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SEAD | SUPER-EFFICIENT EQUIPMENT AND APPLIANCE DEPLOYMENT INITIATIVE

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Power Mode Assessment

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SEAD Computer Working Group

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Abstract

The amount of energy used during the active mode of desktop and notebook computers is an important consideration in overall computer energy efficiency. Despite this, active mode energy efficiency is not addressed by any major energy efficiency initiative. Hurdles to the inclusion of active mode energy efficiency appear to stem from a desire not to adversely impact computational performance and a lack of suitable test procedures. It is shown that some computer performance benchmark applications on the market may hold promise to support the inclusion of active mode energy efficiency specifications within energy efficiency initiatives, but that further work is required in the area. It is also shown that through the development of a simplistic test procedure, active mode energy efficiencies can, to a certain extent, be addressed in environmental initiatives therein encouraging further energy efficiency improvements without impacting computational performance.

Contents

SEAD | SUPER-EFFICIENT EQUIPMENT AND APPLIANCE DEPLOYMENT INITIATIVE

Table of Figures

1. Introduction

The majority of office and domestic computers do not have a singular power demand, rather they have a range of different power demands. The differing power demands are a result of computers having different states of operation, often called "power modes" or "power states". These differing power states reflect differing levels of operational performance ranging from active mode, where computational work is being conducted to off mode, where the computer is in an off state and therefore providing no functionality to the user.

Current initiatives which seek to encourage improvements in the energy efficiency of computers tend to focus on the same set of power modes. Whilst these power modes account for the majority of time spent a computer spends in different power modes, there are other power modes such as active mode that may hold opportunities for further energy savings.

This report investigates whether or not current initiatives are focusing on the most appropriate power modes to encourage increased energy efficiency. A special focus is given to discussing the active mode power demand in computers, which has not yet been addressed in any major energy efficiency initiative, to identify whether or not this power mode should be addressed and if so how energy efficiency initiatives could go about its inclusion in energy efficiency specifications.

2. The Power Modes

In order to assess whether or not energy efficiency initiatives are focusing on the most appropriate power modes, it is first necessary to describe the power modes found in computers and within which initiatives they are used.

Power Mode Definitions

This section of the report introduces the main power modes found in computers and identifies how the power modes are mapped to different types of computers in the main initiatives. With the exception of Maximum Power, the definitions below are taken from the ENERGY STAR v6.1 specification for computers.[1]

Maximum Power: The power state in which the computer is using the maximum amount of power possible. This power mode is not normally entered during normal usage of a computer and is instead only seen when specifically designed programmes to stress either the Central processing unit (CPU) or graphical processing unit (GPU), or both, are installed onto a computer. Maximum power could be considered as the highest power demanding active state in a computer.

Active State: The power state in which the computer is carrying out useful work in response to either a prior or concurrent user input or prior or concurrent instruction over the network. Active State is normally considered to include active processing, seeking data from storage, memory, or cache, including Idle State time while awaiting further user input and before entering low power modes. The amount of work being

[1] US EPA, ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 6.1, available from http://www.energystar.gov/products/certified-products/detail/7629/partners

conducted can vary significantly during active states and so computers will typically have many different power demands during this mode.

Idle State: The power state in which the operating system and other software have completed loading, a user profile has been created, activity is limited to those basic applications that the system starts by default, and the computer is not in a Sleep Mode.
Idle State has more recently been composed of two sub-states: Short Idle and Long Idle.

- Long Idle: The mode where the Computer has reached an Idle condition and the main Computer Display has entered a low-power state where screen contents cannot be observed.
- Short Idle: The mode where the Computer has reached an Idle condition) and the screen is on. Long Idle power management features have not engaged (e.g. HDD is spinning and the Computer is prevented from entering sleep mode).

Sleep Mode: A low power mode that the computer enters automatically after a period of inactivity or by manual selection. A computer with Sleep capability can quickly "wake" in response to network connections or user interface devices with a latency of less than or equal to 5 seconds from initiation of wake event to system becoming fully usable including rendering of display. For systems where ACPI standards are applicable, Sleep Mode most commonly correlates to ACPI System Level S3 (suspend to RAM) state.

Hibernate Mode: A low power mode that the computer may enters either automatically or via user intervention. Upon hibernation, the computer saves the contents of its random access memory (RAM) to a hard disk or other non-volatile storage. Upon wake up, the computer loads the previous user session that was in effect before entering hibernation. For systems where ACPI standards are applicable, Hibernate Mode correlates to ACPI System Level S4 state.

Off Mode: The lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions. For systems where ACPI standards are applicable, Off Mode correlates to ACPI System Level S5 state.

Current Power Mode Usage

Whilst there are a large number of power modes associated with computers, most of the definitions used for these power modes are relatively standard throughout the major initiatives. As such, it is relatively simple to compare the inclusion of power modes across different initiatives as shown in Table 1. It should be noted that there is some overlap in the definition of "idle" with both "short idle" and "long idle" definitions. The extent of this overlap is product specific with "idle mode" for computers including integrated displays being largely comparable to "long idle" and "idle mode" for computers without integrated largely comparable to "short idle".

		Power States							
Initiative	Computer Type	Maximum power	Active mode	Short Idle	Long Idle	Idle Mode	Sleep Mode	Hibernate Mode	Off Mode
ENERGY STAR v6.1	Desktop	No	No	Yes	Yes	No	Yes	No	Yes
	Integrated Desktop	No	No	Yes	Yes	No	Yes	No	Yes
	Notebook	No	No	Yes	Yes	No	Yes	No	Yes
	Workstation	Yes	No	Yes	Yes	No	Yes	No	Yes
	Thin Client	No	No	Yes	Yes	No	Yes	No	Yes
	Small -scale Server	No	No	No	Yes	No	No	No	Yes
EU Ecodesign Regulation	Desktop	No	No	No	No	Yes	Yes	No	Yes
	Integrated Desktop	No	No	No	No	Yes	Yes	No	Yes
	Notebook	No	No	No	No	Yes	Yes	No	Yes
Australian Regulation	Desktop	No	No	No	No	Yes	Yes	No	Yes
	Integrated Desktop	No	No	No	No	Yes	Yes	No	Yes
	Notebook	No	No	No	No	Yes	Yes	No	Yes
EU Ecolabel	Desktop	No	No	Yes	Yes	No	Yes	No	Yes
	Integrated Desktop	No	No	Yes	Yes	No	Yes	No	Yes
	Notebook	No	No	Yes	Yes	No	Yes	No	Yes
	Workstation	Yes	No	Yes	Yes	No	Yes	No	Yes
	Thin Client	No	No	Yes	Yes	No	Yes	No	Yes
	Small -scale Server	No	No	No	Yes	No	No	No	Yes

Table 1 – Use of power modes for varying computer types within major energy efficiency initiatives

All major energy efficinecy initiatives share the commonality that they address at least one form of idle mode for the main types of home and office computers (desktop, integrated desktop and notebook computer). Sleep mode is also covered for each of the main types of home and office computers under each of the main initiatives. Off mode (Standby) is also covered under many of the initiatives.

