. A Brief History of the Home Video Game Console [Online]. Available from: 〈http:/www.thegameconsole.com/videogames70.htm〉 (accessed 04.08.11).
Thomas, S., Boonekamp, P., Vreuls, H., Broc, J.-S., Bossebouef, D., Lapillonne, B., Labanca, N., 2010. How to measure the overall energy savings linked to policies and energy services at the national level? International Energy Program Evaluation Conference, 2010, Paris.
USEPA, 2013. The U.S. Environmental Protection Agency (EPA) Recognition Program for Games Consoles: Performance Requirements Version 1.0.
Vgchartz, 2012a. Monthly Hardware Trends.
Vgchartz, 2012b. Weekly Hardware Comparisons—Europe [Online]. Available from: 〈http:/www.vgchartz.com/tools/hw_date.php?reg=Europe&ending=Weekly〉 (accessed 10.08.12).
Vgchartz, 2013. Platform Totals [Online]. Available from: 〈http:/www.vgchartz.com/analysis/platform_totals/〉 (accessed 25.04.13).
Webb, A., Mayers, K. & France, C., 2011.Estimating consumer usage of games consoles. Conference for the Engineering Doctorate Programmes in Environmental Technology and Sustainability for Engineering and Energy Systems, 2011 University of Surrey.