REPORT ON THE 2017 REVIEW OF THE GAME CONSOLE SELF-REGULATORY INITIATIVE

Final report: October 13th, 2017

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EXECUTIVE SUMMARY AND CONCLUSIONS

This report explains the process undertaken by the Signatories to review the essential elements of the SRI to determine whether any revisions are necessary, taking into consideration the latest technological and regulatory developments.

As a result of the review, various revisions to the SRI are proposed.
The key revisions proposed concern:

- Reduction of tier 4 power levels to match efficiency progress
- Inclusion of power caps for 4K modes
- Introduction of a new higher performance category
- Future-proofing the SRI with conditions to trigger future reviews
- New removability and material efficiency information requirements
- Alignment with new SRI guidelines (COMMISSION RECOMMENDATION of 30.11.2016)

The SRI remains the preferred choice for addressing the energy efficiency of games consoles, due to ease of reaching agreement and the speed of technology development within the sector.

Industry Compliance with the SRI

Under the SRI, each Signatory is required to submit an annual Product Compliance Report (PCR) to the Independent Inspector for each of its game console models in scope.
Since formal endorsement of the SRI in April 2015, the Signatories have undergone two reporting cycles (covering consoles placed on the market in 2015 and 2016, respectively). The Independent Inspector determined that all Signatories were compliant with their SRI commitments for both reporting periods. Improvements to the reporting procedure were made in autumn 2016, after the 1st reporting period, resulting in a smoother process and clearer understanding of expectations for all parties.

Calculation of Energy Savings

This section quantifies the energy savings made by ultra-high definition capable games consoles sold in Europe, driven by the adoption and implementation of the SRI.

To date, the games console SRI resulted in an estimated 2.4 TWh of energy saving in 2016 (and 5.4 TWh to date overall), and is expected to result in an energy saving of 5.1 TWh in 2020 for UHD-capable games consoles. This is significantly higher than the 1.1 TWh savings estimated by 2020 in the original SRI. This is largely due to manufacturers adopting a large variety of energy efficient technologies, reducing power consumption of consoles more rapidly than expected. Over the life time of current generation games consoles, energy savings are expected to be in the order of 36.3 TWh – which is more than the annual energy production of Denmark. As such, energy savings have been maximised for currently available consoles beyond original expectations.

Future Technologies

From Pong to Xbox Scorpio and PS4 Pro, where the video experience evolved from small-screen black-and-white CRTs to high-frame-rate, high-dynamic response and ultra-high definition, the computational performance of games consoles has increased exponentially. The advances in computerized simulations and video rendering have combined to provide an extremely immersive and lifelike gaming experience inconceivable back in the days of Pong.

Whatever innovations are yet to come in gaming, it is possible that increases in the computing power of games consoles will enhance performance in a number of areas, and not only display resolution. For example, frame rate is also a key consideration for gaming and for Virtual Reality, alongside other factors such as scene complexity and density, the sophistication of artificial intelligence of non-player characters, and many other aspects.

Review of Benchmarking

This section summarizes the testing and findings detailed in the research paper “Performance benchmarks for consoles”, by Jonathan Koomey, Kieren Mayers, Joshua Aslan and James Hendy (presented at IEEE Green ICT Workshop, May 24, 2017). The paper reviews potential benchmarks for active gaming, evaluates the power measurements taken of consoles playing a variety of games, and also examined important areas of console performance.

The dynamic nature of consoles creates extreme complexity. It is unlikely that meaningful metrics for comparing *gaming performance* can ever be developed for game consoles and gaming PCs (note that it is possible to measure and report average power consumption of games, however – but not gaming performance / workload). The complexity of these devices makes it difficult to define computational output in a way that can be accurately, consistently, and correctly compared across game consoles or between consoles and PC gaming machines. Without consistent computational benchmarks, it is unlikely that a benchmark for active gaming will ever be sufficient for establishing efficiency regulations or utility incentives to promote more efficient products.

Review of Material Efficiency

This section reviews the SRI's current non-energy efficiency commitments and outlines possible additional requirements proposed for update of the SRI, when considering the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy, COM(2015) 614 and material efficiency requirements.

Out-of-warranty repair service for games consoles is provided, so many are already repaired at end-of-life, extending their useful lifetime (one signatory reports around one in ten of their repairs are out-of-warranty). Repair processes are closely managed by the industry to ensure quality of repair and also maintain intellectual property rights regarding proprietary components. Nevertheless, this section of the report outlines a number of possible additional commitments proposed for inclusion in the updated SRI to further improve the recyclability and reparability of games consoles.

Future Commitments and Proposals

The SRI should be reviewed in 2019 at the latest, or earlier if any Signatory announces specifications for a new console with improved computing performance (e.g. improved GPU performance), in which case the review should be completed within one year.

Manufacturers would prepare and submit sufficient information and justification for any such new category of consoles to the SRI Steering Committee and seek confirmation by the Commission before such review is triggered. Once a review

of any higher performing consoles (those either with improved graphical output or with higher performing technical specifications for components such as CPU, GPU, and memory, compared to those presently defined in the VA) starts, a new category of console and corresponding requirements would be added to the SRI.

Alignment of the SRI with the Commission's Guidelines for self-regulation measures

This section outlines proposed changes to the SRI to comply with the new Guidelines for self-regulation measures published by the European Commission on the 30th November 2016. A systematic and thorough process was agreed by the Signatories to identify which additions or changes were still required to fully comply with the Guidelines.

This review process found that the SRI was already compliant with the Guidelines in most key areas, and identified additional modifications and additions to further normalise the SRI with the Guidelines.

INTRODUCTION

Background on the SRI and its Signatories

The development of the Game Console Self-Regulatory Initiative ("SRI") under the Ecodesign Directive (2009/125/EC) started in 2010 and was formally endorsed in April 2015.

The Signatories of the SRI are the three major game consoles manufacturers: Microsoft, Nintendo and Sony.

The aim of the SRI is to reduce the environmental impact of games consoles over their life-cycle and to achieve energy savings through better design. Under this SRI, manufacturers commit to make ambitious improvements to the energy and material efficiency of their consoles. The SRI remains the most effective approach to ensure the energy efficiency of games consoles: it achieves policy objectives more quickly and at lesser expense than mandatory requirements:

- There are only three manufacturers: easier to reach agreement
- The rate of technology improvement outpaces regulatory processes
- Substantial differences between platforms difficult for standardisation

The current SRI specifies commitments regarding maximum power limits, auto-power down, market coverage, resource-efficiency/ end-of-life design, and user information requirements for different types of mains-powered games consoles, which use more than 20 watts in Active Game mode, "placed on the market" in the EU. When determining possible new commitments, the Signatories consider ways to improve game console energy efficiency without compromising console performance and the gaming experience. Gamers should also benefit by receiving additional information on the energy consumption of their consoles and instructions on how to minimise energy consumption.

The Games Console SRI is a world-leading approach. It is the first agreement of its kind for consoles. As each producer develops and distributes their models globally, the SRI provides a *de facto* global standard.

Objective of the Report

As part of their obligations under the current SRI, the Signatories are required to review the SRI's essential elements in 2017 with a view to updating existing provisions and, if feasible, including new commitments. The objective of this report is to provide a brief overview of the SRI, including its development to date, and detailed description of the Signatories' research and review process underlying the proposed amendments to the SRI.

Review Process Timescales

The first stage or phase of the review process happened in the 1st half of 2017. This stage incurred the bulk of the work, as it included the research and feasibility study on what could be possible to achieve technologically and practically. Informal feedback from preliminary review with the Commission and the following stakeholders has already been considered in this review report and the revised agreement:

- NRDC
- EEB
- ECOS

The second stage of the process, below, is estimated to span from August 2017 until April January 2018. The planned timelines are general and represent 'working-in-progress', as confirmation from the Commission on dates for future Consultation Forum meetings is required in order to plan in more detail.


Oct 17
Finalise proposal
Nov 17
Present proposal to EU Consultation Forum
Dec 17-Jan 18
Review all stakeholder comments & update SRI agreement
Fifth Steering Committee meeting
Jan 18
Revised agreement adopted

COMPLIANCE WITH THE SRI

Under the SRI, each Signatory is required to submit a yearly Product Compliance Report (PCR) to the Independent Inspector for each of its games console models in scope.

The Inspector is an independent third-party (Intertek) which collects and reviews console energy consumption data and other information submitted by the Signatories in order to verify their compliance with the SRI. Based on its review of the Product Compliance Reports, the Independent Inspector produces an Annual Compliance Report (ACR).

To date, there have been 2 reporting cycles from which data from the Signatories was collected to inspect compliance with the SRI: 2015 and 2016. The first ACR was published in May 2016, and the second in May 2017.

After the first reporting period, and with lessons learned, improvements to the reporting procedure were made resulting in a smoother process and clearer understanding of expectations for all parties.

In order to comply with the Self-Regulatory Initiative, Signatories must achieve the following:

- Demonstrate that the SRI covers more than 80% of the games consoles sold in the EU for the preceding reporting period (bi-annually);
- Ensure that Product Compliance reports for all games consoles within the scope of the SRI are submitted to the Independent Inspector on time;
- Ensure that the Product Compliance reports for all games consoles are complete;
- Ensure that no more than 10% of products, within the scope of the SRI, from an individual Signatory fail to comply with the commitments of the SRI.

All three manufacturers met their SRI obligations, including those stated above, for both reporting periods.

Further improvements to the process shall be carried out in view of this Review, including the ones prompted by adherence to the Guidelines for Self-Regulation Measures.

CALCULATION OF ENERGY SAVINGS ACHIEVED

The purpose of this section of the report is to quantify the energy savings made by ultra-high definition capable games consoles sold in Europe, which were the principal focus of energy saving measures targeted by the SRI. Energy savings are achieved through the adoption of power management features and power caps for certain modes; this has been achieved by adopting a range of best available technologies that result in these consoles having lower energy consumption than when compared to business-as-usual.

It was estimated that the SRI would achieve energy savings of 1.1 TWh by 2020. These savings were calculated based on the estimated electricity consumption of the PlayStation 4 and Xbox One with predicted energy efficiency improvements and power management features required to meet the SRI and other regulations (for example, power cap tiers and automatic power down) and compared to the baseline electricity consumption (no energy efficiency improvements made). This review provides updated estimates using power consumption data for all UHD model variants released to date, as well as sales data as compiled by VGChartz[1].

Methodology

Typical Electricity Consumption (TEC) is the method employed to estimate the energy consumption of the PlayStation®4 and Xbox One, formulated by the Energy Star Program[2]. This method allows for a calculation of a weighted average energy usage, based upon the time spent in each particular mode and the power consumption of that mode. The formula for the TEC is shown in Equation 1.

$$TEC = P_1T_1 + P_2T_2 + \cdots + P_nT_n$$

n = console use phase mode

P = power consumption in mode n (W)

T = time spent in mode n (s)

Equation 1: Typical Electricity Consumption (EnergyStar, 2009)

[1] http://www.vgchartz.com/tools/hw_yoy.php?reg=Europe&start_year=2013&end_year=2017&console=

[2] https://www.energystar.gov/ia/partners/manuf_res/Imaging%20Equipment%20TEC_Test_Procedure.pdf

The time spent in a specific mode, T, has to date been estimated through conducting/analysing consumer surveys and, to a lesser extent, meter recordings. The usage estimates used in this analysis are derived from Webb (2014)[3], and subsequently verified by a study by Lawrence Berkeley National Laboratory[4], which conducted a comprehensive meta-analysis of estimate usage studies; however, these applied specifically to previous generation consoles. Webb (2014) applied assumptions to derive the usage of current generation consoles, for example, one assumption applied is that the active usage (gaming, media and other functions whilst the console is on and in use) would decrease by 20% due to the Suspend-to-Ram feature (which allows the console to sleep without losing progress in the game). Suspend-to-Ram was available on the Xbox One from launch and was a feature introduced to the PS4 in March 2015; this is reflected in the two usage profiles show below in Tables 1 and 2 below.

[3] Webb, A. 2014. Evaluating Games Console Electricity Use: Technologies and Policy Options to Improve Energy Efficiency, Doctoral Thesis: University of Surrey.

[4] Desroches, L-B. et al. 2013. Video game console usage and national energy consumption: Reuslts from a field-metering study, Berkeley: Lawrence Berkeley National Laboratory.

Table 1: Usage profiles for the PlayStation 4 –

Mode	Usage (hours/day)		
	Baseline [a]	*Nov 2013 - Mar 2015* [b]	*Mar 2015 - present* [c]
Active gaming [d]	1.08	1.00	0.84
Media [e]	0.74	0.69	0.58
Other functions [f]	0.40	0.38	0.32
Total on time [g]	**2.22**	**2.07** [h]	**1.74** [i]
Standby [j]	4.79	4.17	4.23
Charging enabled [k]	0.00	0.60	0.61
Peripheral charging [l]	0.00	0.05	0.05
Rest (connected/suspend) [m]	16.99	17.11 [n]	17.36 [o]
Total	**24.00**	**24.00**	**24.00**

a. Business as usual case
b. Reduction in inactive time and therefore 'total on time' due to APD feature
c. Suspend-to-Ram feature introduced, reducing inactive time and therefore 'total on time'
d. Based on Nielsen (2017) active usage splits and 'total on time'
e. Based on Nielsen (2017) active usage splits and 'total on time'
f. Based on Nielsen (2017) active usage splits and 'total on time'
g. Mean usage data for previous generation consoles from Nielsen (2009, 2010), MTP (2010), ISFE (2010), Defra (2012), LBNL (2013) - assuming 25% increase in usage due to new features
h. APD reduces 'total on time' by 0.15 h/day, based on 30% of 'total on time' spent inactive (AEA, 2010), 86% of users enabling APD and average APD time of 45 minutes
i. Suspend-to-Ram reduces 'total on time' by 0.41 h/day, based on inactive time of 20 minutes before APD
j. Based on 78% users enabling connected standby (VGChartz, 2010), assuming remaining % in standby
k. 12.5% of users enable low power peripheral charging based on Nielsen (2010)
l. Estimated average time spent chargin peripheral, based on laboratory measurements
m. Based on 78% PS3 users enabling connected standby (VGChartz, 2010)
n. Connected standby
o. Based on assumption that all users who enabled connected standby, also enable suspend mode

Table 2: Usage profiles for Xbox One

Mode	Usage (hours/day)	
	Baseline [a]	*Nov 2013 - Mar 2015* [b]
Active gaming [c]	1.38	1.08
Media [d]	0.96	0.76
Other functions [e]	0.39	0.30
Total on time [f]	**2.72**	**2.14** [g]
Standby [h]	5.74	5.90
Connected standby [i]	15.53	15.96
Total	**24.00**	**24.00**

a. Business as usual case

b. Reduction in inactive time and therefore 'total on time' due to APD features

c. Based on Nielsen (2017) active usage splits and 'total on time'

d. Based on Nielsen (2017) active usage splits and 'total on time'

e. Based on Nielsen (2017) active usage splits and 'total on time'

f. Mean usage data for previous generation consoles from Nielsen (2009, 2010), MTP (2010), ISFE (2010), Defra (2012), LBNL (2013) - assuming 25% increase in usage due to new features

g. APD and Suspend-to-Ram features reduces total 'total on time' by 0.58 h/day, based on 30% of 'total on time' spent inactive (AEA, 2010), 86% of users enabling APD and average APD time of 45 minutes

h. Based on 73% users enabling connected standby (VGChartz, 2010), assuming remaining % in standby

i. Based on 73% Xbox 360 users enabling connected standby (VGChartz, 2010)

To calculate electricity consumption for consoles in Europe, the TEC profile for each console is multiplied from the stock in use, which is derived from the sales figure as compiled by VGChartz. The stock in use is then calculated by applying an industry wide accepted retirement function based on Koomey (1998)[5]. Estimates for future electricity consumption are based on the sales curve shown in Figure 1 below, which shows the average console sales of all consoles on sale in Europe from 1996 to 2017. The projected stock is then calculated based on the ratio of actual sales for the specific console model to average console sales (Figure 1).

[5] Koomey, J. G., et al. 1998. Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector [Online]. University of California. Available: http://enduse.lbl.gov/Info/LBNL-39511.pdf.

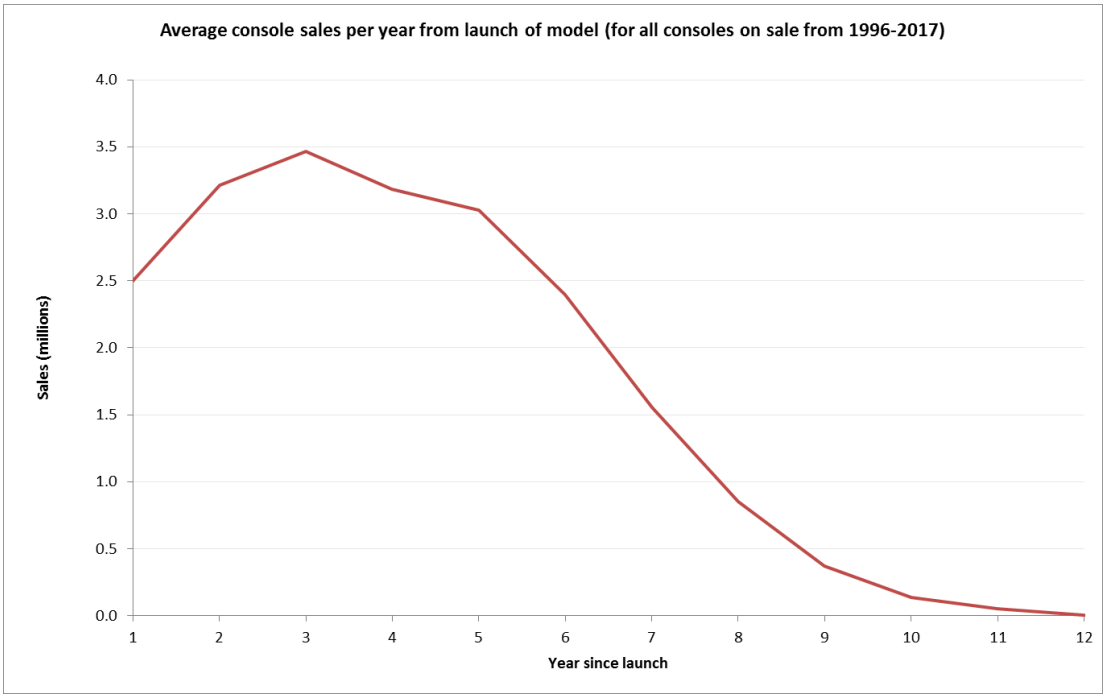


Figure 1: average console sales data for all consoles on sale in Europe from 1996 to 2017 (sales data collated from VGChartz[1])

Results

The power, P, of each mode is gathered empirically by measuring the power consumption using a power meter. The values for power consumption of the four PlayStation 4 models and two Xbox One models are shown in Table 2 and Table 3, respectively, below.