Idle, sleep and off mode power demand requirements are normally included as a constituent of a typical energy consumption (TEC) metric defined in kilowatt hours per year (kWh/year). The TEC metric is based on a defined distribution of time spent in each of the power modes multiplied by the power demand in each of those power modes. The exception to this rule is the EU Ecodesign Regulation which also includes separate power demand limits on the sleep mode in addition to sleep mode power being considered in a TEC approach.

Active mode is not explicitly addressed by any initiative, although ENERGY STAR does include maximum power demand (the most power demanding form of active mode) within a requirement for workstation computers.

3. Energy Use Analysis

Having summarised which power modes are covered under the main energy efficiency initiatives, this section of the report investigates whether the power modes currently covered under these initiatives adequately address the overall energy used by computers. Particularly attention is given to "real world" use as opposed to the idle mode(s) test conditions that are unlikely to exist apart from the first time a computer is started and exactly as supplied.

Use Profile Analysis

In order to conduct analysis on the overall energy use of computers (focussing on the most common types of desktops and notebooks) several data sources were used. The main source of data was the US EPA ENERGY STAR v6.1 database for computers. ENERGY STAR v6.1 does not consider power demand during active mode and therefore does not include a usage profile for this mode and does not include a record, nor a test method for active mode power demand for registered products. In order to assess whether active mode is an important contributor to overall energy use of desktop and notebook computers it was necessary to secure data from other sources.

The Ecma 383 standard, a forerunner of the IEC 62623 standard (which in turn the ENERGY STAR v6.1 requirements are based upon), provides some insights into the amount of time desktop and notebook computers spend in active mode and the amount of extra power that computers draw in active mode compared to short idle mode. These Ecma usage profiles and assumptions concerning active mode power were included within the analysis. The IEC 626223 standard did not adopt the usage of active mode for desktop or notebook computers.

It was deemed that neither the ENERGY STAR nor Ecma data provided a sufficient amount of data concerning the amount of time a computer spends in active mode nor active mode power demands. To further enhance the analysis, additional information was secured from publically available websites and some basic product power testing was also conducted as part of this SEAD project.

Table 2 to Table 4 show the usage profiles that were used to assess the overall TEC values for desktop and notebook computers in the US ENERGY STAR database. It is clear from Table 2 that neither desktop nor notebook computers are assumed to spend any time in active mode. The Ecma values were based on the previous ENERGY STAR v5.2 usage patterns which estimated a total on time (i.e. computer not in sleep or off mode and so in either an idle or active mode) of 30% for notebooks and 40% for desktops. The Ecma values have been normalised to the ENERGY STAR v6.1 use profile which assumes a total on time of 40% for notebooks and 50% for desktops shown in Table 3. Recently published research[2] suggested that computers could spend 20% of their time in active modes. Under this scenario the extra time spent in active mode was assumed to replace time in short idle mode. Table 4 shows the alternative estimated use profiles based on the result of this research.

Power Mode	Notebook Computer		Desktop Computer	
	% of time	Hours/Year	% of time	Hours/Year
Off Mode	25%	2190.0	45%	3942.0
Sleep Mode	35%	3066.0	5%	438.0
Long Idle Mode	10%	876.0	15%	1314.0
Short Idle Mode	30%	2628.0	35%	3066.0
Active Mode	0%	0.0	0%	0.0

Table 2 – ENERGY STAR v6.1 use profiles for desktop and notebook computers

Power Mode	Notebook Computer		Desktop Computer	
	% of time	Hours/Year	% of time	Hours/Year
Off Mode	25.0%	2190.0	45.0%	3942.0
Sleep Mode	35.0%	3066.0	5.0%	438.0
Long Idle Mode	3.3%	291.0	0.0%	0.0
Short Idle Mode	20.9%	1827.7	32.00%	2803.2

[2] California Plug Load Research Center (University of California), October 2014, "Final project report: Monitoring Computer Power Modes Usage in a University Population", Prepared for: California Energy Commission, available from http://www.energy.ca.gov/2014publications/CEC-500-2014-092/CEC-500-2014-092.pdf

Active Mode	15.8%	1385.3	18.00%	1576.8

Table 3 – Ecma 383 use profiles for desktop and notebook computers converted to ENERGY STAR v6.1 equivalent

Power Mode	Notebook Computer		Desktop Computer	
	% of time	Hours/Year	% of time	Hours/Year
Off Mode	25.0%	2190.0	45.0%	3942.0
Sleep Mode	35.0%	3066.0	5.0%	438.0
Long Idle Mode	3.3%	291.0	0.0%	0.0
Short Idle Mode	16.7%	1461.0	30.0%	2628.0
Active Mode	20%	1752.0	20%	1752.0

Table 4 – Alternative estimated use profiles for desktop and notebook computers

In order to consider how the active mode of desktops and notebooks would impact the overall TEC results it was also necessary to identify active mode power demands. Given that active modes are not measured as part of the ENERGY STAR v6.1 test procedure no data was available within the ENERGY STAR database. The Ecma 383 standard includes some published active mode values for a range of desktop and notebook computers. Due to the limited number of results and their age, it would not have been possible to rely on the Ecma recorded active mode values to inform the analysis. However, the "Average Product active power ratio" was applied to all of the short idle values in the ENERGY STAR v6.1 database in order to give estimated active mode power demands.