Table 3: Power consumption of PlayStation 4 models and corresponding TEC profiles

Mode	Power consumption (W)			
PlayStation 4 model	*CUH-1016A*	*CUH-1116A*	*CUH-1216A*	*CUH-2016A*
Active gaming	137.2	115.1	98.5	78.9
Media	90.1	84.9	69.6	48.0
Other functions	80.3	75.9	58.8	42.8
Standby	0.3	0.4	0.3	0.2
Charging enabled	6.3	6.0	3.7	4.0
Peripheral charging	11.4	11.4	11.4	11.4
Connected standby (Rest)	2.7	2.8	1.3	1.2
TEC (kWh/year) Nov 13 – Mar 15	**102.3**	**93.6**	**-**	**-**
TEC (kWh/year) Mar 15 - present	**89.63**	**82.4**	**69.9**	**55.7**

Table 4: Power consumption of Xbox One models and corresponding TEC profiles

Model	Power consumption (W)	
Xbox One model	*Xbox One*	*Xbox One S*
Active gaming	112	62
Media	66.7	32.7
Other functions	61	27
Standby	0.48	0.4
Connected standby	18	8
TEC (kWh/year)	**175.2**	**83.9**

Table 4 below shows the estimated energy savings for ultra-high definition capable consoles, over different timescales.

Table 5: Baseline electricity consumption, estimated electricity consumption and energy savings for PlayStation 4 and Xbox One

Time period	Electricity consumption (TWh)		
	Baseline electricity consumption	*Estimated electricity consumption*	*Energy savings*
Launch to date	10.8	5.4	**5.4**
Annual in 2020	7.7	2.7	**5.1**
Lifetime	58.7	22.4	**36.3**

It is estimated that, to date, energy savings for ultra-high definition capable consoles total 5.4 TWh, approximately equivalent to the annual energy output of a 850 MW power station (assuming 70% capacity factor). In 2020, it is estimated annual savings will reach 5.1 TWh, when comparing estimated electricity consumption to the baseline. Further to this, energy savings over the lifetime, also shown in Figure 2 below, of these consoles is estimated to be 36.3 TWh in total – around 30 percent higher than the annual electricity production of Denmark in 2014[6] (31.0 TWh). Estimates exclude energy savings from HD consoles and UHD gaming capable consoles, as the future market of these consoles is unclear.

[6] Cia.gov. (2017). *The World Factbook — Central Intelligence Agency*. [online] Available at: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2232rank.html [Accessed 4 May 2017].

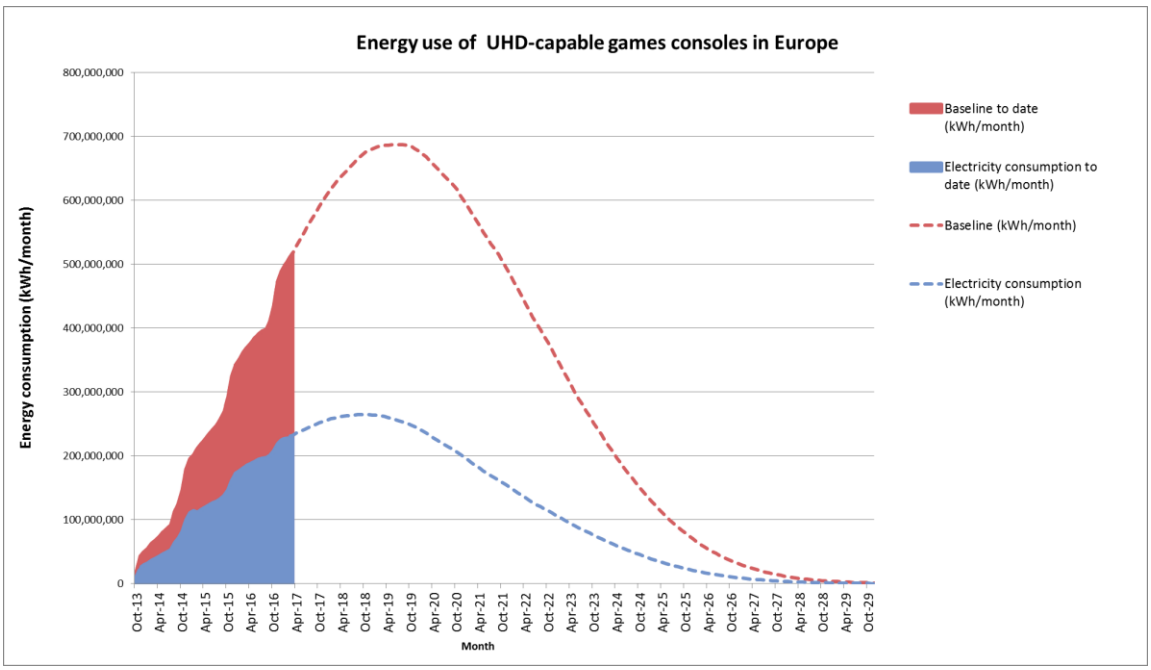


Figure 2: Console electricity consumption (blue) and baseline electricity consumption (red) in Europe – the area in between the curves is the avoided energy use (or energy savings)

Analysis

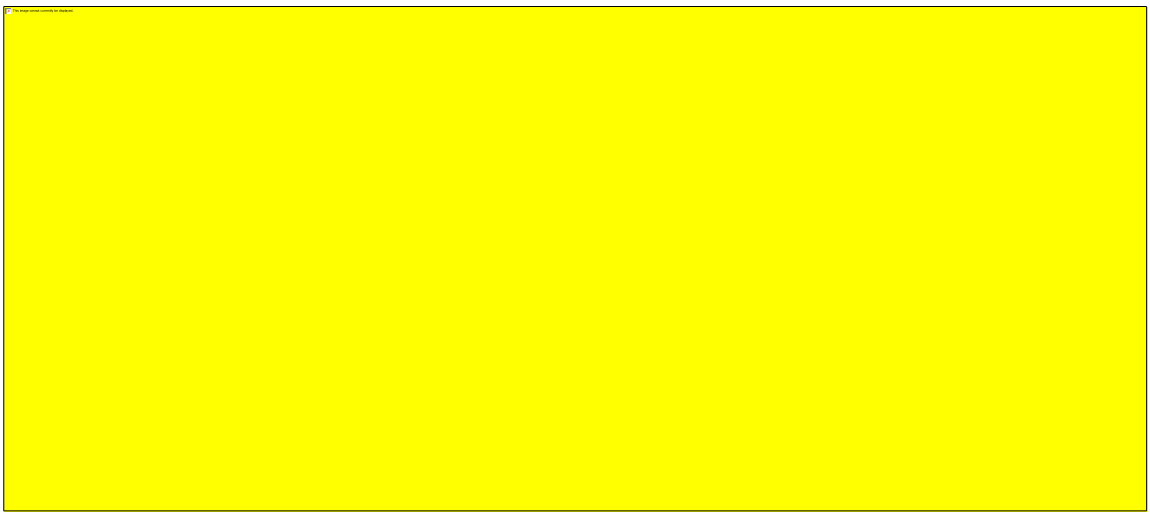
Based on original predictions, compliance with SRI requirements was estimated to result in energy savings of 1.1 TWh by 2020. Energy savings achieved, however, have significantly exceeded this estimate. This is because console power consumption has been reduced over a shorter timescale than previous generations. This is largely due to the adoption of a wide variety of energy efficient technologies by manufacturers; for example:

- *System on a Chip*
- *Efficient power supplies*
- *Clock and power gating*
- *Background download*
- *Low power peripheral charging*
- *Auto power down (APD) set to maximum 1 hour for gaming*
- *APD of USB charging*
- *Suspend to RAM: power down without losing progress*
- *Optimisation of SOC operation and scaling, particularly for media play*
- *Optimisation of memory operation and hardware*
- *Blu-ray electronics condensed and integrated onto the motherboard*
- *Other minor component integrations*
- *Die shrink*

Consoles producers have now adopted a variety of energy efficient technologies suggested within previous studies conducted by academics, expert consultants, and environmental NGOs (Table 5). Exceptions are:

- The use of separate video architecture, which is not economically or technically feasible. Webb (2014) estimates the payback period from consumer energy cost savings vs the cost of additional components would significantly exceed estimated console product lifetime.[7] This was the case for the original SRI proposal, and even more so today considering the power savings achieved in media mode. Technically, introducing separate video circuitry would require that the console circuitry powers down while the separate video circuitry powers up, introducing significant and unnecessary latency.
- The use of dynamic frequency and voltage scaling (where the frequency of a CPU can be adjusted automatically to save energy),[8] which is a relatively new energy efficiency technology for new chip architectures. Implementing such new technologies would require complete redesign of existing console's operating systems and chip architecture. Typically chip design can cost hundreds of millions of dollars, which is not feasible in the mid-point of console lifetime.

Table 5: Review of efficiency improvements suggested for games consoles in previous studies



[7] Webb, A. E. *Evaluating Games Console Electricity Use: Technologies and Policy Options to Improve Energy Efficiency*. Engineering Doctorate Thesis, University of Surrey.

[8] https://en.wikipedia.org/wiki/Dynamic_frequency_scaling

Note: assessment of technology adoption is based upon ultra-high definition capable console models

As such, gaming power consumption has been systematically reduced to a minimum with little further opportunity for reduction. In fact, PlayStation 4 and Xbox One consume less power in navigation and media modes than previous generation models (Figures 3 and 4 respectively).

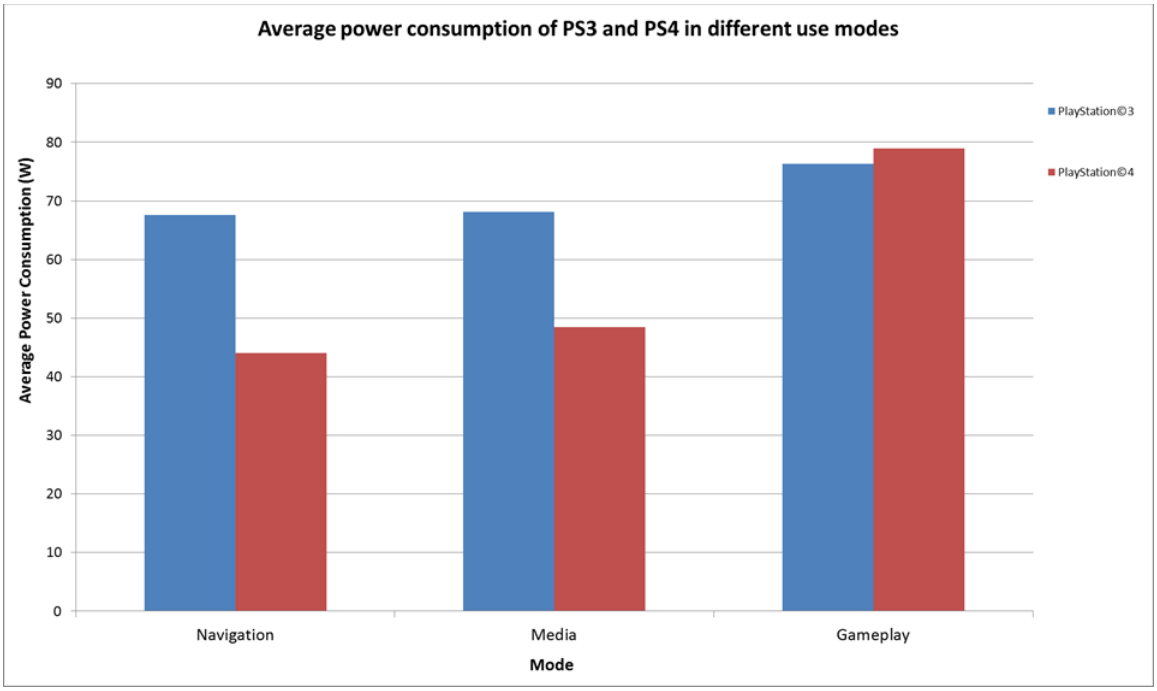


Figure 3: Power consumption of latest PS3 and PS4 models in navigation, media and gameplay modes

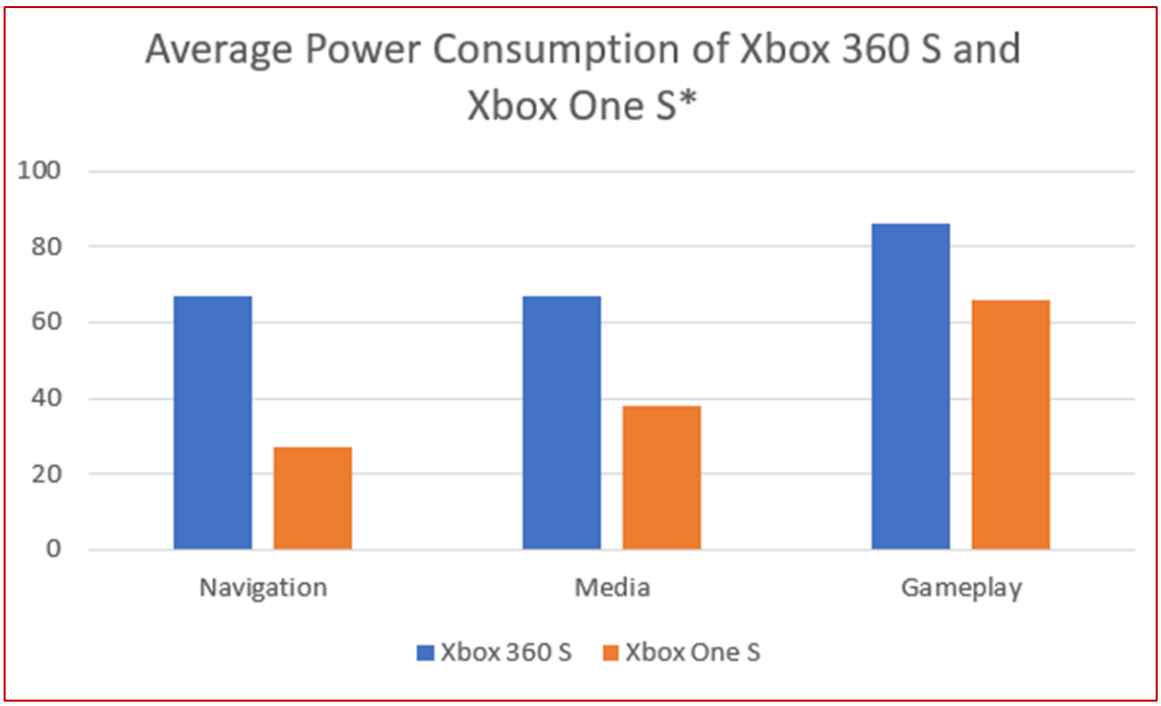


Figure 4: Power consumption (W) of Xbox 360 S and Xbox One S

Finally, as discussed in the next section, Sony launched the new PlayStation®4 Pro 4K gaming console in 2016, which has around twice the performance of PlayStation®4 and is capable of both media and game play in 4K resolution. This console also incorporates the energy efficient technologies listed above, but being a new console is not included in energy saving estimations as at present future sales are unknown. For reference, power consumptions of PlayStation®4 Pro are (based on an average of 5 samples, and an average of 3 games):

Table 6: Power consumption of PlayStation®4 Pro

Mode	Power consumption	
	HD	UHD
Navigation	*60.4*	*66.7*
Blu ray media play	*59.5*	*78.7*
Streaming media play	*59.3*	*89.4* *(YouTube)*
DVD media play	*54.1*	*N/A*
Average game play	*126.1*	*148.1*

Conclusions

To date, the games console SRI has resulted in 5.4 TWh of energy savings for ultra-high definition capable consoles, and savings for the year 2020 are expected to be 5.1 TWh, over four times the 1.1 TWh savings originally targeted in the SRI. Over the lifetime of current generation games consoles, energy savings are expected to be in the order of 36.3 TWh – 30 percent higher than the electricity production of Denmark. As such, energy savings have been maximised for currently available consoles beyond original expectations.

In the beginning, there was Pong (**Error! Reference source not found.**). It was a simple machine which hooked up to the antenna port on a black-and-white cathode-ray-tube television and allowed one or two players to play ping-pong by turning knobs that moved virtual “paddles.”

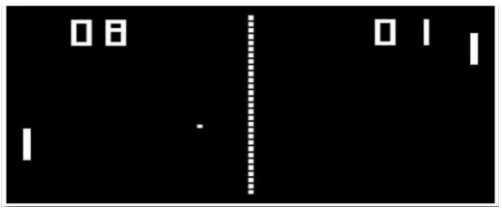


Figure 5: Pong, one of the earliest video games

Over the years, taking advantage of advances in computer technology and TV technology, electronic gaming evolved.

Figure 6: Evolution of consoles in the last two decades

The Oxford English Dictionary defines a games console as “a small electronic device for playing computerized video games.” It further defines a game as “an activity that one engages in for amusement or fun.” Olympic games, football games, children’s games, Pong; they come in all shapes and sizes. The one element they have in common is that they are *fun*.

As the video experience evolved from small-screen black-and-white Cathode Ray Tubes (CRTs) to high-frame-rate, high-dynamic response and Ultra-High

Definition (UHD), the computational function increased in a non-linear fashion. For example, a change in resolution from High-Definition, (920 thousand to up to 2 million pixels per frame) to Ultra-High Definition, 4k (approximately 8 million pixels per frame) requires a *squaring* of the necessary computational power. Other enhancements such as High Dynamic Range (HDR) and higher frame rates also add to the computing load. At the same time, the use of computers to simulate believable and amusing user experiences – games – has evolved as well. The advances in computerized simulations and video rendering combine to provide an extremely immersive and lifelike gaming experience inconceivable back in the days of Pong (**Error! Reference source not found.**).

Despite the additional processor loads, some of the games consoles currently on the market are capable of streaming UHD video media, and some of the latest console models which even run games in UHD resolution, accomplish this using less electricity than was required by some of the previous generation consoles to stream High Definition. This is accomplished using a number of powerful advances in silicon technology commonly referred to as Moore's Law – the observation that the number of transistors in a dense integrated circuit doubles approximately every two years, primarily by shrinking the number of transistors that can be stuffed on a chip. As a result, the amount of electricity required for a given unit of computing has gone down in step functions over the last 40 years. However, the physical limits of silicon processing have begun to put the brakes on this phenomenon and we expect to see an added energy cost in the future for a commensurate increase in gaming power. One of our current challenges is to render the UHD experience in real-time gaming.

In addition, one area of increased interest is in virtual reality -- the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment. Right now, such equipment is in its nascent stages and the user experience is under continuous development, but a lot of work is being done in this area. It is worth noting that some of the present limitations, such as wearing a helmet tethered to a large processing unit, are the kinds of problems that, when solved, will enhance user experience – perhaps reminiscent of the Holodeck of Star Trek fame.

As for what is in the future will depend on the evolution of concepts like silicon die-shrink, video rendering, game rendering and game composition, and translating those concepts into a device that an interested gamer can afford to purchase and to operate. From a manufacturing perspective, conservation of the energy required to play a game has always been, and will always be, a key driver in the evolution of a new platform. The savings on the cost of manufacturing are passed on to the consumers through savings in the purchase of the hardware as well as a reduction in energy cost in use.

Whatever innovations are yet to come in gaming, it is possible that increases in the computing power of games consoles will enhance performance in a number of areas, and not only display resolution. For example, frame rate is also a key consideration for gaming and for Virtual Reality, alongside other factors such as scene complexity and density, the sophistication of artificial intelligence of non-player characters, and many other aspects.

REVIEW OF BENCHMARKING

Under the SRI, Signatories are required to consider "*the feasibility of including computational performance in console efficiency benchmarks, where applicable and comparable across devices performing gaming*" as part of the 2017 review.[9] This requirement was included to address the Commission's view that the review should include "*a commitment to attempt to cover the "gaming mode" (the main mode of a console)*".[10]

We have undertaken a detailed review of potential benchmarks, which included conducting power measurements with a variety of games. We also reviewed important areas of console performance with the guidance of energy efficiency and benchmarking expert Dr. Jonathan Koomey at Stanford University in the US. Following this detailed study (full report included in Annex C), our conclusion is that, due to the complexity of games consoles and their differences to PCs, there is no consistent way gaming performance and power consumption can be meaningfully measured and compared:

"*The dynamic nature of consoles creates extreme complexity. It is unlikely that meaningful metrics for comparing gaming performance can ever be developed for game consoles and gaming PCs. The complexity of these devices makes it difficult to define computational output in a way that can be accurately, consistently, and correctly compared across game consoles or between consoles and PC gaming machines. Without consistent computational benchmarks, it's unlikely that a benchmark for active gaming will ever be good enough on which to base efficiency regulations or utility incentives to promote more efficient products.*"

Koomey *et al.* 2017, p14 (see Annex C).