	Notebook Categories			Desktop Categories				
Measurement	NB1 (W)	NB2 (W)	NB3 (W)	DT1 (W)	DT2 (W)	DT3 (W)	DT4 (W)	DT5 (W)
Off Mode	1	1	1	1.6	1.6	1.6	1.6	1.6
Sleep Mode	1.5	1.5	1.5	2.8	2.8	2.8	2.8	2.8
Long Idle Mode	22.7	19.3	22	39.3	55	120.9	210.5	168.1
Short Idle Mode	32.8	28.2	28.1	39.3	55	120.9	210.5	168.1
Active Mode	34	28.7	30.3	40	56.5	122.8	227.3	168.7
Product active power ratio	1.03	1.02	1.08	1.02	1.03	1.02	1.08	1.00

Average Product active power ratio	1.04

Table 5 – Ecma 383 Active Mode ratios for desktop and notebook computers

Whilst the Ecma 383 standard provided some insights into the active mode power of desktops and notebook computers, the published ratio of 1.04 (i.e. the ratio of active mode compared to short idle mode) appeared to be very low. Further research was conducted to identify additional, up to date, data concerning active/short idle ratios. Table 6 illustrates the active/short idle ratios for a selection of Intel X99 based desktop computers. It is clear that the estimated average active/short idle power demand ratio, at 2.86, is significantly higher than the Ecma 383 published result. It should be noted that the ratio of active/short idle for the products shown in Table 6 is likely to be higher than average due to the fact that the X99 based desktops are gaming computers. However, the large variance between the Ecma and sourced active/short idle ratios suggests that the consideration of active mode power demand may be more important than estimated in the Ecma standard.

Desktop Computer Motherboard	Long Idle	Idle	OCCT Load	Active/Short Idle Ratio
ASRock X99E-ITX	56	58	179	3.09
ASRock X99 OC Formula	57	60	180	3.00
ASRock X99 WS	60	62	201	3.24
ASRock X99-A	66	68	213	3.13
Gigabyte X99-SOC Champion	67	69	202	2.93
Asus TUF X99 Sabertooth	68	70	210	3.00
Gigabyte X99-Gaming G1 WIFI	71	72	202	2.81
Gigabyte X99-UD7 WIFI	72	74	202	2.73
Asus X99 Deluxe	76	76	219	2.88
Asus X99 Rampage V Extreme	78	83	219	2.64
MSI X99S Mpower	80	82	206	2.51
MSI X99S SLI Plus	80	81	218	2.69
ASRock X99 Extreme11	89	90	244	2.71
ASRock X99 WS-E/10G	90	92	247	2.68
		Average Product active power ratio		2.86

Table 6 – Alternative Active Mode ratios for desktop computers[3]

The different active mode usage profiles and active mode power demands were applied to the products listed in the US ENERGY STAR database using the ENERGY STAR CPU performance score and graphics type categorisation. The results of this analysis are discussed below.

Power Mode Energy Use Analysis

Figure 1 illustrates the average TEC (kWh/year) for desktop computers in the US ENERGY STAR v6.1 database depending on which use profiles are applied and the assumed increase of active mode power demand over short idle power demand. It is clear that applying the Ecma active mode use hours as well as the added active power demand (the active power ratio of 1.04 discussed earlier), results in some more energy use for each type of desktop computer than is assumed to be used under the ENERGY STAR v6.1 test procedure (where active mode is not considered). However, it is very clear that by applying the estimated active use hours and active mode ratio, identified as part of this research, then the overall expected TEC increases significantly. This suggests that further research into the energy used in active mode by desktop computers is warranted.

[3] Anandtech, July 2015, The ASUS TUF X99 Sabertooth Review, available from http://www.anandtech.com/show/9453/the-asus-tuf-x99-sabertooth-review/5

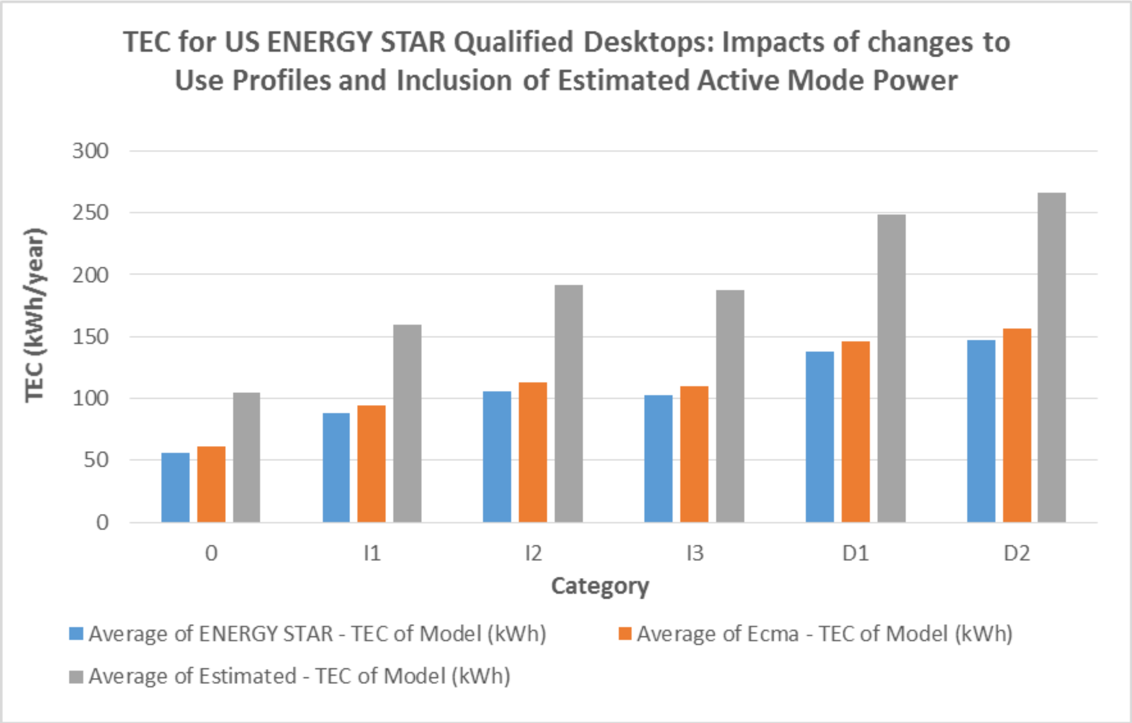

Figure 1 – Average TEC for Desktop Computers in the US ENERGY STAR database based on differing use profiles and inclusion of active mode power demands

Figure 2 shows how the energy used by desktop computers, under the ENERGY STAR v6.1 TEC approach, is divided amongst the different power modes. This clearly shows that the short idle power mode contributes by far the greatest amount of energy to the overall TEC value under the ENERGY STAR idle, sleep and off modal approach.

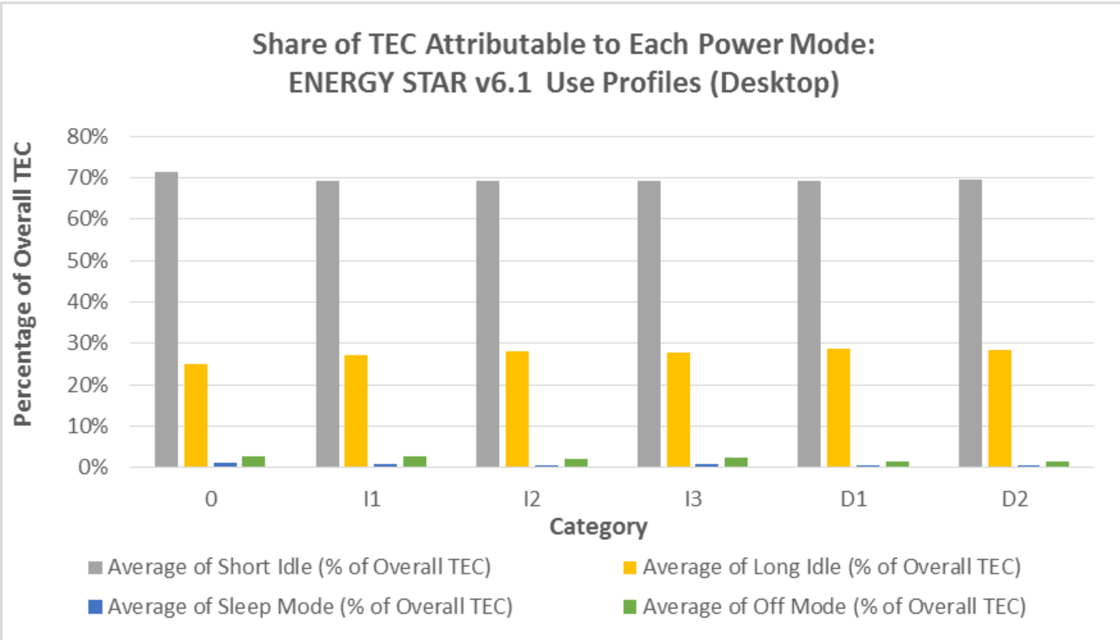

Figure 2 –Share of TEC per Power Mode for Desktop Computers in the US ENERGY STAR database based on the ENERGY STAR v6.1 use profiles

Figure 3 shows how the energy used by desktop computers, under the Ecma assumptions, is divided amongst the different power modes. It is shown that whilst the short idle power mode accounts for the greatest amount of energy, energy use in active mode, using 1.04 multiplier from short idle power to active power, is also considerable.

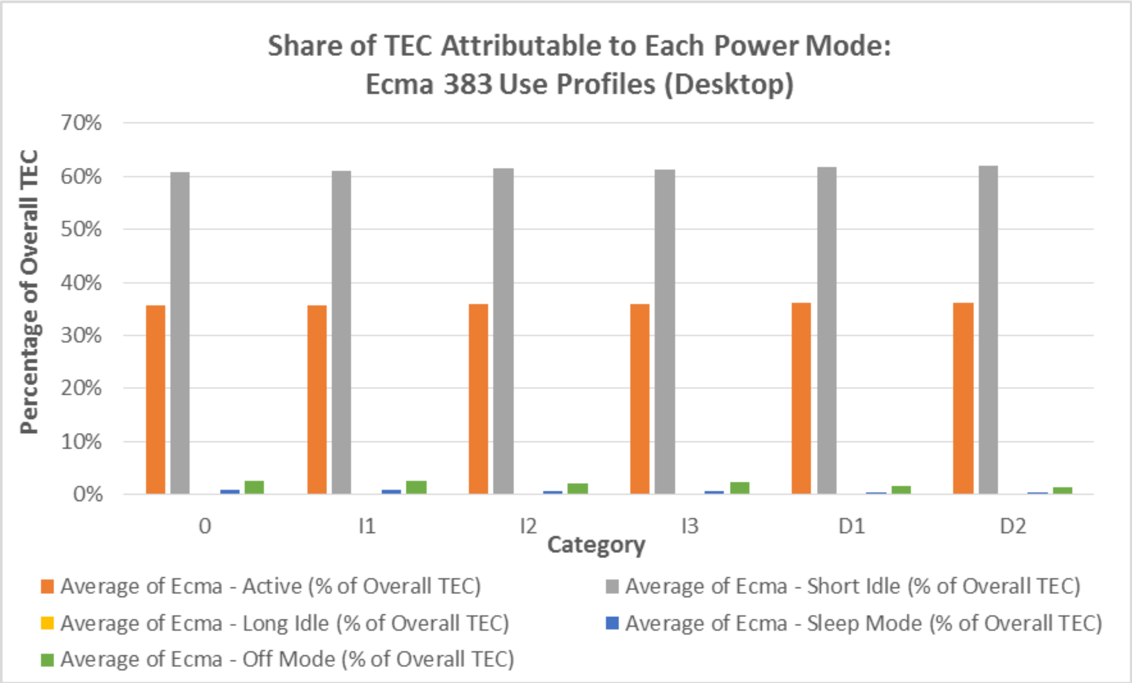

Figure 3 – Share of TEC per Power Mode for Desktop Computers in the US ENERGY STAR database based on Ecma 383 use profiles and active mode power demand ratio