[9] See Section 3.2 of the "Self-Regulatory Initiative to further improve the energy efficiency of Games Consoles"

[10] http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8239

Note that this finding relates to the relative performance of different games on different consoles, and not to measuring average power consumption (which signatories will continue to measure and report).

In spite of this limitation, the existing SRI has already resulted in 4.8 TWh of energy savings to date, an estimated 31% of which was from reduced average power consumption in gaming mode. Substantial progress has been made, and the Commission's expectation to reduce power consumption in active gaming mode has already been addressed under the existing SRI framework. This is attributable to the adoption of specific energy saving technologies that reduce console power consumption in all modes in order to meet the power caps for navigation and media mode.

The review of possible benchmark methods in Annex C includes an analysis of a number of types of benchmarking approaches, including:

- Console GPU performance specifications (tFLOPS)
- PC GPU benchmarks
- Server SPEC & SERT benchmarks
- Frame rate
- Hardware performance indices / weighting

In order to establish an adequate energy efficiency benchmark for active gaming mode, it would be necessary to establish a metric representative of gaming performance and workload, which can be consistently applied to different console platforms and games. Gaming itself is a creative and innovative endeavour, aimed at maximising the enjoyment of the user. Clearly, measuring the amount of 'fun' any particular game delivers is not an easily quantifiable workload characteristic. There are multiple performance-related factors to be considered in determining a console's hardware specifications, and also when developing each different game. These include (but are not limited to):

- Frame rate
- Resolution
- Anti-aliasing

- Tone mapping
- Rendering
- Special effects
- Procedural texturing
- Scene complexity
- Graphical fidelity
- Dynamic reflections
- Visual density

Consequently, the power consumption of each console differs, depending not only on the particular hardware specifications and capabilities of that console, but also on the type of games played. Furthermore, the power consumption of each console varies at different stages of game play depending on user choices and activity. The detailed benchmarking study (in Annex C) includes power measurements demonstrating statistically significant differences in power consumption between different samples of the same console, different types of games, and also different stages of game play. Even playing the same game repeatedly on the same console results in very different power profiles (depending on the user activity and choices within the game).

Although it is possible to measure average power consumption of game play (indeed the SRI already requires signatories to report a representative measure of gaming power consumption), it is not possible to derive a comparable and representative benchmark of gaming performance or workload:

- **Repeatability and representativeness:** It is not possible to create a repeatable or representative gaming workload due to the limitless number of combinations an permutations of user actions and activity in any particular game, which make game play dynamic and unpredictable (user actions within a game impact gaming power consumption significantly).
- **Normalized to consistent levels of service:** It is not possible to normalise any measure of gaming performance to any consistent level of service; gaming performance is multi-faceted, abstract, and varies dynamically during game play.

- **Comparable across platforms:** Benchmarks are not comparable across console platforms; different console platforms have different architectures, operating systems, functions, and specifications that mean comparisons are difficult.

In conclusion, the development of a reliable energy efficiency benchmark for games console active gaming mode is infeasible. It is nevertheless worth noting that the Signatories have reduced the energy use of active gaming already by 1.5 TWh under the framework of the current SRI (based on the data presented in the Section on “Calculation of Energy Savings Achieved”), so taking further measures to reduce energy consumption would be of limited additional benefit. Worse yet, limiting the active power consumption of any computational device would severely limit its performance and main function, thereby stifling its development and innovation.

Within the existing SRI framework, power caps are set for navigation and media modes, depending on broad console performance categories based on resolution alone (high definition and ultra-high definition capable). In addition, Signatories must publicly report a measure of average gaming mode power consumption. In the future, it is conceivable that console performance may be increased without a corresponding change in screen resolution. If a Signatory announces plans to launch a console with significant performance increase, its specific modes and functions, power requirements, and performance should be considered as part of a review of the SRI on a case-by-case basis (see section on “Future Commitments and Proposals”).

REVIEW OF MATERIAL EFFICIENCY

In the past few years, a lot of political attention has been given to measures that would improve material efficiency of electronic appliances. The EU aspiration to move from a linear production model to a circular economy is described in the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy, COM(2015) 614.

The waste hierarchy approach promoted at EU level seeks first to prevent that goods become waste by improving product durability, then to enable the reuse of components when a product is discarded and finally to recycle raw materials to feed them back into the production circle. While the waste management aspect is addressed in the EU Waste Framework Directive, policy measures that could help improve product durability are currently under discussion at EU level.

Views from the European Parliament, as expressed in the own-initiative report of the Internal Market and Consumer Protection Committee on a longer lifetime for products: benefits for consumers and companies and from the European Environmental Agency's report on Circular by design - Products in the circular economy, have helped the Signatories understand the societal and political expectations relating to improvement of product design to encourage product durability and ease of repair.

In order to determine what types of Circular Economy-related requirements could be implemented to help meet these expectations, the Signatories undertook a detailed and systematic review of the various technical reports, standards and documents available, examining how material efficiency has been addressed by different sectors as well as the circular economy package itself. The standards and documents reviewed include:

- JRC Technical Report: Feasibility study for setting-up reference values to support the calculation of recyclability / recoverability rates of electr(on)ic products – DRAFT REPORT

- NL Ministry Environment/Eco-design - Marking requirements for EEE items (relevance and feasibility)- Recycled content- Strategic metal recycling
- CEN-CENELEC-ETSI work programme in response to M/543 on material efficiency - BT154/DG10216/INF
- Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Closing the loop - An EU action plan for the Circular Economy
- IEEE1680.1, 4.3.1.6 JRC Science and Policy Report: Environmental Footprint and Material Efficiency Support for product policy
- Draft Commission Regulation (EU) Implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for electronic displays and repealing Regulation 642/2009 with regard to eco-design requirements for televisions
- OCAD3E Waste Electrical and Electronic Equipment Authorised Coordinator Agency
- Technical report: Application of environmental contribution modulation criteria
- EuroVAprint: Industry voluntary agreement to improve the environmental performance of imaging equipment placed on the European market, SRI V.5.2, April 2015
- JRC Technical Report: Analysis of durability, reusability and reparability - Application to dishwashers and washing machines
- EU GPP guidance for the purchase of Computers and Monitors
- Lot 5 TV materials efficiency requirements
- Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for electronic displays
- Austrian Standard ONR 192102 Label of excellence for durable, easy to repair electrical and electronic equipment
- Working Document: Potential Eco-design requirements for servers and data storage products

From this review, the Signatories compiled a list of the different types of material efficiency requirements and proposals currently under discussion in the EU. The

Signatories considered the feasibility of implementing each requirement for their consoles. A copy of their analysis is set out in Annex A. In addition, this list of possible requirements was reviewed with European Recycling Platform (one of Europe's largest Producer Responsibility Organisations, www.erp-recycling.org) who organise take-back and recycling of Waste Electrical and Electronic Equipment from households in most EU countries and is used by console producers to collect, treat, and recycle their products within the EU. This was then used to determine the possible additional SRI non-energy efficiency commitments.

The following sets forth the material efficiency commitments included in the current SRI:

- A refurbishment or out of warranty repair service for each games console will be made available, and supported by the following requirements:
    - Technical documentation shall be made available to authorised repair centres to enable repair or refurbishment of each games console
    - Spare parts shall be made available to authorised repair or refurbishment centres for each games console
    - To improve both recycling and reuse at end-of-life, maintenance and refurbishment of each games console shall be possible by non-destructive disassembly
    - Consumers will be informed of end-of-life processing, refurbishment, and out-of-warranty repair options available within the operating instructions of each games console (with instructions either provided with the console itself, onscreen or hardcopy, or online)

- To improve recycling at end-of-life, console plastics parts >25g will be marked indicating their material composition, with the following exceptions:
    - The part has <1cm^2 level surface available for marking
    - The performance or function of a part is compromised e.g. buttons with tactile surface, plastic lenses, or display screens
    - External transparent parts

- Marking is not technically possible due to the specific production method of the plastics used in the part e.g. extrusion moulding

Console manufacturers already provide effective out of warranty repair services, which are closely managed by the industry to ensure quality of repair and also protection of intellectual property rights regarding proprietary components. One of the SRI Signatories reports that around one in ten of every consoles repaired in its service operations are repaired out of warranty, extending its useful life and preventing it from becoming waste. Nevertheless, there are a number of possible new additional commitments proposed for inclusion in the SRI to provide for the recyclability and reparability of games consoles.

With respect to requirements in parallel EuP lots for PCs (lot 3), displays (lot 5), and enterprise servers (lot 9), an amended requirement for component removability is considered below:

- Manufacturers shall ensure that joining or sealing techniques do not prevent the removal of the components, applicable to games consoles, listed in point 1 of Annex VII of Directive 2012/19/EU, when present. Exemptions apply where non-removable joining and sealing techniques may be used to ensure either user safety necessary to comply with safety-related EU legislation or product quality necessary to avoid wear and tear that would otherwise shorten the product's useful life. For batteries, exemptions in the Battery Directive 2006/66/EC amended by Directive 2013/EC/EU apply.

- Accessing components shall be enabled by documenting the dismantling operations needed to access the targeted components[11], including for each of these operations: type of operation, type of fastening technique(s) to be undone, and tool(s) required.

In support of this, the European Recycling Platform confirmed that removability of components listed in Annex VII of the WEEE Directive was important in

[11] Components, applicable to games consoles, listed in point 1 of Annex VII of Directive 2012/19/EU.

ensuring effective treatment at end-of-life. On the other hand, they also pointed out that automated mechanical recycling is needed to recycle materials from components following pre-treatment, and so further removability would not necessarily result in increased recycling, which corresponds to the latest research on the yield and effectiveness of various WEEE recycling processes.[12]

In addition, based on further feedback from the European Recycling Platform, the following additional information can be provided for manual disassembly to improve recyclability:

- Whether plastic casing contains brominated flame retardants;
- Whether LCD displays contain mercury[13]

The above information shall be included within product disassembly instructions provided to repair and recycling operations in support of improved end-of-life recycling.

In addition to the requirements proposed above, NGO organisations suggested we should consider ensuring that plastic components >100 g are removable and made of polymers that are compatible for recycling. While this could indeed improve end-of-life recycling of our products within WEEE, we will need more

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[12] P. Ford, E. Santos, P. Ferrão, F. Margarido, K.J. Van Vliet, and O. Elsa. Economics of end-of-life materials recovery: a sudy of small appliances and computer devices in Portugal. *Environ. Sci. Technol.* DOI: 10.1021/acs.est.6b00237

[13] As defined in ANNEXES to the 2016 Draft COMMISSION REGULATION (EU) …/… of XXX implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for electronic displays, repealing Regulation (EC) No 642/2009 with regard to ecodesign requirements for televisions and amending Regulation (EC) No 1275/2008 with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment and Regulation (EU) No 617/2013 with regard to ecodesign requirements for computers and computer servers

'Mercury Free' means a product in which concentration values of mercury (Hg) by weight in homogeneous materials do not exceed 0.1% as defined in Directive 2011/65/EU of June 8, 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

time to evaluate this possibility and propose to include this in the next planned review of the SRI.

To support product life extension, the provision of the following information to consumers either provided with the console itself, onscreen, in hardcopy, or online, is proposed:

- How to keep products in good working condition (e.g. how to keep the product dust free, how to install system updates, how to remove trapped disks, etc.)
- How to delete personal data (e.g. if the consumer wishes to send the console for reuse)
- Options available (if any) to consumers to upgrade the performance of their consoles (e.g. installing a bigger hard drive)

In addition, following feedback from discussion with NGO organisations, we propose to retain the existing SRI commitment: “To improve both recycling and reuse at end-of-life, maintenance and refurbishment of each games console shall be possible by non-destructive disassembly”, but limited to key components required for repair including: motherboard, hard disk drive, optical drive, and internal power supply.

Furthermore, we considered a number of other possible aspects as summarised along with our conclusions below:

- **Providing consumer information on average product life span:**
  At present there is no way to measure the lifetime of Printed Circuit Board (PCB) or to accelerate the duty cycle for testing. Average product life span will be affected by a number of different factors like the amount the product is used, the environment it is used in, the way the item has been looked after and maintained, etc. For games consoles, improvements to product quality are made based on feedback received from repair channels over the lifecycle of each generation such that their reliability improves. As a consequence, many previous generation consoles are still in use, often as collector items. Surveys of WEEE arising have found

consoles are usually more than 5 years old when disposed (new console generations launched around every 5 yrs).[14]

- **Standardising use of plastic polymers:**
  While standardising or limiting the range of plastics polymers used in consoles could help improve the quality of plastics from automated or manual recycling process, it would severely limit design possibilities. To ensure the marketability of games consoles, it must be possible to give new games consoles a new look and feel. As above, we have already committed to ensure plastic parts >25 g are labelled by polymer type (where marking is feasible).
- **Standardising the components used for ease of repair:**
  Games consoles incorporate advanced, specialised, and proprietary technologies. Harmonising components would drastically limit innovation and undermine competition between producers. As above, we will ensure that key components are removable at end-of-life to facilitate end of life treatment and repair.
- **Making spare parts available to third party repair companies:**
  We already provide effective out-of-warranty repair services to consumers, so demand for third party repair is consequently low and each year we receive requests for parts for repair very infrequently, if at all. A survey of a third of Repair Cafes across Europe, registered with The Repair Café Foundation, found that 95% of respondents did not receive games consoles for repair at their ”cafés” at all, and for the overwhelming majority of the remaining 5%, consoles were not among the items bought in frequently. Our repair model is also already environmentally efficient and optimised in a way beyond what is possible through third party repair: before production of any model ends, we will try to predict stock of spare parts needed based on past experience, and avoid overstocking and wasting materials. Some repair centres used in the console industry even salvage and refurbish parts from models beyond recovery, or replace broken units with refurbished models if parts run low. On the other hand, making spare parts available to third party companies or to anyone who

[14] Survey on waste electronics disposal in Hampshire County Council in the UK conducted by R, Peagam and K. Mayers submitted to the Journal of Industrial Ecology (as yet unpublished)

requests them would be less efficient or environmentally beneficial, as the process would not be directly controlled by the Signatories, and we cannot predict third party requirements or usage for the future. This is likely to result in overstocking of spare parts that could eventually become redundant and end up as waste, which we currently avoid. Furthermore, third parties would not possess the proprietary tools to run the diagnostics on failures or the capacity to report this type of information back to the manufacturers in order to deliver product quality improvements over the product lifecycle which is vital in preventing future product failure. Allowing access to service modes would infringe intellectual property rights and is likely to result in third party companies trying to make their own counterfeit versions of console products and peripherals. Also, it would allow unqualified personnel to try and repair consoles, and as a result could jeopardise product safety for consumers.

- **Provide schematics and repair instructions on request:**
  Providing console technical schematics and repair instructions on request to any third-party repair centre would not be feasible. We would not be able to ensure safety and quality of the repaired consoles. If unqualified personnel have access to this information they may be encouraged to access core components of the product that should not be accessible for safety and quality reasons. Providing schematics would also infringe intellectual property rights and could result in companies trying to copy console technology. As above, we propose instead to provide FAQ instructions and / or tips for extending the product life so that consumers can fix minor faults and / or take precautionary steps to avoid such problems themselves.
- **Providing access to system software 'service modes':**
  Making firmware available to third party repairers is strictly not possible; doing so would infringe our main intellectual property rights (our core operating systems), and would allow our copyright protection systems to be circumvented, opening up the possibility for console games to be pirated.
- **Providing information on location and amount of critical metals, flame retardants, and 'recyclability indexes' to recyclers:**
  There is no demand from recyclers or our take-back schemes for

recycling information such as recyclability indexes or the amount of critical metals and flame retardants in our products. The European Recycling Platform confirmed, as part of this assessment, that such detailed information is not required and cannot be used during recycling. Obtaining such information from complex supply chains would be time consuming and of little value. This experience is shared by many companies who have already to date provided such information online for recyclers (according to IEC/TR 62635) over several years, and for the most part the information goes un-accessed and un-used. At present little is understood regarding loss of critical metals from raw materials production, from use in concentrations in products which are technically too low to recover and lost within the recycling process themselves[15] [16]. Where new technology may be developed in future, such as on critical metals, producers maintain direct relationships with their take-back and recycling schemes and can share information related to their products directly to recycling companies in support of their obligations under the WEEE Directive, which the European Recycling Platform confirmed was sufficient for future recycling development. As above, we will provide information on plastic polymers used, the presence of brominated flame retardants and use of mercury in screen backlights for use by recyclers.

Following the review, please see Section on “Future Commitments and Proposals” for an overview of proposed new requirements.

[15] Zimmermann, T. & S. Goesling-Reisemann. Critical metals and dissipative losses: A screening study. Science of the Total Environment. 461-462 (2013), pp 774-780.

[16] Zimmermann, T. & S. Goesling-Reisemann. Recycling potentials of critical metals – analysing secondary flows from selected applications. Resources. 3 (2014), pp291-318; doi:10.3390/resources3010291

FUTURE COMMITMENTS AND PROPOSALS

This section provides an overview of the changes we propose to the SRI, according to the review of commitments in the previous section.

The power consumption of games consoles has already been optimised and their energy use minimised as far as technically feasible, with very substantial energy savings (see Section on “Calculation of Energy Savings Achieved”). In addition, benchmarking of power consumption of games consoles in active gaming mode is technically not possible (see Section on “Review of Benchmarking”). On this basis, we propose to update the SRI to reflect the latest power savings, and maintain energy savings and power consumption at present levels. For the future, we propose conditions under which any requirements for future console technology are reviewed.

With respect to material efficiency requirements, there have been significant new developments within the European Union on the subject of “Circular Economy” (as summarised in Section on “Review of Material Efficiency”). To reflect these developments we propose changes to the SRI described below.

Console categories

The UHD category should be split into two to reflect consoles launched since the start of the SRI, including available 4K modes which were not previously covered in the SRI:

- **UHD media capable:**
  “Game Consoles having potential of rendering video output with resolutions greater or equal to 4K (3840 pixels x 2160 lines) in addition to capability defined for High Definition Console in media mode only”
- **UHD gaming capable:**
  “Game Consoles having potential of rendering video output with resolutions greater or equal to 4K (3840 pixels x 2160 lines) in addition to capability defined for High Definition Console in media and gaming mode”

It is important to note, however, that any future increases in console computing performance may not be synchronised with changes in resolution and output

format. A different approach to screen resolution may be required to classify consoles by their performance level in future (see “Future review” below).