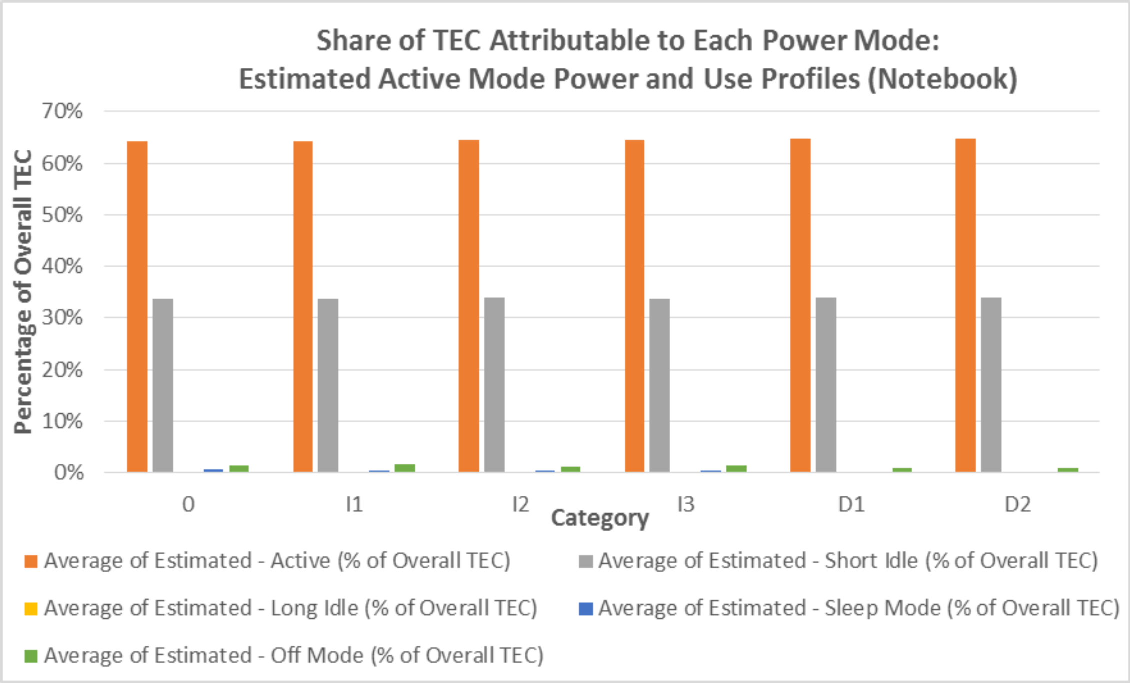

Figure 4 – Share of TEC per Power Mode for Desktop Computers in the US ENERGY STAR database based on Estimated use profiles and active mode power demand ratio

Figure 4 shows the share of TEC attributable to each power mode when the estimated active mode use profiles and power demands (i.e. those identified during the course of the research) are applied to desktops in the US ENERGY STAR database. The graph clearly shows that active mode accounts for by far the most energy use. This again suggests that further research should be conducted on the active mode of desktop computers to ascertain whether additional energy savings would be possible from tackling this power mode.

Figure 5 to Figure 7 show the results of the same analysis but in terms of absolute TEC (kWh/year) rather than percentages of TEC.

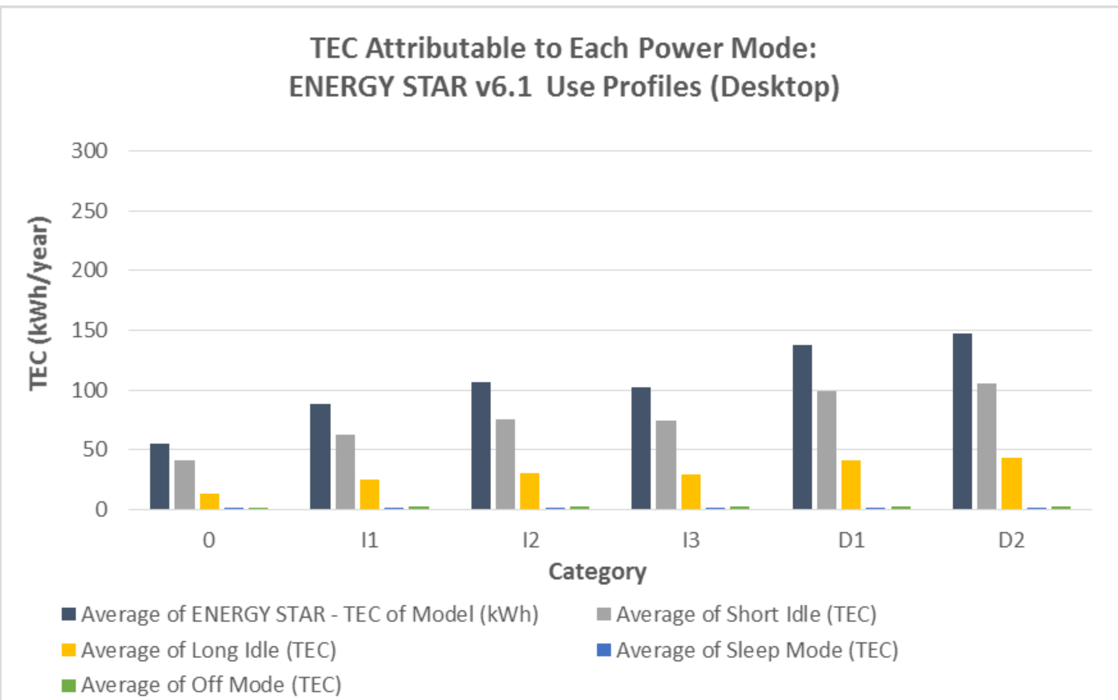

Figure 5 – TEC per Power Mode for ENERGY STAR Desktop Computers based on the ENERGY STAR v6.1 values