Power requirements

Power caps should be revised as follows:

- UHD media capable consoles & HD consoles:
    - New tier 4 (2019)
        - 50 W HD navigation
        - 60 W HD media play
- UHD media capable consoles:
    - New tier 4 (2019)
        - 50 W 4K navigation
        - 60 W 4K media play
- UHD gaming capable consoles:
    - New tier 4 (2019)
        - 70 W HD navigation
        - 70 W HD media play
        - 70 W 4K navigation
        - 110 W 4K media play

With respect to the proposed 110 W power cap for 4K media play on UHD capable games consoles, the main Graphics Processor of the console SoC is required to achieve the level of rendering necessary, which results higher power consumption than HD media modes. As reported in the section “Calculation of Energy Savings Achieved”, on average the most common 4K media play options on PlayStation®4 Pro consumes on average between 79-89 W. There is statistical variation in the power consumption of the hardware components for each console manufactured. During testing of samples designed to identify the worst case scenario (e.g. using the highest power consuming SoC, memory and subsystem) total power consumption could increase by approximately 20% in comparison to a typical sample. In addition to this, variable elements such as temperature can increase hardware power consumption by as much as 9% and similarly, variable elements for the software, such as content dependency (e.g. considering playback formats whose processing load is large, such as BDAV 1080i 60 fps) and margin for high image quality (e.g. additional algorithms to

improve 4K image), could increase power consumption by as much as 6%. Therefore, in the worst outlying cases, it is possible some samples may consume up to 110 W, as shown in figure 7 below.

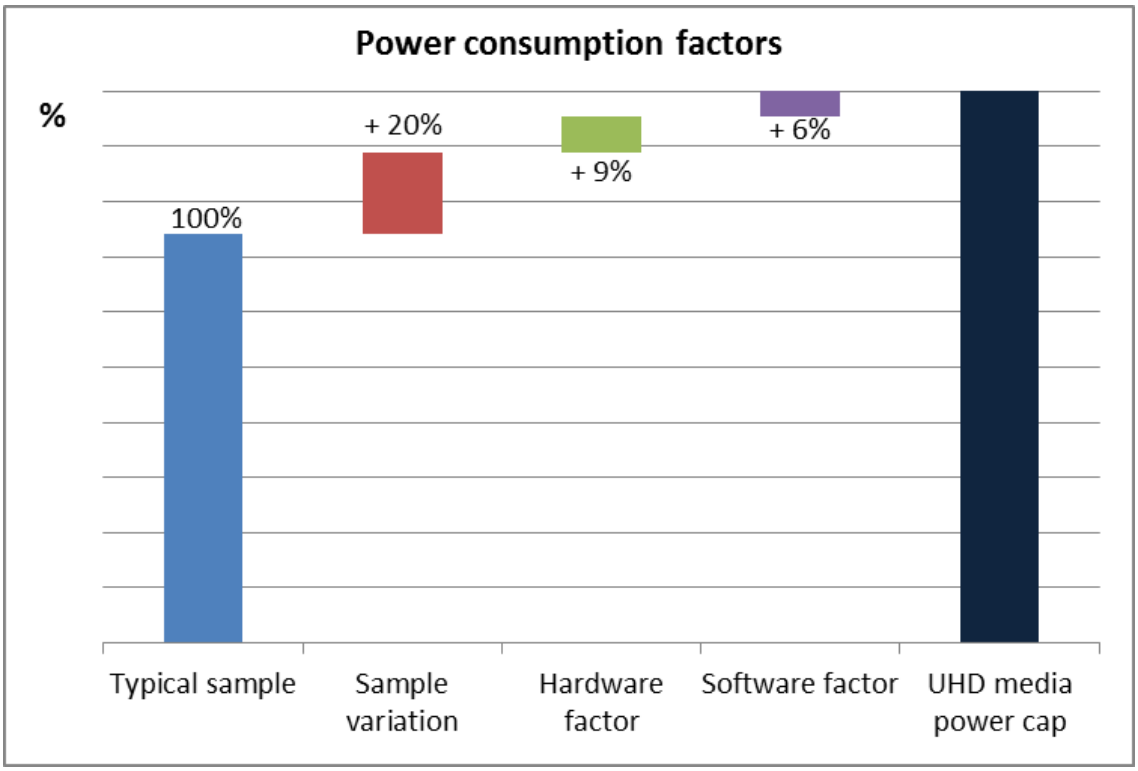

Figure 7: Worst case power consumption of PlayStation®4 Pro in UHD media mode

In their initial feedback NGOs expressed some concern over the proposed new caps being higher than the reported power measurements. These caps are proposed in view of the energy savings and power reductions achieved already, and include sufficient margin to ensure that peak variations in power consumption measured between different console samples can be accommodated. As explained in the "Calculation of the Energy Saving Achieved" section, we have already incorporated recommended energy efficient technologies wherever feasible, and opportunities for further reductions are very limited. Nevertheless, these caps will all be reviewed again, taking into consideration any new technologies, during the next review of the SRI.

Power management

The power management requirements of the SRI are already optimal – no changes proposed.

Testing requirements

- HD navigation and media limits must be tested using a HD display without HDR (to prevent console upscaling of HD content to 4K)
- 4K navigation and media limits must be tested using a 4K display without HDR (to ensure consoles can output 4K content)

Reporting requirements

The SRI includes a requirement for Signatories to provide information to consumers on the power consumption of consoles in navigation, media, and active gaming modes. In their initial feedback on this SRI proposal, NGOs noted that games consoles now have a number of different 'standby' capabilities, with various functions and levels of power consumption. They suggested the power consumption of these could also be measured and reported to consumers. Each console has a different range of standby capabilities which the user can select which are not easily comparable. Consequently, taking this NGO suggestion into account, we propose to provide consumers with information on each user-enabled standby capability available on each console, together with information on its power consumption.

Material Efficiency requirements

As summarised in the section on "Review of Material Efficiency" there are a number of new additional commitments we propose for the SRI to ensure the recyclability and reparability of games consoles.

With respect to requirement in parallel EuP lots for PCs (lot 3), displays (lot 5), and enterprise servers (lot 9), we propose to include an amended requirement for component removability to Section 3.3 of the SRI:

- "*Manufacturers shall ensure that joining or sealing techniques do not prevent the removal of the components, applicable to games consoles, listed in point 1 of Annex VII of Directive 2012/19/EU, when present.*"

We also propose make the following information available for recycling and repair operations to aid removal of these components:

- Accessing components shall be enabled by documenting the dismantling operations needed to access the targeted components[11], including for

each of these operations: type of operation, type of fastening technique(s) to be undone, and tool(s) required. Exemptions apply where non-removable joining and sealing techniques are required used to assure user safety, product quality or product functionality compliance with EU legislation.

We also propose to retain the existing SRI commitment: “To improve both recycling and reuse at end-of-life, maintenance and refurbishment of each games console shall be possible by non-destructive disassembly”, but limited to key components for required for repair including: motherboard, hard disk drive, optical drive, and internal power supply.

In addition, we propose the following information within product disassembly instructions provided to repair and recycling operations to support recycling:

- Whether plastic casing contains brominated flame retardants
- Whether LCD displays contains mercury[13]

Finally in terms of design for recyclability, we will review the possibility of ensuring that plastic components >100 g are removable and made of polymers compatible for recycling in the next planned review of the SRI.

To support product life extension we also propose to provide the following information either provided with the console itself, onscreen, in hardcopy, or online, to consumers:

- Information on how to keep products in good working condition e.g. how to keep the product dust free, how to install system updates, how to remove trapped disks
- How to delete personal data (e.g. if the consumer wishes to send the console for reuse)
- Options available (if any) to upgrade the performance of their console e.g. installing a bigger hard drive

Future review

The revised SRI should be reviewed again in 2019, or earlier if any Signatory announces specifications for a new console with significantly improved computing performance (e.g. improved GPU performance), requiring a new category of console and new requirements to be defined and determined. In either case, the review process should be concluded within one year,

ALIGNMENT OF THE SRI WITH THE COMMISSION'S GUIDELINES FOR SELF-REGULATION MEASURES

This section outlines changes proposed to the SRI to conform with the new Guidelines for self-regulation measures published by the European Commission on the 30th November 2016.

The aim of the Commission's new Guidelines is to facilitate consistent implementation of self-regulation measures across the different sectors that might enter into a self-regulatory or voluntary agreement. They contribute to increasing the credibility of self-regulation by requiring that SRI agreements more clearly demonstrate their added value, more closely involve third-parties, strengthen the role and responsibilities of the Independent Inspector and provide for a stricter schedule and response mechanism for compliance reporting. The Commission asked the Signatories of the Game Console SRI to align the existing SRI with the Guidelines as part of their 2017 review.

At the time of the initial drafting of the Games Consoles SRI in 2015, the Signatories took into account and integrated the requirements from the Commission's draft Guidelines that were still under development at the time. For this reason, most of the SRI is already aligned with the Commission's final Guidelines.

For the 2017 SRI review, the Signatories systematically examined the Commission's final Guidelines to identify which additions or changes to the current SRI were still required. The Signatories prepared a list of all requirements introduced by the final Guidelines and checked the SRI section by section to see if it fulfilled each of these requirements or not. For requirements that were partially or not covered, the Signatories discussed and agreed on amendments to the SRI . See Annex B for an overview of this detailed assessment.

This review process revealed that the SRI was already aligned for the most part with the Guidelines in terms of:

- The openness of the SRI to all industry players and interested stakeholders, including the provisions relating to the functioning of the Steering Committee and Consultation Forum
- The level of ambition of the SRI, which meets the Guidelines requirements in terms of scope, market coverage and level of requirements
- The importance given to compliance verification, through verification methods, Signatories' reporting obligations and the role of the Independent Inspector in auditing

The main changes or additions to the SRI concern:

- The new roles and responsibilities of the Independent Inspector. The revised SRI will include:
  - A process detailing the circumstances that could trigger product testing by the Independent Inspector
  - A process by which the Independent Inspector can conduct on-site inspections
  - A requirement for the Independent Inspector to report all allegations received to the Steering Committee

- The involvement of interested third-parties. The revised SRI will include:
  - Possibility for observers to comment during the Steering Committee meetings
  - A requirement to include contact to Independent Inspector on website and a procedure for raising complaints with Independent Inspector
  - Possibility for observers Member States market surveillance authorities to request technical documentation
  - A clause to the SRI review process requiring that signatories must include evidence justifying the level of ambition when submitting for SRI proposals, and make this documentation available on the SRI website.

- The mechanisms for ensuring compliance. The revised SRI will include:

    - Specification that non-compliance that continues for more than twelve months after an Independent Inspector's report will lead to the exclusion of the signatory from the SRI (it is noted that the EU Guidelines suggest 6 months; we are proposing 12 months due to the lead time required to develop, test, and implement hardware and firmware changes to games consoles)
    - Specification that Signatories not submitting compliance reports on time are subject to audit

- The promotion of self-regulation as an effective policy tool. The revised SRI will include:
    - Evidence on how the SRI achieves policy objectives faster than a mandatory measure
    - The commitment for Signatories to co-operate with other SRIs

The only point where the new proposed SRI text will slightly differ from the Guidelines is the timing for the Independent Inspector to finalise the annual compliance report.

The new SRI will keep the existing timing, which allows one additional month for the deadlines related to the annual compliance report, compared to what suggested in the Guidelines. The Signatories feel that a tighter deadline would unduly put pressure on the Independent Inspector to finalise the compliance verification, without leaving sufficient time for potential clarifications that may be needed between the Signatories and the Independent Inspector. Experience from previous years showed that end of May is an appropriate - although already tight - deadline.

As a result from the process described above, we have amended the new proposed SRI text to be in line with the Commission’s Guidelines for self-regulation measures of 30th November 2016**.**

ANNEX A: REVIEW OF EXISTING MATERIAL EFFICIENCY STANDARDS

Topic	Description	Possible CE requirements	JRC Technical Report: Calculation of recyclability / recoverability rates of electr(on)ic products	NL Ministry Environment/Eco-design - Marking requirements for EEE items	Verbal confirmation with Hans Paul Siderius (NL) and Stephan Arditi (EEB).	Current VA	CEN-CENELEC-ETSI work programme in response to M/543 on material efficiency	Communication from the Commission closing the loop - An EU action plan for the Circular Economy	IEEE1680.1, 4.3.1.6 (similar to Printer VA B32)	Microsoft suggestions	JRC Science & Policy Report: Environmental Footprint & Material Efficiency Support for product policy	Commission Regulation No .../2015 of XXX Eco-design requirements for electronic displays and Tvs	OCAD3E Technical report: Application of environmental contribution modulation criteria	Printers VA	JRC Technical Report: Durability, reusability & reparability of dishwashers & washing machines	EU GPP guidance for the purchase of Computers and Monitors,	Lot 5 TV materials efficiency requirements	Discussion on mandatory design reparability standards within CENELEC.	Directive 2009/125/EC Eco-design requirements for electronic displays,	Austrian Standard Label of excellence for durable, easy to repair electrical and electronic equipment.	Working Document: Potential Eco-design requirements for servers and data storage products
Components and materials	**Standardise the components used in products**	The components must be standardised.																		x	
	Plastic casing parts may only consist of up to four separable polymers or polymer blends.	All plastic casing parts may only consist of up to four separable polymers or polymer blends.												x							

	Design casing so it can be recycled in to high quality products	Large-sized casing parts must be designed in a way that the contained plastics can be used for the production of high-quality durable products by applying available recycling techniques.												**x**							
	Only use one plastic material type in each plastic enclosure part >100 g.	Only use one plastic material type shall be used in each plastic enclosure part >100 g." (as written in IEEE1680.1, 4.3.1.6)							**x**												
		Plastic casing parts with a mass greater than 100 grams have to consist of one single polymer or a polymer blend.												**x**							

	Limit the use of coating on plastic to recyclability	The use of coatings for special parts is to be reduced to a minimum, unless it can be demonstrated that it does not alter recyclability. Galvanic coatings on plastic parts are not permissible.												x							
Dismantling	**Design products so components are accessible and removable**	Design the product so that components, consumables or assemblies can be accessed or removed.				x					x							x	x	x		
		Facilitate repair, remanufacture or reuse by enabling the ability to access or remove certain components, consumables or assemblies from products.				x																
		Improve the accessibility and extractability of components from servers, in order to facilitate both the reversible disassembly for reuse and the dismantling for recycling.									x											

		Make disassembly of the following components possible by non-destructive means: o batteries; o PCB assemblies larger than 0.1 dm2; o display panels larger than 1 dm2; o mercury containing components; o capacitors; and in addition; o PMMA boards; o internal power supplies.																		x		

		Displays shall be designed in such a way that the following components can be removed without hindering environmentally-sound preparation for re-use and recycling of components or whole appliances. 1. Printed circuit boards >10 cm2 2. Capacitors containing PCBs 3. LCDs larger than 1 dm2 4. Mercury containing backlights 5. PMMA board 6. Enclosure (the external housing that protects the internal parts from environmental effects and prevents the user from coming into contact with moving, radiating, or current-carrying components)																x				

	Improve repairability with use of modular and inter-exchangeable components	Consider modular and inter-exchangeable designs to improve reparability, with widely available components and interfaces.																x			
	Plastic parts >100 g shall be manually separable	Plastic parts >100 g shall be manually separable into recyclable plastic streams with commonly available tools.												x							
	Products are to be easy to dismantle with the use of screws over glue and welding	Appliances must be easy to open and disassemble. Instead of glue and welding together, screw and snap connections must be used.																		x	
		Dismantlability for depollution: No proprietary tools. No non-dismantlable fixings (welding, soldering, gluing) of the components of concern.													x						

		Non-separable connections (e.g. glued, welded) between different materials shall be avoided unless they are technically or legally required.												x							
		Use reverse joining techniques (no welding or gluing) for components to be accessed such as mother board, memories and storage devices etc.																			x
	Products are to be easy to dismantle with the use of standardised screws	Product shall utilize commonly used fasteners for joining components, subassemblies, chassis and enclosures.												x							
		Standardization of screws and fastenings that would improve dismantling times.							x												

	Products are to be easy to dismantle with the use of universally available tools	No use of proprietary (non-destructive) information and tools for disassembly (for the purpose of repair), including: 1-physical fastening tools 2- wiring and connection map/diagrams, 3-disassembly map/exploded view 4. repair step manuals													**x**						
		Specified parts must be easily accessible and replaceable by the use of universally available tools. (i.e. screwdriver, spatula, plier or tweezers)														**x**					
Life span	**Design products to have an**	Average life span must be at least 10 years.																		**x**	

	average life span	Minimum lifetime equal to a fixed value (e.g. expected number of cycles for to a fixed period or expected life cycle.)													**x**						
		Testing and reporting average lifetime and checks for 'planned obsolescence'.						**x**													
Markings	**Add markings or tracers to WEEE to aid separation and identifying components**	Add a Fluorescent tracers to the WEEE plastic like ABS to make it identifiable during recycling process.		**x**																	
		Introduce new marking techniques to help WEEE recyclers increase the recycling rate of strategic metals. RFID, digital watermarking, QR codes are the technical options investigated. Labels have less potential to be used by recyclers.		**x**																	

		Mandatory labelling of critical WEEE components.													x						
	Plastic parts >50 g shall specify the polymer and mark type flame retardant or if cadmium or mercury free .	Plastic parts heavier than 50 g shall be marked by specifying the polymer and flame retardant type according to the EN standards.															x				
		Introduce Mercury free logo and Brominated fire retardant logos to be marked on products.									x										
		Mark any flame retardants present in plastic parts.																	x		
		Use of a cadmium free logo.																	x		
		Use of a mercury free logo.																	x		

	Plastic parts >50 g shall specify the polymer and flame retardant type .	Product plastics shall be marked by material type (ISO 11469 referring ISO 1043, resin identification code, SPI, DIN, or country specific). Marking requirement does not apply to plastic parts weighing less than 25 g or with surface area less than 50 cm^2; tape; plastic protective and stretch wraps and labels; or plastic pieces when due to shape marking is not possible. Exempted are plastic parts contained in reused complex modules.												**x**							
		To improve recycling console plastics parts >25g will be marked indicating their material composition (using ISO conforming marks) (Currently in VA)				**x**															

		Mark plastic parts >50 g																	x		
Bonus system	**Bonus system for the use of reused components**	Introduce a bonus system for servers which are brought on the market with reused components.								x											
Documentation	**Information on the percentage of recycled material content**	Assess the proportion of any type of re-used components or recycled materials, based on mass of recycled vs total mass of a material, taking into consideration specific characteristics of that material and traceability aspects (e.g. documentation).					x														
		Information on the minimum percentage of postconsumer recycled plastic content shall be made available to customers.												x							

	Creation of calculation methods of RRR indexes.	Creation of calculation methods of RRR indexes. This would consequently be supported by the creation of tabulated values for EoL treatment of materials and components used in products.					**x**														
	Reports showing minimum recyclability % tested for all products.	Reports showing minimum recyclability % tested for all products.	**x**																		
	Bill of Materials	Create a Bill of materials / Register of materials for each product.	**x**																		
	Provide product data for recyclers	Provide average product data to the recyclers, annual updates.								**x**											

	Make repair and end of life documentation available including exploded diagrams to third party repairers	Provide recyclers with technical information including exploded diagram of the product illustrating the components that need special handling and other targeted components, documentation of the sequence of the disassembly operations, and the availability of firmware to test the functionality of and compatibility between components in the server.									**x**											
		Easy access to appliance service documents, especially disassembly plan, exploded view, circuit diagrams… must be available.																			**x**	

		Make repair and end-of-life documentation available, INCLUDING: o A diagram showing the location of key components o Instructions how to remove those components o The reason why parts may not be marked o The location of components containing cadmium, lead, arsenic, indium and their concentration, and instructions on removal o List of parts and flame retardants used, and their concentration and location																	x			
		Mandatory communication, by a harmonised user manual template, of instructions to ensure durability (if not performed automatically by the appliance)													x							