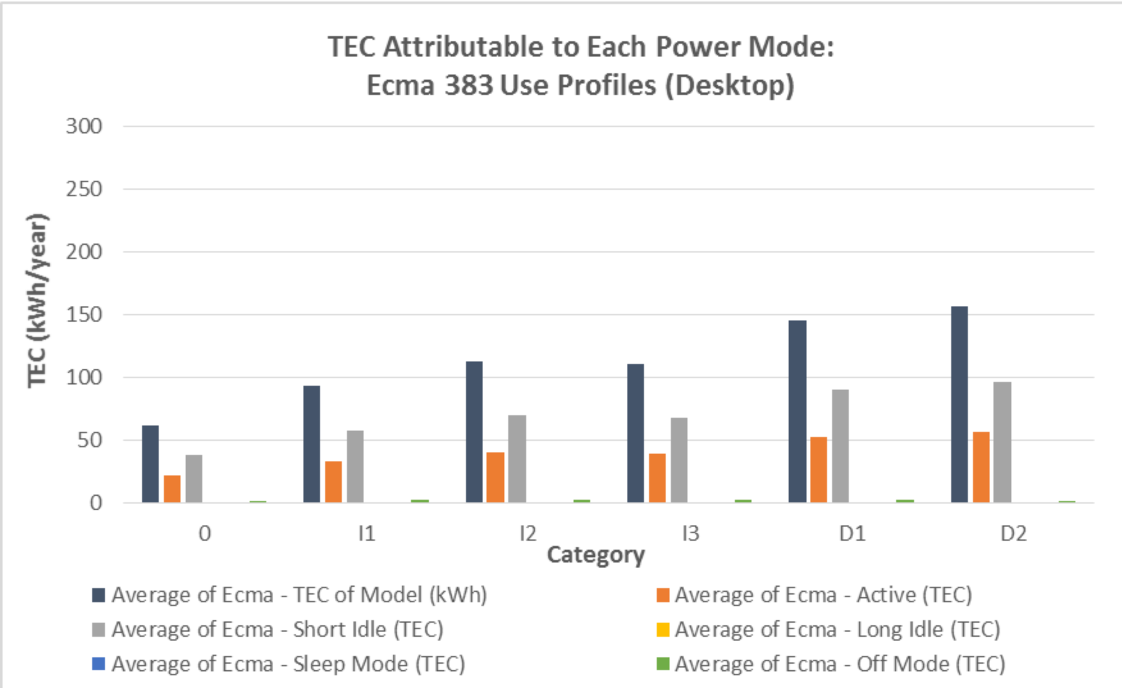

Figure 6 – TEC per Power Mode for ENERGY STAR Desktop Computers based on Ecma 383 values

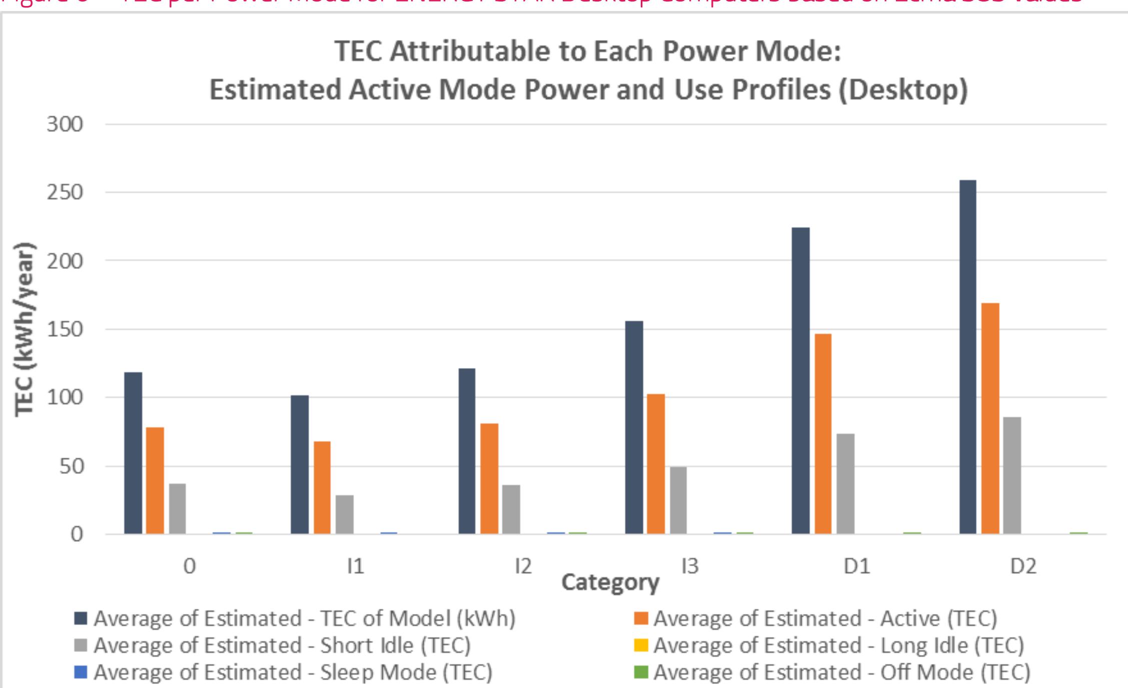

Figure 7 – TEC per Power Mode for ENERGY STAR Desktop Computers based on the Estimated values

Figure 8 to Figure 14 show the results of the same analysis (i.e. comparing the impacts of active mode energy use across the three scenarios (ENERGY STAR, Ecma and further estimated)) but for notebook computers. Again it can be seen that short idle is the dominant energy use mode under the ENERGY STAR conditions, but, in contrast to desktops, also accounts for the most energy when the Ecma use and active mode ratios are applied. However, when the active use hours and power ratios are increased under the "estimated" scenario, the active mode once again becomes the dominant power mode in terms of energy use (as illustrated clearly in Figure 11). It should be noted that as the estimated active mode ratios were based on findings from desktop gamin computers they are likely leading to an overestimation of active mode power demand in the notebook computers (i.e. notebook computers are unlikely have as large a delta between active and short idle as in gaming desktop computers).

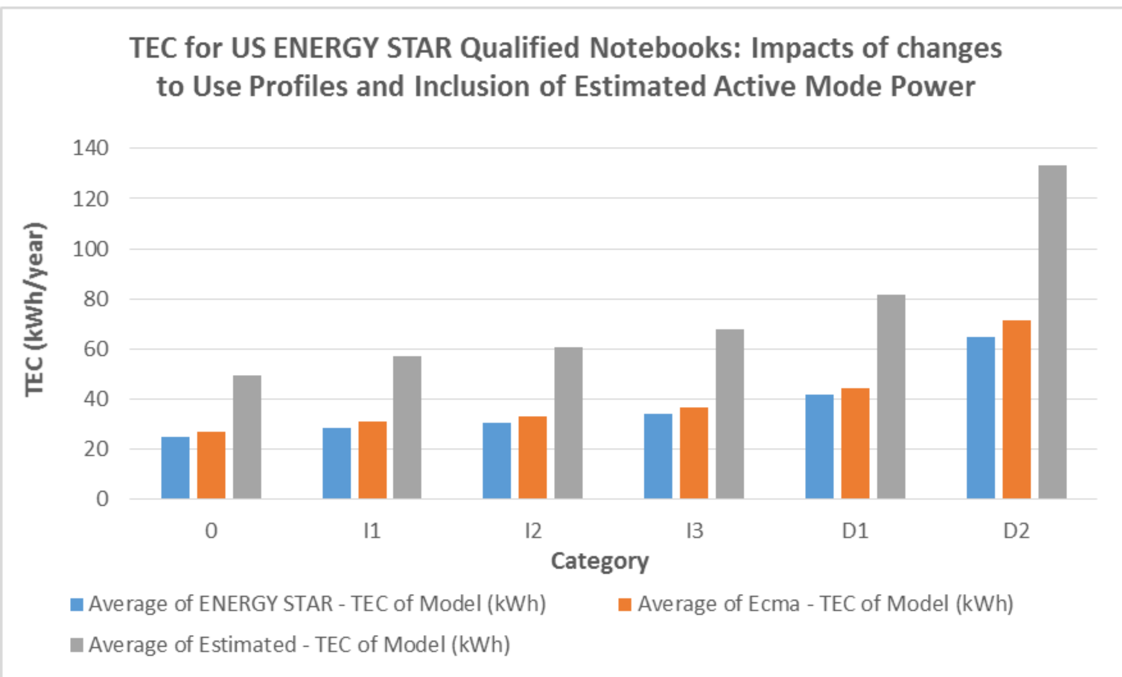

Figure 8 – Average TEC for Notebook Computers in the US ENERGY STAR database based on differing use profiles and inclusion of active mode power demands

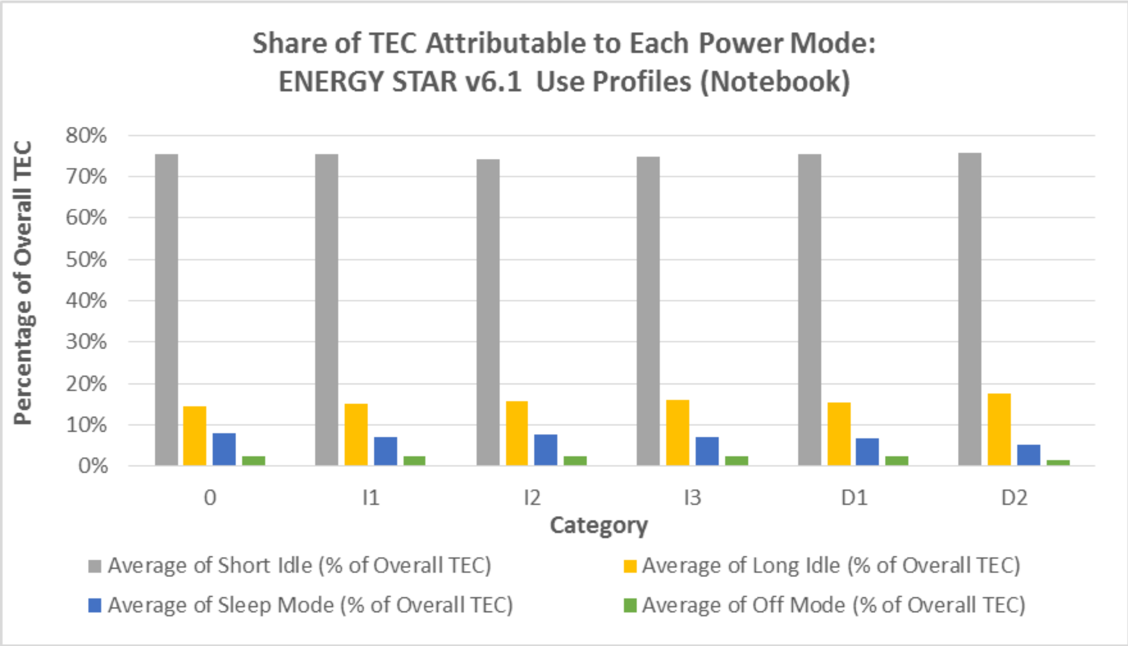

Figure 9 – Share of TEC per Power Mode for Notebook Computers in the US ENERGY STAR database based on the ENERGY STAR v6.1 use profiles