		Manufacturer shall provide a manual with an exploded diagram of the device illustrating the parts that can be accessed and replaced, and the tools required.														x					
		Provide information on the disassembly operations needed to access the targeted components to professional recyclers, including dismantling sequence, tools required, number of fasteners.																			x
		All producers should provide spare parts, schematics, and repair instructions to anyone that asks.					x														

		Technical evidence, such as dismantling diagrams, shall be made available to market surveillance authorities and recyclers upon request, detailing the steps, tools, or processes required for the extraction of the above listed components.															x				
	Information on critical raw materials	Provide information including the total weight per product of critical raw materials (i.e. Cobalt, Neodymium, Palladium etc.)																			x
		Providing information about the location and amount of critical raw materials included in enterprise servers, especially in HDDs.								x											

Repair	**Data deletion tools to be compulsorily available with the product at the moment of its placing on the market.**	Data deletion tools to be compulsorily available with the product at the moment of its placing on the market.																				**x**
Third party repair	**Extend repairablility to external repair companies**	Extend repairability to external repair shops. Standard suggests that manufacturers must provide to external repair companies detailed documentation and support, including: service documents, list of reference spare parts and telephone access to service operations, information on serial errors and special tools, procedure for servicing routines, trainings, etc.																**x**				

Software / firmware	**Make latest firmware available to third party repairers**	Make latest firmware available for upgrading and to test functionality and compatibility of different components.																			**x**
	No use of proprietary means (e.g. software) of appliance reprogramming /resetting for the purpose of repair.	No use of proprietary means (e.g. software) of appliance reprogramming /resetting for the purpose of repair.													**x**						
	No use of proprietary means of error diagnosis	No use of proprietary means of error diagnosis for the purpose of repair.													**x**						
Spare parts	**Make spare parts available for a set period of time**	Spare parts must be available for an additional 10 years.																		**x**	
		Make spare parts available for the entirety of service life of the product (average service life of at least 5 years for brown goods and 10 years for white goods)																**x**			

		Spare parts available for a fixed minimum horizon, fixed by the regulator.													x					
	Spare parts need to be made available with no restriction	No restriction of access (physical or economic) to original spare parts.													x					
		Maximum delivery time of spares fixed by the regulator.													x					
		Manufacturer must guarantee the availability of spare parts, including as a minimum Computers (I) HDD/SSD, (ii) Memory, (iii) Rechargeable battery, Displays (I) Screen assembly and LCD backlight (ii) Power and control circuit boards (iii) Stands (excluding those integrated with the enclosure) for at least three years from the date of purchase.														x				

	Spare parts available to anyone who requests	All producers should provide spare parts, schematics, and repair instructions to anyone that asks.						**x**													
	Spare parts available to authorised repair centres	Spare parts shall be made available to authorized repair or refurbishment centres for each games console. (Currently in VA)				**x**															
Warrantee	**Provide repair services for out of warrantee products.**	Provide repair services for out of warrantee products.				**x**															
	Extended warantee to 2 years and remove the 'burden of proof' from consumers.	Extend the warrantee periods from 1 year to 2 years and removing the 'burden of proof' from consumers.			**x**																

	Mandatory commercial guarantee of the seller and or OEM beyond the current 2yr for consumer goods.	Mandatory commercial guarantee of the seller and or OEM beyond the current 2yr for consumer goods in the EU(1999/44/EC), currently revised [2015/0288(COD)] If the OEM defines the duration, this can additionally be labelled.													**x**						
Takeback	**Increase take back contirbutions if set environmental criteria is not met**	Increase takeback contributions by 20% if: - Plastic parts of products has the presence of brominated fire retardants, - You fail to provide technical documentation to authorised repairer and - Fail to provide spare parts.											**x**								

ANNEX B: REVIEW OF NEW EU GUIDELINES FOR SELF-REGULATORY MEASURES

Topic	Summary of SRI Guidelines' requirements	Location in the new guidelines	Does present Games Console SRI cover it?	Notes	If yes, where?	Changes/Additions to the SRI	Location of correspondent change in revised SRI	Text of the Guidelines
Participation	Ensure openness of participation	3.1 Openness of Participation	Yes	This procedure was followed in the setting up of the SRI, which is reflected in a number of sections of the SRI agreement.	4.2; Annex E	No change needed		*Companies interested to establish a self-regulation measure should make a public announcement of their intention to do so before the process of developing the measure is started. They should provide a contact point, so as to give an opportunity for other companies to participate.*
Participation	List conditions and procedure for Signatories joining and withdrawing from the agreement	3.1 Openness of Participation	Yes	The SRI provides for the conditions and procedure for interested parties to join or withdraw from the SRI.	Title page; 4.2; 8; Annex D;	No change needed		*The self-regulation measure should contain a list of the companies who are signatories to the measure. Companies active in the same product market should be able, at any time, to join the self-regulation measure, on the condition that they participate in its operational costs. The membership form to be completed and signed by a company wishing to become a signatory should be attached to the self-regulation measure. The signatories should send to the Commission, without undue delay, the original completed and signed membership forms.* *A signatory withdrawing from the self-regulation measure should give at least a month written notice to the Chair of the Steering Committee (see section 3.5). The*

								Chair should inform the Steering Committee of the withdrawal of a signatory within a week of receipt of the written notice.
Objectives	Include notes providing evidence on how the agreement achieves policy objectives faster than a mandatory measure	3.2 Added Value	Partially	The SRI summarises the added value, but does not include reference to studies comparing expected results of an alternative mandatory measure	Annex E; Annex F	The benefit of the SRI compared to regulation was determined and assessed as part of the Commission's own impact assessment. This evidence will be referenced the revised SRI.	Annex E - Compliance with the Self-Regulation Criteria (Annex VIII)	*Proposals for self-regulation measures or for revised versions of existing self-regulation measures should be accompanied by an explanatory note explaining how the proposal would meet the ecodesign objectives more quickly or at lesser expense than mandatory requirements, supported by evidence.*
Separate Agreements	Include references to any and all relevant separate agreements or association related documents and make them publicly available	3.2 Added Value	n/a	There are no separate agreements impacting the SRI	n/a	No change needed		*If some or all of the signatories have concluded a separate agreement or association of any kind in relation to the objectives of the self-regulation measure, all relevant documents relating to the agreement or the association should be mentioned and made publicly available.*
Timeline (Review)	Add new dates or circumstances for review after 2017	3.2 Added Value	No	The SRI only references date of 2017 review	7.2	The SRI will be reviewed in the year the final tiers apply, or earlier if any console producer declares a new type of console with different	7.2 Decisions to Amend the Self-Regulatory Initiative	*The self-regulation measure should provide for a review of all the essential elements, indicating a date or specific circumstances that trigger the review. The timing of the review should be justified based on the need for the measure to (continue to) deliver added value, taking into account the stages of requirements included in the measure*

						functions and/or performance.	*and the pace of technological development of the product group concerned.*
Civil society	Ensure review/revision process is open to participation of observers on the Steering Committee, and the proposal for review/revision is submitted to the Commission	3.2 Added Value	Yes	The SRI Steering Committee is open to observer participation, and the review process itself must take views of stakeholders into consideration. It is already the case that the proposal for review/revision must be submitted to the European Commission	4.3; 7.2; Annex E	No change needed	*The review should establish whether a new version of the measure is needed. The review and revision process should be open to participation of observers on the Steering Committee. The findings of the review process and, where relevant, the proposal for the revised self-regulation measure should be submitted to the Commission.*
Market coverage	Ensure Signatories cover at least 80% of units placed on the EU market, and provide related evidence - compliled and checked by an independent inspector - to the Commission according to the required schedule	3.3 Representativeness	Yes	The process for submitting market data "from independent third party source", and the role of the Independent Inspector in reviewing market coverage, is clearly described within the SRI	4.2; 5.3; Annex B	No change needed	*The self-regulation measure should state the market coverage of its signatories which should be at least 80% of units placed on the Union market and/or put into service of the type of products covered by the measure. The signatories should provide evidence, compiled or verified by an independent legal or natural person proving that the self-regulation measure has a market coverage of at least 80%. This should be sent to the Commission:* *• when submitting a self-regulation measure or a revised version of an existing self-regulation measure, with the findings having been generated or updated within the previous six months;* *• within three months of any change in the signatories (e.g. after the withdrawal of a signatory or after a relevant division of a*

							signatory has been sold off to a non-signatory), unless the most recent report shows that the market coverage will remain at least 80% following the change; and *• two years after sending the latest report, to update coverage following changes in the market.*
Market coverage	Include a precise definition in the SRI of the objective and independently verifiable indicator(s) which are to be used to assess claimed market coverage	3.3 Representativeness	Yes	The SRI already describes calcuation process and data requirements	Annex B	No change needed	*The self-regulation measure should define the precise indicator(s) used to assess the market coverage claimed. The indicators should be objective, measurable and verifiable by an independent body. The indicators should cover all energy-related product categories covered by the measure.*
Scope	List product types in the scope of the SRI and any exemptions applicable	3.4 Quantified and staged objectives	Yes	Product coverage is clearly defined within the SRI. There are no categories of products covered by the definition of games consoles in section 2.1 that are exempted	1; 2;	No change needed	*The self-regulation measure should list all the types of products within its scope, provide definitions of these products, and list product types belonging to the product group falling within the scope of the self-regulation measure but exempt from its requirements. Justifications should be provided for any exemptions made.*
Requirements	Clearly specify any design and information requirements for products in	3.4 Quantified and staged objectives	Yes	Design and information requirements are clearly stated in the SRI	3;	No change needed	*The self-regulation measure should lay down design, and where appropriate, information requirements for the products within its scope. The requirements should relate to significant environmental impacts*

	scope of the agreement.						*over the product life-cycle and aim at improving the environmental performance of the products.*
Requirements	Include measurement methods and indicators used to ensure compliance with the SRI requirements	3.4 Quantified and staged objectives	Yes	Precise measurement and verification methods are included in the SRI	Annex A-1; Annex A-2	No change needed	*It should be possible to measure compliance with the requirements using clear and reliable indicators. Details of how compliance is to be measured and verified should be provided. The self-regulation measure should provide documentation on which the proposed requirements are based. Any major differences between the proposed requirements and the documentation should be highlighted.*
Requirements	Clearly specify levels and timing of any requirements within the SRI	3.4 Quantified and staged objectives	Yes	The SRI includes successive levels of requirements, presented with a date of their application.	3.2	No change needed	*The requirements should be presented with a date of their application and if the self-regulation measure covers a long time-span it should include successive levels of requirements.*
Requirements	Ensure that 90% of products from each Signatory are covered	3.4 Quantified and staged objectives	Yes	The SRI specifies that its requirements shall apply to at least 90% of games console units placed on the market and/or put into service by each signatory.	3	No change needed	*The requirements should apply to at least 90% of all units (covered by the self-regulation measure) placed on the market and/or put into service by each signatory.*
Civil society	Ensure the Consultation Forum is consulted on any self regulation measure	3.5. Involvement of civil society	Yes	The SRI requires that the conclusion of the review process is presented to the Consultation Forum. In addition, according to the Commission's own process, the Commission will consult the Consultation Forum before the official adoption of the	5.2; 7.2	No change needed	*The Consultation Forum, which includes Member States' representatives, industry, trade unions, traders, retailers, importers, environmental protection groups and consumer organisations, should be consulted on any proposal for a self-regulation measure.*

				revised SRI.				
Steering Committee	Establish a Steering Committee including all Signatories and the Commission with equal voting rights, and allowing participation of stakeholders and the independent inspector as observers	3.5. Involvement of civil society	Yes	The SRI respects requirements relating to the Steering Committee composition and participation	4.3	No change needed		*The self-regulation measure should establish a Steering Committee that will manage the operation of the measure.* *The Steering Committee should consist of all signatories to the self-regulation measure and the Commission. Each of these should be represented by one member who all have equal voting rights.* *Members of the Consultation Forum, and the Independent Inspector should have the status of observer to the Steering Committee, without voting rights.*
Steering Committee	The Steering Committee should meet at least once per year in Brussels	3.5. Involvement of civil society	No	The SRI requires at least one physical meeting, in Brussels if possible.	4.3	The revised SRI will state that the Steering Committee must meet in Brussels	4.3 Governance	*The Steering Committee should meet at least once per year in Brussels.*

Civil society	Ensure openness and proper functioning of the Steering Committee	3.5. Involvement of civil society	Yes	The SRI reflects requirements relating to the Steering Committee's functioning. Relevant stakeholders (part of the Consultation Forum) shall be provided information about the meetings of the Steering Committee via the SRI website and may participate to the meetings as observers, without voting rights. These stakeholders may include EU Member States, NGOs and any other person or entity the Steering Committee considers to be a legitimate stakeholder.	4.3; 5.2	No change needed		*The meetings of the Steering Committee should be open to interested parties, including companies from the sector covered by the self-regulation measure that are not signatories to it.* *The Steering Committee should elect a Chair from among its members. The Chair should include in the draft agenda for a Steering Committee meeting all points requested by the members and observers. Invitations to the Steering Committee meeting should be sent to all members and observers.*
Timeline (St. Comm.)	Announce date of Steering Committee and provide draft agenda one month in advance	3.5. Involvement of civil society	No	The SRI specifies '30 days'	5.2	The revised SRI will specify "one month"	5.2 Transparency of the Self-Regulatory Initiative	*An announcement of the Steering Committee meeting, including a draft agenda, should be published on the website of the self-regulation measure no later than one month before the meeting.*
Timeline (St. Comm.)	Issue all meeting documents one week in advance of the Steering Committee meetings	3.5. Involvement of civil society	No	The SRI specifies '7 working days'	5.2	The revised SRI will specify "one week"	5.2 Transparency of the Self-Regulatory Initiative	*Documents to be presented and discussed at the Steering Committee meeting should be sent to all members and observers of the Steering Committee, and should be published on the website of the self-regulation measure no later than one week in advance of the meeting.*

Civil society	Ensure observers the right to speak in Steering Committee meetings	3.5. Involvement of civil society	No	The SRI provides that observers may attend Steering Committee meeting and "may be invited to comment".	4.3	The revised SRI will specify "and are allowed to comment during the meeting"	4.3 Governance	*All participants should have a right to take the floor at the Steering Committee meetings and to request that the Chair record their views in the minutes.*
Timeline (St. Comm.)	Ensure Steering Committee minutes are finalised and published within one month of meetings, with two weeks for attendees to comment	3.5. Involvement of civil society	Partially	The SRI specifies two weeks for comments, but '30 days' to finalise and publish minutes	5.2	The revised SRI will specify "one month" to finalise and publish minutes	5.2 Transparency of the Self-Regulatory Initiative	*The draft minutes should be sent to all members and observers of the Steering Committee and they should be given at least two weeks to submit comments on them. The final minutes should be published on the self-regulation measure's website within one month of the meeting.*
Website	Establish a website will all required information on the SRI	3.5. Involvement of civil society	No	The SRI includes a requirement to set up a website with many of the points covered, but does not require previous SRI versions, non-compliance list, or Independent Inspector contact details to be on the website.	4.3	The revised SRI will require to include in the website all relevant materials indicated in the guidelines, including previous SRI versions, non-compliance list, and independent inspector contact details.	3.4 Other Commitments	*A website should be established for the self-regulation measure. The website should contain at least:* *• the most recent and previous versions of the self-regulation measure;* *• an up-to-date list of signatories and information on recent withdrawals and exclusions of signatories;* *• summary versions of reports on the market coverage (without disclosure of individual signatories' commercial or confidential data);* *• up-to-date lists of products declared compliant by the signatories (products found to be non-compliant by the Independent Inspector should not be included);* *• the compliance reports produced by the Independent Inspector;* *• an up-to-date list of non-compliant signatories;* *• for every Steering Committee meeting: invitations, draft agendas, meeting documents and meeting minutes; and*

								• *information on the Independent Inspector, including its contact details.*
Website	Include contact details for Independent Inspector in website, and ensure enquiries are responded to within one month	3.5. Involvement of civil society	No	The website does not include contact details for Independent Inspector, and the SRI does not set time to respond to enquiries	n/a	The revised SRI will include a requirement to include contact to Independent Inspector on website, with a response time of 30 days maximum	3.4 Other Commitments	*The website should allow visitors to submit questions about the self-regulation measure to the signatories and to the Independent Inspector. These should be replied to within one month.*
Civil society	Ensure external parties can submit complaints to the Independent Inspector	3.5. Involvement of civil society	No	Complaints are presently raised with the Signatories or the Commission directly. The SRI needs to allow external parties to raise complaints with the Independent Inspector.		The revised SRI will include a procedure for raising complaints with Independent Inspector	Annex C – Method of Data Collection and Processing by Independent Inspector	*The self-regulation measure should ensure that any party can submit, free of charge, substantiated allegations of possible non-compliance to the Independent Inspector.*

Civil society	Include the possibility for the Independent Inspector itself to trigger testing and the requirement to report all allegations to the Steering Committee	3.5. Involvement of civil society	No	The current SRI states that only the Commission can trigger 'audit' testing by the Independent Inspector and does not include reporting obligations by the Independent Inspector on the allegations received.		The revised SRI will include a process by which the Independent Inspector can trigger product testing themselves and will require them to report all allegations received to the Steering Committee	Annex C – Method of Data Collection and Processing by Independent Inspector	*The Independent Inspector should evaluate these allegations and, where appropriate, follow-up by requesting information from the signatory concerned, by testing and/or by an inspection. The Independent Inspector should at each Steering Committee meeting provide an overview of all allegations submitted since the last meeting and, if it has not investigated any of them, provide its reasons for this.*
Access to Documentation	Ensure authorities and observers participating in the Steering Committee can gain access to technical documentation to assess the level of ambition of the SRI	3.5. Involvement of civil society	No	The SRI does not require Signatories to provide compliance documentation to Member State representatives, or to provide documentation justifying the level of ambition of the SRI	n/a	The revised SRI text will mention Member States market surveillance authorities and will specify that they can request the test reports and other documents listed as evidence for the Independent Inspector in the SRI. In addition, it will include a clause to the SRI review process requiring that signatories must include the necessary documentation and evidence justifying the level of ambition when submitting for SRI proposals, and make this documentation available on the SRI	7.2 Decisions to Amend the Self-Regulatory Initiative and Annex C – Method of Data Collection and Processing by Independent Inspector	*The self-regulation measure should include a requirement that the signatories provide, upon request, the Commission and observers to the Steering Committee with access to technical data on the environmental performance of products and models covered by the measure, including all characteristics related to special conditions, to enable the Commission and observers to the Steering Committee to assess the level of ambition and the impacts of proposed and existing self-regulation measures. The rules on access to such data need not apply to commercially sensitive data.* *The self-regulation measure should include a requirement that the signatories provide, upon request, market surveillance authorities of the Member States responsible for ecodesign with specific documentation and information, to the extent this is not included in the documentation supplied with the products, to enable them to verify compliance with the requirements of the self-regulation measure, including through testing.*

						website. e.g. in the form of a review report		
Ind. Insp.	Define the role and responsibilities of the Independent Inspector	3.6 Monitoring and reporting	Yes	The SRI respects requirements relating to the definition of the roles and responsibilities of the Independent Inspector	4.4; Annex C	No change needed		*An Independent Inspector should monitor compliance of signatories with the self-regulation measure. The self-regulation measure should state the rules that apply to the Independent Inspector, which can be a natural or legal person.* *The Independent Inspector should have the necessary skills for verifying compliance with the requirements and be free of conflict of interest. The Independent Inspector's contractual obligations should not restrict its role in carrying out compliance verification.* *The Independent Inspector should:* *• perform its duties with due care and supervise adequately all tasks for which it is responsible;* *• be impartial in all its activities, basing its opinions and reports solely on the facts; and* *• respect confidentiality, where necessary, in order to protect the signatories' commercial interests or sensitive data and to this end sign a 'non-disclosure agreement' with the signatories to the self-regulation measure, if requested.*
Ind. Insp.	Define a procedure and selection criteria for choosing the Independent Inspector	3.6 Monitoring and reporting	No	The SRI does not include procedure and selection criteria for choosing the Independent Inspector.	n/a	The revised SRI will include a procedure and criteria for selection Independent Inspector	4.4 Administration of the Self-Regulatory Initiative	*The self-regulation measure should lay down the procedure to select an Independent Inspector and how it will be ensured that the Inspector is free of conflict of interest and has the necessary skills for verifying compliance with the requirements. The appointment of the selected Independent Inspector is to be agreed with the Commission services. The Steering Committee should be involved in determining the terms and conditions of the*

							contract of the Independent Inspector.
Documentation	Define rules on submission of documentation	3.6 Monitoring and reporting	Yes	The SRI respects requirements relating to the submission of documentation	5.3; Annex B	No change needed	*The self-regulation measure should lay down rules on at least the following aspects of the documentation to be submitted by each signatory to the Independent Inspector:* *• the type of market and technical data to be reported;* *• the format in which the data are to be submitted;* *• the means by which documentation is to be sent; and* *• the frequency and timing of the submission of documentation.* *Each signatory should report all the information and data (including market data and data on the environmental performance of products) necessary for the Independent Inspector to reliably verify the signatory's compliance with all the commitments undertaken in the measure.*
Market coverage	Provide market data so the Independent Inspector can determine whether 90% of each Signatory's products comply with the SRI requirements.	3.6 Monitoring and reporting	Yes	Calculation process and data requirements are described within the SRI	Annex B	No change needed	*Signatories should provide market data allowing the Independent Inspector to establish whether at least 90% of their products comply with the commitments. If signatories commit to ensuring that 100% of their products comply with the commitments, they are not required to provide specific market data to the Independent Inspector.*
Documentation	Ensure rules on data reporting are followed	3.6 Monitoring and reporting	Yes	The SRI respects requirements relating to data	5.3; Annex B	No change needed	*Reporting should be carried out for every model covered by the self-regulation measure that is placed on the Union market*

				reporting			*and/or put into service. If the difference between certain models is not relevant to the self-regulation measure (i.e. it does not concern any aspect related to the requirements), reports may combine similar models, provided that this is indicated. The information and data reported by the signatories may differ only inasmuch as their respective commitments differ.* *The format in which data are to be submitted to the Independent Inspector should be the same for all signatories.* *The means should, as far as possible, take advantage of electronic means of communication, whilst taking account of confidentiality requirements and the administrative burden placed on all parties concerned.* *The period to be reported on should be one year. Each signatory should every year provide the documentation within two months after the end of the reporting period.*
Documentation	Specify the deadline for Signatories to respond to additional requests for information from the Independent Inspector on their compliance reports	3.6 Monitoring and reporting	Yes	The SRI does not have a specific deadline for Signatories to respond to additional requests for information from the Independent Inspector	Annex C	No change needed	*Additional requests made by the Independent Inspector for signatories to provide any missing information after the deadline should be honoured within a short deadline, to be specified in the self-regulation measure.*

Ind. Insp.	Ensure that the Independent Inspector can choose themselves between checking documents, product testing, and site visits to check compliance	3.6 Monitoring and reporting	No	The SRI empowers the Independent Inspector to decide on verification activities based on procedures set out in the SRI itself, but does not include provisions for onsite inspections	Annex C	The revised SRI will Include provisions allowing Independent Inspector to conduct onsite inspections.	Annex C – Method of Data Collection and Processing by Independent Inspector	*The self-regulation measure should empower the Independent Inspector to verify compliance with the requirements of the self-regulation measure through:* *• checking the documentation provided by signatories;* *• testing products; and* *• inspecting the signatories' premises* *The Independent Inspector should decide on an appropriate combination of these methods.*
Testing	Ensure that rules on product testing are followed	3.6 Monitoring and reporting	Yes	The SRI respects the Guidelines' requirements for sample selection procedure and choice of test facilities	Annex A-1; Annex C	No change needed		*Testing concerns verifying the characteristics of products covered by the self-regulation measure by means of physical tests performed in a laboratory. As a general rule, this should be done in an independent laboratory, preferably an accredited one. As an alternative, testing activities may be performed on the premises of one of the signatories, provided that full objectivity can be guaranteed.* *The Independent Inspector should select, at random, an adequate number of products from different signatories for testing, preferably acquiring them from retailers in different Member States (physical or online shops). If signatories provide the products directly, they should not be involved in selecting the samples.* *The Independent Inspector may select specific models or select models from a specific signatory if information obtained from any source points to possible non-compliance of those models or that signatory.* *The signatories should provide, on the request of the Independent Inspector, specific documentation and information required for the purpose of testing, if this is not included in the documentation supplied*

with the products.
The detailed test reports for each separate product tested should be provided to the Commission and to the signatory concerned.

Inspections	Allow the Independent Inspector to trigger onsite inspections	3.6 Monitoring and reporting	No	The SRI does not allow the Independent Inspector to perform onsite inspections, and does not include an inspection process or criteria.	n/a	The revised SRI will include a requirement allowing the Independent Inspector to conduct onsite inspections in the case that signatories are using onsite power testing processes and facilities, and when producer's own testing results are inconsistent with either the Independent Inspector's or other stakeholder test results. The purpose of such inspections is to confirm testing requirements have been properly met and testing properly conducted. The inspection will be limited to the power testing facility itself.	Annex C – Method of Data Collection and Processing by Independent Inspector	*The Independent Inspector may carry out an inspection of a specific signatory on the basis of specific information justifying such an inspection. The specific information should be disclosed to the signatory concerned.* *An inspection should only be used as a means of checking compliance with the commitments made under the self-regulation measure if no other more cost-effective means is available. During an inspection, the Independent Inspector should only carry out those activities that are strictly necessary for checking the compliance of the signatory with the commitments made under the self-regulation measure.* *The Independent Inspector should not give the signatory advance warning of the inspection or only at short notice. The signatory should provide any support required.* *The Independent Inspector should send a draft of the inspection report to the signatory concerned for comment within one month of the inspection. The signatory should submit its comments within two weeks of receiving the draft report. The Independent Inspector should, within two weeks, amend, if necessary, the draft report to take account of the comments received from the signatory. The report, including the reason for the inspection, should be provided to the Commission and to the signatory concerned. A summary should be presented at the first meeting of the Steering Committee held following the finalisation of the report. The summary should not disclose any commercially sensitive information, unless this is necessary to prove non-compliance.*

Timeline (Reporting)	Ensure that the annual compliance report by the Independent Inspector is finalised according to a specific schedule	3.6 Monitoring and reporting	Partially	The SRI provides for a slightly different schedule for finalising the annual compliance report.	5.3	The new SRI will keep the existing timing, which requests the annual compliance report to be ready by end of May, while the Guidelines suggest by end of April. The Signatories feel that a tighter deadline would unduly put pressure on the Independent Inspector to finalise the compliance verification, without leaving sufficient time for potential clarifications that may be needed between the Signatories and the Independent Inspector. Experience from previous years showed that end of May is an appropriate - although already tight - deadline.	No change implemented	*The Independent Inspector should prepare the draft compliance report and send it to the members of the Steering Committee at the latest three months after the end of the reporting period. The members of the Steering Committee should be allowed two weeks to submit their comments on the report. The Independent Inspector should submit the final version of the compliance report to the Steering Committee at the latest four months after the end of the reporting period.*

Ind. Insp.	Ensure that compliance report includes the contents required by the Guidelines	3.6 Monitoring and reporting	Yes	The Compliance report includes the required content from the Guidelines.	5; Annexes B & C	No change needed		*The compliance report should include:* *• information about the data collection and processing methods used and any difficulties encountered in preparing the report*;* *• the results of document checking*;* *• the approach for selecting products for testing and if specific models or signatories were targeted, the reasons for doing so*;* *• a list of products tested and a summary of the individual results;* *• summaries of any inspections carried out during the reporting period;* *• a list of non-compliant signatories;* *• information about the reasons for any non-compliance*; and* *10* *• recommendations for future reporting periods.* *The self-regulation measure may specify that the items indicated with an asterisk (*) should be presented in aggregated form summarising the results for all the signatories combined and not include individual signatories' commercial or confidential data. In such cases, individual reports containing the specific information separately for each signatory concerning those items should be provided to the Commission and to the signatory concerned.*
Non-compliance	Ensure appropriate actions are taken to address non-compliance monitoring and reporting	3.6 Monitoring and reporting	No	The SRI provides for the procedure leading to the exclusion of a Signatory that would either fail to submit a Product Compliance Report or fail to meet the SRI requirements. The SRI however does not require an	5.4	The revised SRI will specify that non-compliance that continues for more than six months after an Independent Inspector's report will lead to the exclusion of the signatory from the	5.4 Non-compliance with the Requirements	*Non-compliance should be subject to a graduated scale of sanctions.* *A signatory failing to report its compliance report to the Independent Inspector should be subject to an inspection by the Independent Inspector in the year following the reporting period concerned. A repeated failure to report compliance documentation should lead to immediate exclusion of the signatory from the self-regulation measure.* *A signatory that, according to the*

				audit of Signatories that failed to submit the Product Compliance Report. The deadline to address any non-compliance before exclusion is currently longer than requested in the Guidelines.		SRI . It will also specify that Signatories not submitting compliance reports on time are subject to audit.	*Independent Inspector's inspection or compliance report, has not complied with the requirements of the self-regulation measure should be required to take corrective action. Non-compliance that continues for more than six months after the report by the Independent Inspector should lead to immediate exclusion of the signatory from the self-regulation measure. The Chair should inform the Steering Committee in writing of the exclusion of any non-compliant signatory within one week of receiving information from the Independent Inspector that a condition for immediate exclusion has been met.*
Cost	Requires signatories to share costs of Independent Inspector and costs of operating the SRI	3.7 Cost-effectiveness of administering a self-regulatory initiative	Yes	The costs of the Administrator and of the Independent Inspector are fully assumed by the Signatories.	4.3	No change needed	*The signatories should bear all expenses related to the Independent Inspector and its activities, the website and the operation of the Steering Committee, except for the costs of participation of the representative of the Commission and the observers other than the Independent Inspector.*
Cost	Encourage Signatories to share best practices with other SRIs	3.7 Cost-effectiveness of administering a self-regulatory initiative	Yes	The SRI encourages Signatories to share best practice with other SRIs	3 Commitments	No change needed	*The self-regulation measure should encourage the signatories to share expertise, experience, information and best practice with signatories to other ecodesign self-regulation measures.*
Sustainability	Ensure SRI states its policy objective	3.8 Sustainability	Yes	The SRI objectives are consistent with the policy objectives of the EU Directive 2009/125/EC on Energy Related Products	1 ; Annex E	No change needed	*The self-regulation measure should state its policy objectives. These should be consistent with the policy objectives of the Directive.*
Incentives	Ensure consistency of SRI with national incentives	3.9 Incentive compatibility	n/a	The SRI is consistent with national requirements or incentives of Member States	n/a	No change needed	*The proposed self-regulation measure should be consistent with other factors and incentives at national level.*

ANNEX C: REVIEW OF BENCHMARKING PAPER

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V28, March 23, 2017

Performance benchmarks for consoles

Games consoles are popular devices. Approximately 85 million consoles were sold within Europe over the last ten years – enough for approximately two in every five European households [1]. In 2013 alone, they were estimated to have consumed 6 TWh of electricity in Europe [2], equivalent to the electricity consumption of two million UK homes [3]. As a result, the energy efficiency and climate change impact of games consoles have become concerns for policy makers on an international basis.

In April 2015, the European Commission recognized a Voluntary Agreement (VA) together with console manufacturers to improve the energy efficiency of games consoles under the Ecodesign Directive. Under this VA, manufacturers are committed to ensure games consoles meet targets for maximum power consumption in certain operational modes and minimum automatic power down limits, together with requirements for material efficiency and information reporting. These targets are expected to achieve energy savings of one terawatt-hour per year by 2020 in the EU [4].

Currently, power consumption targets agreed within the VA apply only to media and navigation modes. Measuring the power consumption of such modes is straightforward, as the modes themselves are well defined, meaning test results can be accurately compared among consoles with similar capabilities, with few exceptions. There are many complexities, on the other hand, when attempting to benchmark console performance in active game play.

In 2017, the VA will undergo review, to update the agreement and set new targets for the future. In preparation for this review, console manufacturers must consider “the feasibility of including computational performance in console efficiency benchmarks, where applicable and comparable across devices performing gaming” [4]. If feasible, policy makers anticipate that the development of a gaming efficiency benchmark would allow targets to be set to improve active gaming power consumption, like those established for other modes, and for reporting performance versus efficiency to consumers.

Identifying a suitable metric is a complex task, as the definition of active gameplay is unclear and multifaceted. A wide range of activities fall under active gameplay, and depending on the game, software design, frame rate, video resolution, and system architecture, the power use can vary tremendously. Many games perform computations in the background even if the user is not active, so even the concept of “active game play” may not be clearly defined. Many console games dynamically modify resolution, frame rate, and other image characteristics to optimize the gaming experience for each console platform, depending on the underlying hardware and the gaming software, making gaming performance even more complex and harder to compare between platforms. In addition, user preferences and game design, which are not under the control of console manufacturers, can have a large effect on power consumption in active game play.

The development of computational efficiency benchmarks is not only important for games consoles, but for other products, such as Gaming PCs, where energy efficiency is a topic of concern. For example, Mills and Mills [5] state that “gaming is the most energy intensive use of personal computers” and have conducted pioneering research investigating potentially suitable metrics for PCs, discussed further below. The authors found that the typical enthusiast gaming PC consumes ~1400 kWh/year compared to ~160 kWh/year for the average console, and the aggregate global energy use to be two-times higher for gaming PCs than for consoles. Moreover, they project this gap in demand to widen substantially by the year 2020.

The purpose of this article is to investigate the potential for developing a benchmark to measure the energy efficiency of active gaming across games consoles, in response to the requirement in the console voluntary agreement for the EU.

Creating consistent comparisons

Game consoles vary by system architecture and capabilities, and these capabilities change over time. Current generation consoles (like PS4®, PS4®Pro, Xbox One, WiiU, Nintendo Switch, and the forthcoming Microsoft Xbox One X console) have much more powerful graphics and computational capabilities than older generation consoles. Graphics resolution is higher, frame rates are faster, and the overall gaming experience is quite different for these newer machines. In addition, game consoles are increasingly being used to stream video, listen to music, and perform other non-gaming functions. The *computing services* delivered by these devices are simply not comparable to those from earlier consoles.

Even within current generation consoles there are differences in delivered computing services. Game consoles modify frame rates and video resolution depending on the hardware capabilities of each console (to give the best possible gaming experience on each machine). This dynamic nature of consoles makes it difficult to create a truly consistent comparison of computing services (i.e. gaming performance). In fact, there are many dimensions of gaming performance beyond frame rate and resolution. **Table 1** defines some of those factors.

Another interesting subtlety is that current generation consoles, because of their system-on-a-chip design (and other innovations, see [6]) are more “energy proportional” [7] than earlier consoles, and so save more energy when the device is not being used or operating with lower computational output. This makes measurements of efficiency more complicated (because performance and efficiency are both dynamic and varying rapidly over time).

Table 1: Factors affecting gaming performance

Term	*Definition*	*Note*
Frame rate	Frame rate, also known as frame frequency, is the frequency (rate) at which an imaging device displays consecutive images called frames. The term applies equally to film and video cameras, computer graphics, and motion capture systems. Frame rate is usually expressed in frames per second (FPS). Tearing, stutter, dropped frames, and partially rendered frames can sometimes be an issue, adding more complexity, but at higher FPS rates these issues disappear.	1
Resolution	The display resolution or display modes of a digital television, computer monitor or display device is the number of distinct pixels in each dimension that can be displayed. It is usually quoted as width × height, with the units in pixels: for example, "1024 × 768" means width is 1024 pixels and height is 768 pixels.	2
Anti-aliasing	In digital signal processing, spatial anti-aliasing is the technique of minimizing the distortion artifacts (like rough edges) when representing a high-resolution image at a lower resolution. Anti-aliasing is used in digital photography, computer graphics, digital audio, and many other applications.	3
Tone mapping	Tone mapping is a technique used in image processing and computer graphics to map one set of colors to another to approximate the appearance of high-dynamic-range images in a medium that has a more limited dynamic range	4
Rendering	Rendering is the process of generating an image from a 2D or 3D model (or models in what collectively could be called a scene file) by means of computer programs. Also, the results of such a model can be called a rendering.	5
Special effects	Special effects are created for games by visual effects artists with the aid of a visual editor.	6
Procedural texturing	A procedural texture is a computer-generated image created using an algorithm intended to create a realistic surface or volumetric representation of natural elements such as wood, marble, granite, metal, stone, and others, for use in texture mapping.	7
Scene complexity	Scene Complexity controls the in-game representation of how detailed objects are. A higher setting here results in more complex geometry in things like foliage, rocks, as well as making objects remain highly detailed at farther distances from the player. This is due to LOD (level of detail), which is used to swap lower resolution objects in as the player moves farther away from them and higher resolution objects in as the player moves closer to them. Lower settings result in a less detailed world and objects lose their detail at closer distances to the player.	8
Graphical fidelity	Graphical fidelity can be defined as the combination of any amount of the three things that make up beautiful games (or virtual beauty in general): detail, resolution, and frame rate	9
Dynamic reflections	Dynamic reflections and shadowing move relative to the objects in the game.	10
Visual density	The perceived "visual density" of a screen—and thus the amount of anti-aliasing possibly needed to make computer graphics look convincing and smooth—depends on screen pixel density ("ppi") and distance from the user's eyes.	11

Notes:

1) https://en.wikipedia.org/wiki/Frame_rate

2) https://en.wikipedia.org/wiki/Display_resolution

3) https://en.wikipedia.org/wiki/Spatial_anti-aliasing

4) https://en.wikipedia.org/wiki/Tone_mapping

5) https://en.wikipedia.org/wiki/Rendering_(computer_graphics)

6) None

7) https://en.wikipedia.org/wiki/Procedural_texture

8) https://steamcommunity.com/app/322920/discussions/0/604941528469072612/

9) "https://www.reddit.com/r/pcmasterrace/comments/51u8zk/psa_the_graphical_fidelity_triangle_a_visualized/"

10) None

11) http://phrogz.net/tmp/ScreenDens2In.html

An additional complexity when comparing game consoles to gaming PCs is that the Graphics Processing Units (GPUs) in consoles are custom designed (omitting some compatibility firmware) and so allow console designers lower level and faster access to the GPU's capabilities than is possible on a gaming PC. GPUs are a significant contributor to both electricity use and gaming performance, and architectural differences among them can't be ignored in attempting to create consistent comparisons.

Overall, a console's power consumption in different modes will depend strongly on GPU utilization, performance, and efficiency. GPU characteristics are, however, not the only determinants of console power consumption and cannot be used to provide a predictable or consistent benchmark (Table 2). Console power consumption is impacted by many other factors such as: CPU, memory, and power supply performance; differences in the functions provided by the operating system; the level of optimization of the firmware; and differences in chip architecture, design, and die-size.

Table 2: Console GPU performance vs power consumption

			Reported power consumption per mode [2] (W)				
					Media		
Console	**Launch year**	**GPU performance [1]**	Navigation	*Streaming*	*DVD*	*Blu-ray*	Average gaming
Microsoft Xbox One	2013	1.31	61.0	63.0	68.0	69.0	106.0
Sony PlayStation®4 (launch model)	2013	1.84	77.6	81.9	97.4	89.1	115.1
Microsoft Xbox One S	2016	1.40	27.0	32.0	33.0	33.0	62.0
Sony PlayStation®4 Slim	2016	1.84	44.0	48.4	43.8	48.5	78.9
Sony PlayStation®4 Pro	2016	4.20	60.4	59.3	54.1	59.5	126.1

1. See http://www.eurogamer.net/articles/digitalfoundry-2016-what-the-hell-is-a-teraflop-anyway & https://www.playstation.com/en-gb/explore/ps4/tech-specs/

2. See http://efficientgaming.eu/compliance-reports/product-compliance-report/. Tests for average gaming taken for three top selling games over 5-minute periods.

Measuring performance and energy efficiency

Assessing the energy efficiency of computing devices performing a computing task (like consoles or personal computers) is a challenge. To measure efficiency, we combine a measure of the output of the device (like computations, game play, or a set of consistently defined tasks) with a measure of the

electricity needed to deliver that output (typically measured in kilowatt-hours or kWh). This relationship can be characterized using **Equation 1** [8]:

$$Computing\ efficiency = \frac{Computational\ output}{Electricity\ consumption\ to\ deliver\ output} \quad (1)$$

Equation 1 is simple, but applying it to computing devices isn't. Computational output depends a great deal on the computing task, software, and hardware. For general-purpose computers, performance benchmarks have always engendered controversy. On the one hand, computer scientists rightly worry that performance is strongly influenced by the characteristics of each workload, and it's difficult to define precisely what a generally applicable set of workloads might be for any set of users. On the other hand, high-level comparisons require some benchmark to be used, even if imperfect, and in practice, differences between benchmarks are less important when examining long term big-picture trends, as for example in [9, 10, 11].

Many researchers have wrestled with this problem in the past, including Knight [12, 13, 14], Moravec [15], McCallum [16], and Nordhaus [17]. The work of SPEC <http://www.spec.org> grew out of those early efforts, and it remains a widely-used set of benchmarks that have the imprimatur of industry acceptance. SPEC has many different benchmarks for different applications, and each part of the Information Technology (IT) industry gravitates towards the metrics that are most applicable (or most advantageous) for their application. There are metrics that focus on database queries, metrics that focus on application performance, and metrics that focus on computational speed for CPU based or scientific workloads.

The SPEC workloads were eventually paired with power measurements, at least for servers (https://www.spec.org/power_ssj2008/), growing out of some earlier work [18]. Those measurements (and lots of industry meetings) resulted in what is known as SPEC power, a metric that tied performance measurements for a CPU intensive workload with power measurements at different levels of equipment utilization, resulting in curves that look like those shown in **Figure 1**.

The most important parameters for servers are the idle power (i.e., power use measured with zero computing load) and the maximum power use (measured at maximum computing output). The load curve is typically a straight line between these two points for a server, though of course some computing devices may have workload/power curves with a different shape. Power use and performance are measured simultaneously, so as the computing benchmark is run, power use is tracked, and as the workload becomes more computationally intense, power use generally increases.

Curves of this type characterize the relationship between computing performance and power use. Curves that have high part-load savings (i.e. draw little power at idle) are said to be "energy proportional" [7]. Because most computing activities are concentrated into a small number of hours per year, an energy-proportional computing device will also be an energy-efficient device.

The SPEC power metric has persisted over time (starting in 2007), but is limited to the CPU-intensive SPEC_jbb benchmark. Some in the industry expected SPEC to extend power measurements to other benchmarks, but that has not occurred, and the SPEC power database, while it is still updated by manufacturers, represents the best-in-class servers that manufacturers *want* to benchmark, so it is not representative of typical practice. Nobody forces manufacturers to run SPEC power, so it is widely believed that they just run the servers they expect to do well in the test.

This lack of applicability to the broader market led the EPA's Energy Star server program[17] to commission a new benchmark from SPEC, called the Server Efficiency Rating Tool (SERT). Manufacturers use this tool, found at https://www.spec.org/sert/, to qualify their servers for the Energy Star Servers program. SERT reports similar information to SPEC power, but using a more general benchmark suite of computing activities. There are no current requirements by Energy Star on active computing efficiency for servers, but the program does require the workload/power curve to be created and reported for each server that qualifies for the Energy Star label.

[17] https://www.energystar.gov/products/spec/enterprise_servers_specification_version_2_0_pd

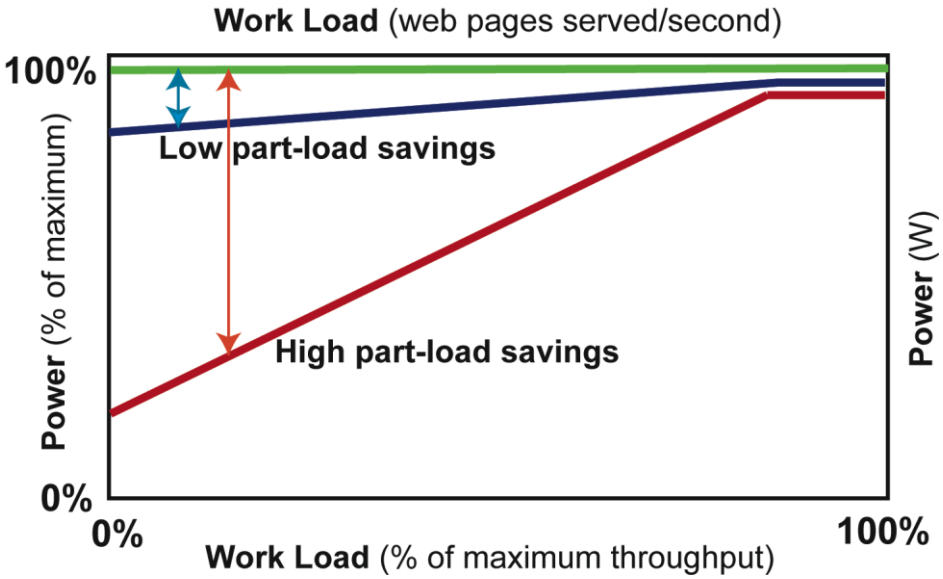

Figure 1: Conceptual Diagram of Energy vs. Computation Metric

Source: Nordman [19].

Developing efficiency benchmarks for gaming PCs and consoles

Benchmarking active power efficiency of game consoles is more complicated than for servers. First, the system architectures can vary greatly among console manufacturers, and even more widely when gaming PCs are considered. Second, the concept of "active use", which is clear for a server, may be impossible to define for a console (much console computing happens in the background even if there is no user input or network traffic, and the gaming experience varies significantly across consoles even when considering the same game). Finally, the way games are programmed can have a big effect on power use, with the same game showing widely different power use on different consoles, depending on how much the code is optimized for each platform, the type of game (e.g., sports games vs first-person shooter games) and how frame rates, resolution, and other gaming performance factors are dynamically modified during the game. Because of these complexities, it is unlikely that a curve like Figure 1 can be created for consoles—workload just isn't as uniform (or simple) as it is for servers.

In the preparatory discussions leading up to the voluntary agreements for consoles (2013-2014) there was some discussion of how one might benchmark active compute output, with most attention being paid to measurements of active power when running popular games. The VA currently includes a requirement

for signatories to measure this metric and report publicly. In such a scheme, a set of widely used games would be chosen using an objective metric and then power use measured as each game is played, with a focus on just the first five minutes of the game.

Such an approach would be difficult to implement, in part because it would be dependent on characteristics of each game. For example, while some activities in the game may be computationally intensive, other activities may be less so, and power use will vary significantly while playing. The results would vary over time, creating problems for enforcement, because manufacturers would have to retest old models every year using the latest games.

Any protocol for measuring power use under active game play will have to create procedures to ensure tests are consistently applied, repeatable, and representative of actual gaming use. These procedures would also need to be modified over time to reflect the changing mix of popular games and would need to be carefully designed so that electricity use is measured for delivering comparable levels of service (e.g., resolution and frame rates) so that the comparisons between different consoles and gaming PCs are truly consistent ones.

A look at the characteristics of some popular games confirms the complexity of the benchmarking task for gaming platforms.[18] Consider four of the best-selling games for 2015[19]:

1. Call of Duty: Black Ops III – Runs dynamic resolution to try maintain 60 FPS[20].

2. Fallout 4 – Performance issues on both PS4 and Xbox one (Patch 1.03)[21] and Frame rate issues dropping below 30 FPS[22].

[18] Methods discussion for analyzing frame rates at: http://www.eurogamer.net/articles/digitalfoundry-2015-how-we-measure-console-frame-rate

[19] We omitted Madden NFL 2016 (the NPD number two game by unit sales in 2015) because it's a US football-centric game that isn't as widely played in Europe, hence the Eurogamer web site didn't test it.

[20] http://www.eurogamer.net/articles/digitalfoundry-2015-call-of-duty-black-ops-3-face-off

3. Star Wars Battlefront – Differing native resolutions (lower on Xbox One)[23].

4. Grand Theft Auto 5 – Lower detail / object density noted for Xbox One[24].

Different consoles run different games differently, which shouldn't be surprising. Games are regularly updated by downloadable patches, and a different patch version of a game can affect performance on a console (or a gaming PC). To correctly estimate efficiency in a consistent way would involve correcting for any differences in the quality of graphics output, but since these differences vary dynamically, the calculational and tracking challenge is not a trivial one.

As a proof of concept, **Figure 2** shows power measurements for four popular games taken by Joshua Aslan of Sony in June 2016 on five examples of Sony's PlayStation®4 (all are Model # CUH12xxA). The measurements are taken every second over a five-minute period. The "whisker plots" show maximum, 75th quartile, median, 25th quartile, and minimum values over the measurement period. Taller boxes imply more variation in the data values than shorter boxes.

Appendix A contains the distributions of power consumption for every console and game combination, as well as the time series of power use over time as each game was played on each console. We compare these results using ANOVA statistical tests in Appendix C, which show that the variability observed in the measured power consumption is statistically significant (at the 95% confidence interval) between the console sample used, the sequence of user actions and choices at each stage of a game over time (or phase of gameplay), and the type of game.

Due to the complexity of almost limitless choices, permutations, and combinations of user actions possible within each game, it's impossible to

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[21]http://www.eurogamer.net/articles/digitalfoundry-2016-fallout-4-patch-improves-console-graphics-quality

[22] http://www.eurogamer.net/articles/digitalfoundry-2015-fallout-4-face-off

[23] http://www.eurogamer.net/articles/digitalfoundry-2015-star-wars-battlefront-face-off

[24] http://www.eurogamer.net/articles/digitalfoundry-2015-grand-theft-auto-5-pc-face-off

replicate a test exactly. Median, maximum, and minimum power measurements vary for each game title tested when played on different console samples. This demonstrates the difficulty in replicating gameplay (due to the limitless combinations of user actions possible within each game, as well as unseen background functionality not under direct user control) and the statistical variation in hardware and software of the console sample itself. In addition, the plots below highlight the capability of new generation consoles to dynamically scale power consumption as required. Some games, like Call of Duty, show significant power scaling, while others, such as Battlefield 4 (a competing title to Call of Duty), show much less variation.

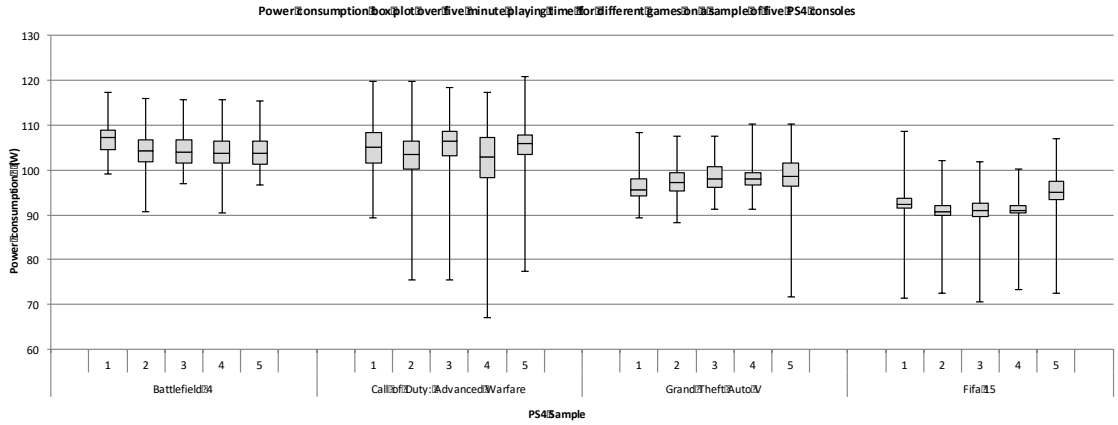

Figure 2: Characteristics of power measurements for four popular games over a five minute period

Power use even varies significantly when playing the same game on the same console. **Figure 3** shows the same whisker chart as in Figure 2, but with measurements taken when playing one game five different times on the same console (Console 2 from Figure 2). Appendix B shows the detailed distributions and time series measurements for these data, just as in Appendix A. The progress of the game and variations in the way the game story evolves affect power use significantly (verified in Appendix C; Tables C-2 to C-5).

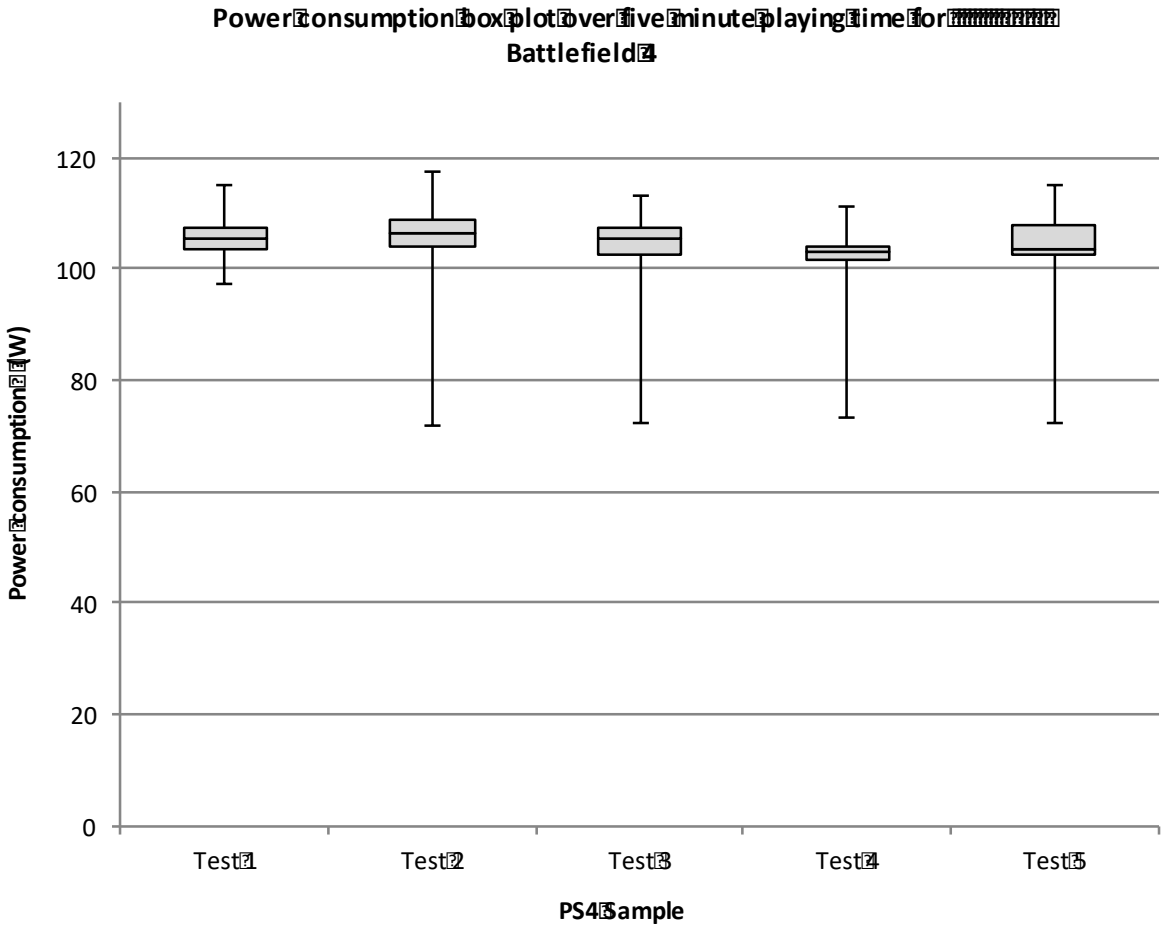

Figure 3: Characteristics of power measurements for one popular game played over a five-minute period five different times on the same console unit

A different approach to benchmarking (distinguished from measuring power levels associated with operating a console) is to give consumers a relative ranking of different products based on component characteristics, which is the approach taken by Enervee.[25] This rating system involves detailed technical knowledge of the hardware specifications in four major subsystems: CPU, GPU, RAM, and hard disk drive.[26] Enervee develops a "performance factor" for each of these subsystems and weights that performance factor equally across the four categories. The Enervee Score takes that performance factor and divides by

[25] https://enervee.com/video-game-consoles/

[26] http://cleantechnica.com/2013/08/02/playstation-4-leads-the-way-in-video-game-console-energy-efficiency/

estimated annual energy consumption, and the result is scaled for all products in the category to cover a 0 to 100 scale.

Enervee's approach gives consumers a credible basis on which to compare the hardware efficiency of consoles, but it is more of a relative informational scale than anything on which a regulation could be based. It also is focused only on hardware, but as shown above, software also has a huge influence on the quality of gaming experience and the level of computational output from a computing system. Ignoring software simplifies the benchmarking task but makes it less likely that a benchmark will be reflective of user experience and actual computing services delivered.

Mills and Mills [5] analyze component-based rated power for gaming PCs, then compare rated power of all components to actual electricity consumption measured while running a GPU frames per second (FPS) benchmark (a benchmark for GPUs of gaming PCs from Unigine: https://unigine.com/products/benchmarks/). They also compare rated to actual component power draws for two CPUs, two GPUs, two motherboards, two power supplies, and three monitors. In addition, they benchmarked the CPUs with Cinebench and examined the effects of overclocking CPUs on performance.

Unfortunately, FPS is not the only measure of graphics performance, never mind gaming performance. In addition, the Unigine benchmark is limited to use with PC GPUs. This benchmark is not technically compatible for use with gaming consoles, because the software layers that allow the CPU to access the GPU in consoles are different than in PCs. On consoles, these layers are less intrusive and more highly optimized, allowing for better performance and energy efficiency for a given GPU and CPU architecture. This also means the system layers needed for a GPU benchmark such as Unigine to run on a PC do not exist on a console, and adding them would result in a benchmark that would not be representative of games console power consumption and efficiency in actual use (because real game play takes advantage of the much faster GPU access the console has, without the interference of the additional system layers in a gaming PC).

A related component-based approach is that used in [20] to create a consistent comparison of energy consumption associated with improving GPUs in gaming PCs. Other examples include the set of allowable total energy consumption adders associated with GPUs of different performance summarized in recently proposed California efficiency standards for computing devices [21] and a 2013 European Union regulation for PCs and servers [22]. Such an approach focuses on an important component – e.g., the GPU- and characterizes a critical parameter affecting performance of that component – e.g., frame buffer bandwidth – or some measurement of performance of that component – like GB/s of data transfers to and from the GPU. Such measures may be relevant for standardized PC architecture, but not for console architectures that are integrated and optimized. Consoles do not have dedicated high bandwidth memory for use with discrete GPUs, but instead use shared high bandwidth memory for use with integrated system components.

What makes a good benchmark?

A good efficiency benchmark should be

- repeatable
- representative of real world computing activities
- normalized to equivalent levels of computing services (e.g. frame rates and video resolution, which are related to specifications like HD, Ultra HD, etc)
- comparable in a meaningful and accurate way across platforms (e.g. between types of consoles and between consoles and PC gaming platforms)
- stable over time
- regarded as neutral by competing companies
- based on publicly disclosed test procedures and system settings

The value of a computing benchmark depends on the purpose to which it will be put. Benchmarks have been used for consumer efficiency information, but they have also been used for regulatory proceedings and for utilities to pay incentives to customers to improve the energy efficiency of appliances and electronic equipment. Consumer information represents the least demanding application of computing benchmarks. The bar is higher for benchmarks used in regulatory proceedings or to calculate incentive payments, as it should be. Some efficiency

benchmarks are used internally by companies to improve relative efficiency of computing platforms, but are not intended for external consumption.
Below we review the various criteria in the context of existing attempts to benchmark console/gaming PC performance and energy use. These attempts all fall short of what would be needed to create an ideal benchmark, but we can still learn something from each attempt.

Repeatability and representativeness

A reproducible gaming benchmark would require that settings on each device be systematized and recorded. These parameters would include OS/firmware version, game patch version, console system settings (such as native output resolution i.e. 1080P) and in-game graphics settings (if available).
No measurement of gaming performance can be repeated exactly, because game play is dynamic and unpredictable, due to the many possible combinations of actions possible in a game. For this same reason, it's impossible to create a representative computing task for gaming devices in the way industry has done for servers.

Normalized to consistent levels of service

Normalizing to consistent service levels is also impossible, because of the dynamic nature of video resolution, frame rates, and other factors affecting game performance, the complexity of branching choices inside of games, and the multi-faceted nature of the computing services delivered by gaming devices. Industry has attempted to simplify characterization of video services using terms like HD, Ultra HD, or "generations" of consoles within the current version of their VA, but these categories don't reflect differences in all important aspects of gaming performance. In future, such generational characterizations will need to account for measures of overall console performance beyond image resolution or frame rate.
An additional complexity is that the purpose of gaming is not to produce any specific output (as for servers or computers in business), but *to have fun*. Each person has a unique perspective, and not everything about consoles that can be measured matters to people using the machines. In some cases, changes in console capabilities may not even be visible to users. Given these realities, it is unclear how we can quantify user experience in a consistent and reproducible way.

Comparable across platforms

Because of the differences in the architecture of consoles and PCs, creating a cross platform benchmark has proved to be a challenge. No cross-platform benchmarks that are representative and normalized by level of service currently exist, and it is unlikely that one can be created.

Stable over time

This criterion will never be met exactly, because computing platforms change over time, requiring modifications of benchmarks. But to the extent possible, benchmarks need to remain stable. This criterion shouldn't be hard to meet, assuming industry could agree on a reasonable benchmark. The rate of change in the technology industry makes it imperative to "future proof" any performance metrics to the extent possible.

Vendor neutrality

Even if a test could be designed that is "fair", vendors may object if it disadvantages their product. This implies that a neutral third party would need to design and take charge of the testing.

Based on publicly disclosed procedures

This criterion is relatively easy to meet, and it is in the interest of all stakeholders to release the information so the tests become widely accepted.

Conclusions

The dynamic nature of consoles creates extreme complexity. It is unlikely that meaningful metrics for comparing gaming performance can ever be developed for game consoles and gaming PCs. The complexity of these devices makes it difficult to define computational output in a way that can be accurately, consistently, and correctly compared across game consoles or between consoles and gaming PCs. Without consistent computational benchmarks, it's unlikely that a benchmark for active gaming will ever be good enough on which to base efficiency regulations or utility incentives to promote more efficient products.

Acknowledgments

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APPENDIX A: DETAILED MEASUREMENTS

This appendix shows power use by five different PlayStation® units while playing four different games. **Figure A-1** shows the distribution of power measurements for all combinations of consoles and games, while **Figure A-2** shows the second by second power measurements over time for the same combinations.

Figure A-1: Distribution of power measurements for five consoles playing four games

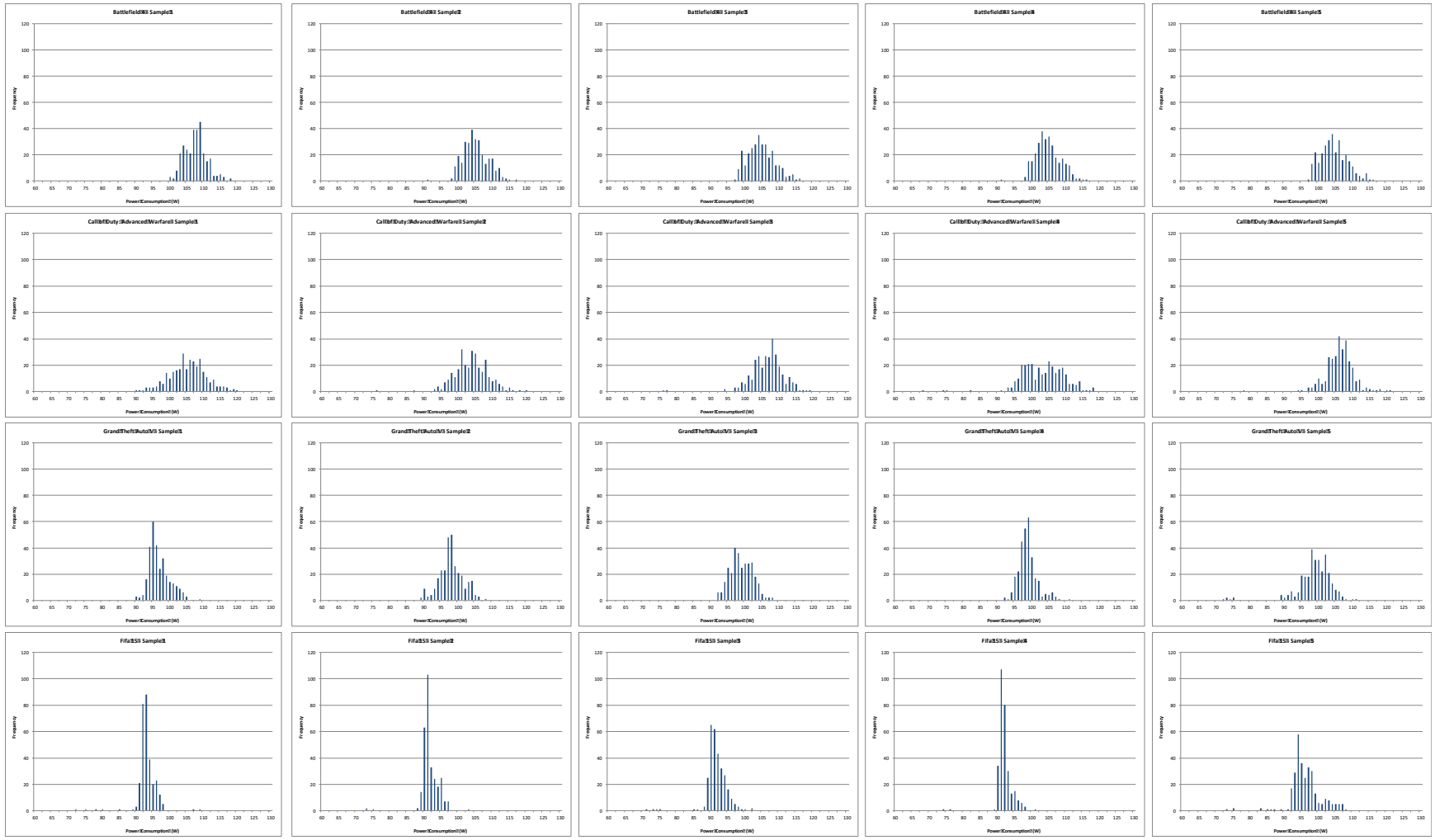
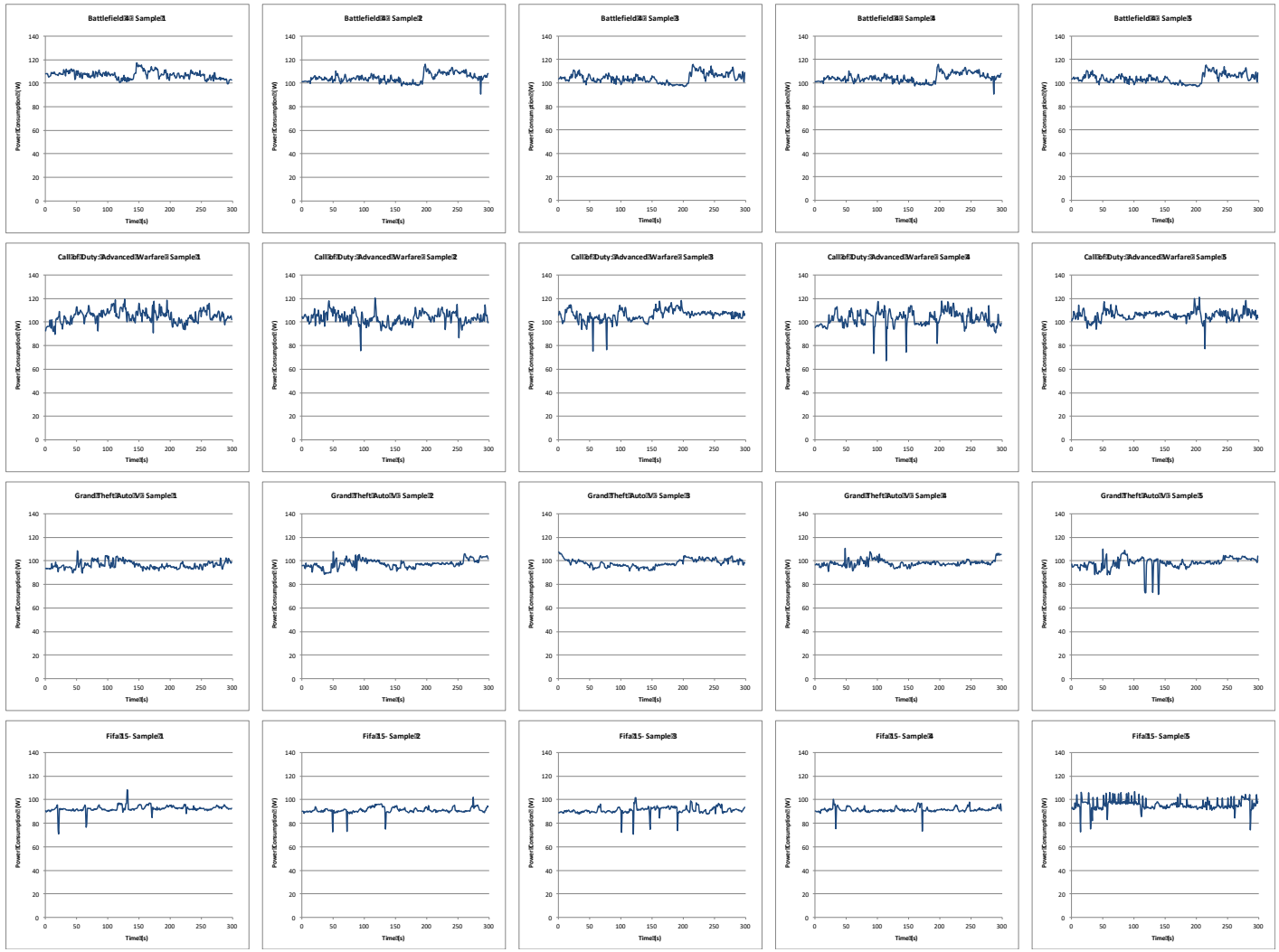


Figure A-2: Time series of power measurements for five consoles playing four games



APPENDIX B: DETAILED MEASUREMENTS OF GAME PLAY ON A SINGLE CONSOLE

This appendix shows power use by the same PlayStation® unit (Console Sample 2 from the figures in Appendix A) while playing the same game (Call of Duty) five different times. **Figure B-1** shows the distribution of power measurements for all five times this console was used to play Call of Duty, while **Figure B-2** shows the second by second power measurements over time for the same combinations.

Figure B-1: Distribution of power measurements for one console playing one game five times

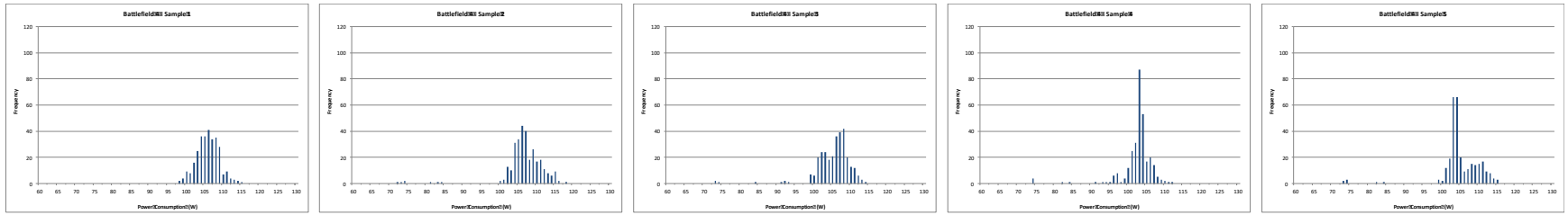
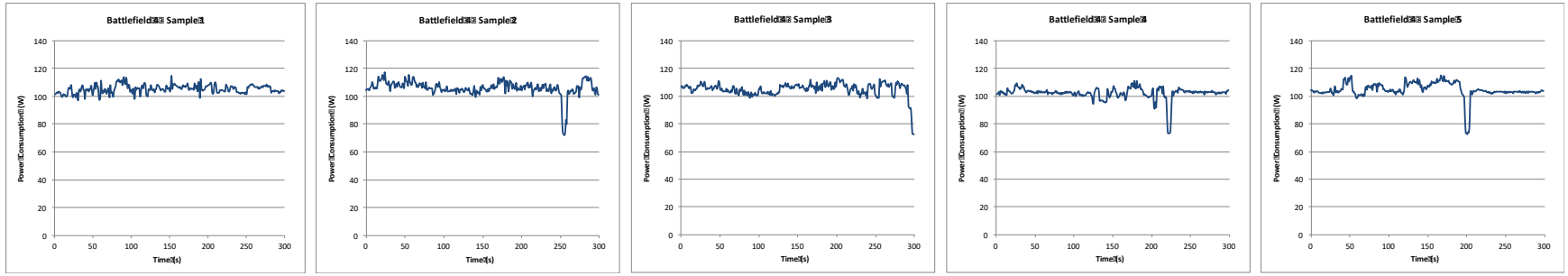


Figure B-2: Time series of power measurements for one console playing one game five times



APPENDIX C: ANALYSIS OF VARIANCE

This appendix details the ANOVA tests for statistical significance between the independent variables of console sample, game used and phase of gameplay on the dependent variable of console power consumption.

All tests are conducted at the 95% confidence interval, $\alpha = 0.05$

1. Console sample and game used

Test used: two-way ANOVA with replication.

Independent variables: console sample and game used

Dependent variable: measured power consumption (sample size of 300, as measurements were made every second for five minutes)

H_0 :

1. there is no significant difference between the measured power consumption of consoles using different samples
2. there is no significant difference between the measured power consumption of consoles using different games
3. there is no interaction between console sample and game used

Table C-1: Two way ANOVA test for console sample and game used

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	158878.6	3	52959.53	3277.595	0	2.606394
Columns	2741.958	4	685.4894	42.42402	3.85E-35	2.373418
Interaction	7251.822	12	604.3185	37.40046	3.61E-85	1.753788
Within	96625.13	5980	16.15805			
Total	265497.5	5999				

$F > F_{crit}$ and $P < 0.05$ for each case, so we reject all the statements of the null hypothesis.

Interpretation:

Therefore there is statistically significant variability between the console samples tested (using the same game) and between the different games played (on the

same console). On top of this, there is a statistically significant interaction between the console sample used and game tested – and power consumption does depend on the type of game tested.

2. Console sample and gameplay phase

To test if the variability due to the period of gameplay – each sample was split into 30 second periods; the first 30s is phase 1, the second 30s is phase 2 etc. Since we have proved that power consumption has significant variability due to the game used, the impact of time/sequence of action (or "phase" of gameplay) and console sample for each game are tested separately:

Test used: two-way ANOVA with replication:

Independent variables: console sample and gameplay phase.

Dependent variables: measured power consumption

H_0 :

1. there is no significant difference between the measured power consumption of consoles using different samples
2. there is no significant difference between the measured power consumption of consoles during different gameplay phases
3. there is no interaction between console sample and gameplay phase

Battlefield 4:

Table C-2: Two way ANOVA test for console sample and gameplay phase using Battlefield 4

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	5069.955	9	563.3284	83.31999	1.2E-124	1.886324
Columns	2043.844	4	510.9611	75.57452	3E-58	2.378065
Interaction	5493.683	36	152.6023	22.57089	3.4E-114	1.424915
Within	9803.483	1450	6.761023			
Total	22410.97	1499				

$F > F_{crit}$ and $P < 0.05$ for each case, so we reject all the statements of the null hypothesis.

Call of Duty:

Table C-3: Two way ANOVA test for console sample and gameplay phase using Call of Duty: Advanced Warfare

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	1958.049	9	217.561	10.35588	1.26E-15	1.886324
Columns	2465.296	4	616.3239	29.33694	1.74E-23	2.378065
Interaction	8733.473	36	242.5965	11.54756	5.58E-57	1.424915
Within	30462.27	1450	21.00846			
Total	43619.09	1499				

$F > F_{crit}$ and $P < 0.05$ for each case, so we reject all the statements of the null hypothesis.

Grand Theft Auto V:

Table C-4: Two way ANOVA test for console sample and gameplay phase using Grand Theft Auto V

ANOVA

Source of	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Variation						
Sample	3288.483	9	365.387	41.48103	2.58E-66	1.886324
Columns	926.1715	4	231.5429	26.2862	4.54E-21	2.378065
Interaction	3900.752	36	108.3542	12.30105	3.63E-61	1.424915
Within	12772.37	1450	8.808533			
Total	20887.78	1499				

$F > F_{crit}$ and $P < 0.05$ for each case, so we reject all the statements of the null hypothesis.

FIFA 15:

Table C-5: Two way ANOVA test for console sample and gameplay phase using FIFA 15

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	585.2578	9	65.02865	7.187958	2.9E-10	1.886324
Columns	4558.468	4	1139.617	125.9679	2.32E-92	2.378065
Interaction	1439.366	36	39.98238	4.419463	2.53E-16	1.424915
Within	13117.99	1450	9.046888			
Total	19701.08	1499				

$F > F_{crit}$ and $P < 0.05$ for each case, so we reject all the statements of the null hypothesis.

Interpretation:

There is, therefore statistically significant variability between the console samples tested (during the same gameplay phase) and between the different gameplay phases (on the same console). On top of this, there is a statistically significant interaction between the console sample used and gameplay phase – and power consumption does depend on the gameplay phase (i.e. power consumption varies through each 30s segment of gameplay).