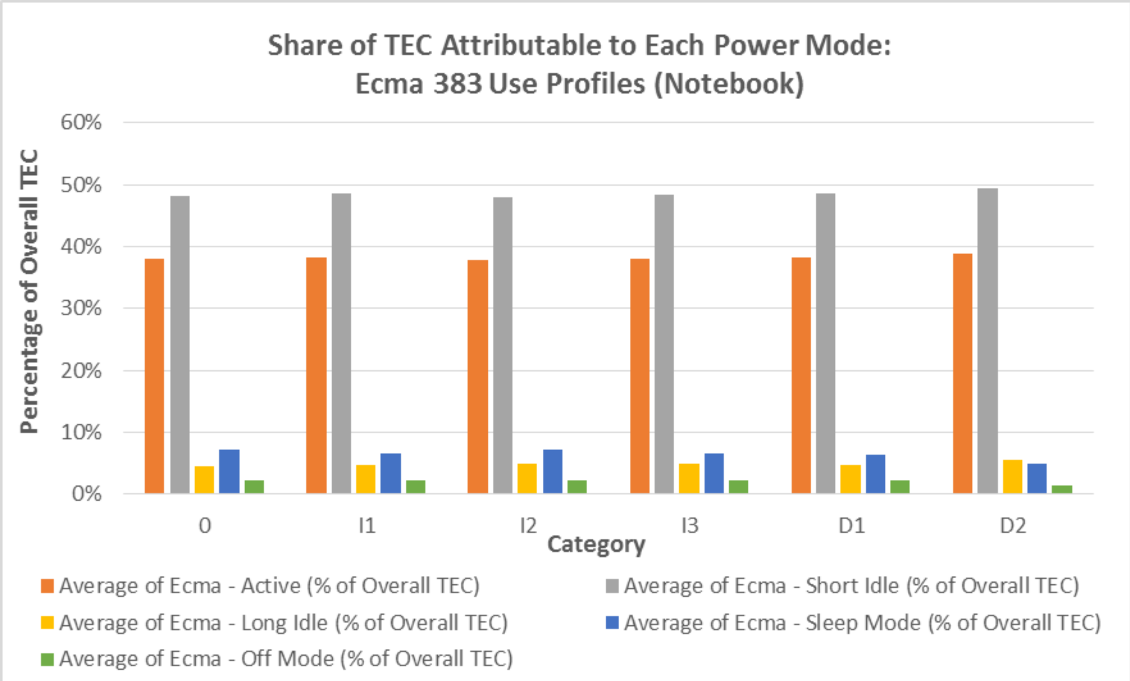

Figure 10 – Share of TEC per Power Mode for Notebook Computers in the US ENERGY STAR database based on Ecma 383 use profiles

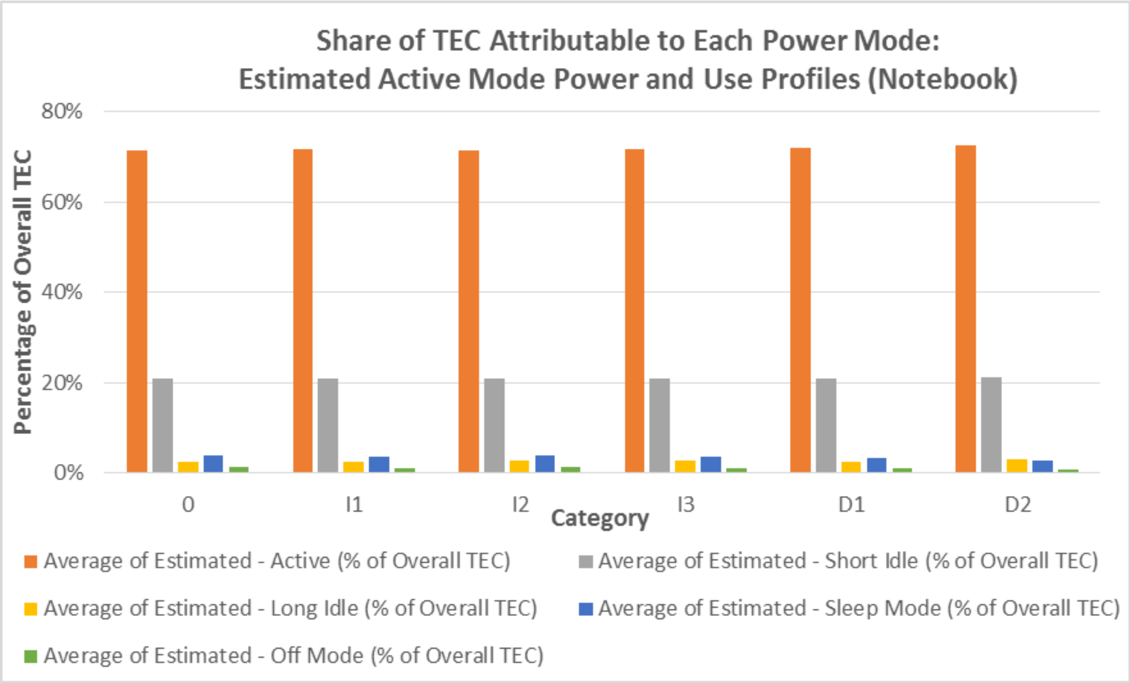

Figure 11 – Share of TEC per Power Mode for Notebook Computers in the US ENERGY STAR database based on Estimated use profiles

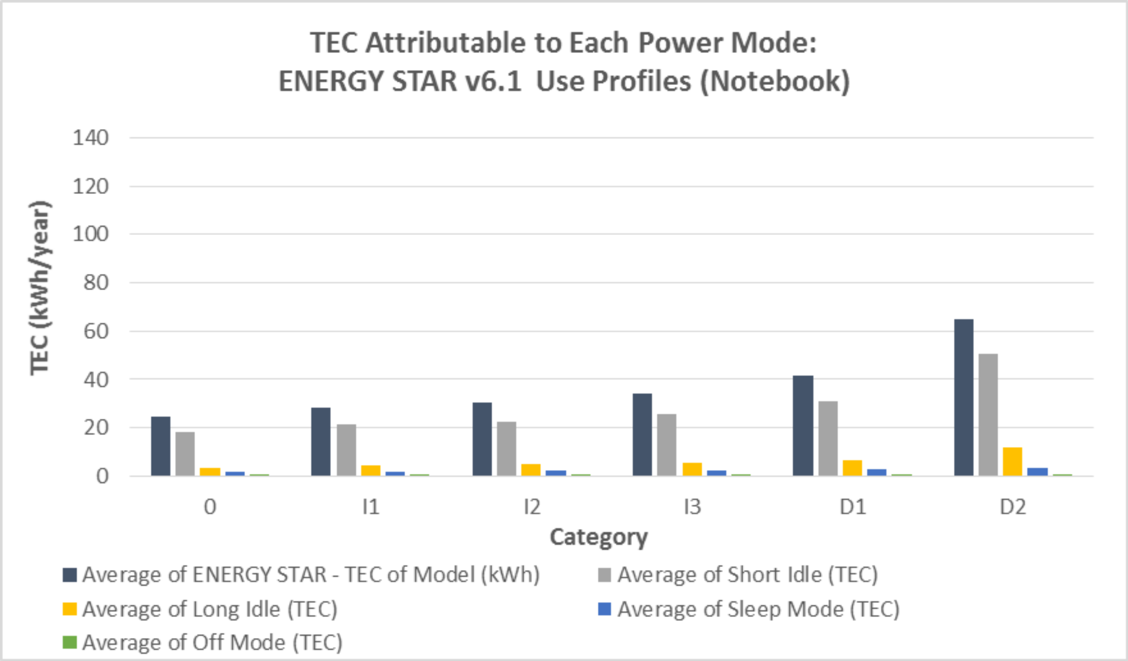

Figure 12 – Average TEC for Notebook Computers in the EU ENERGY STAR database over time compared to the EU Ecodesign Requirements

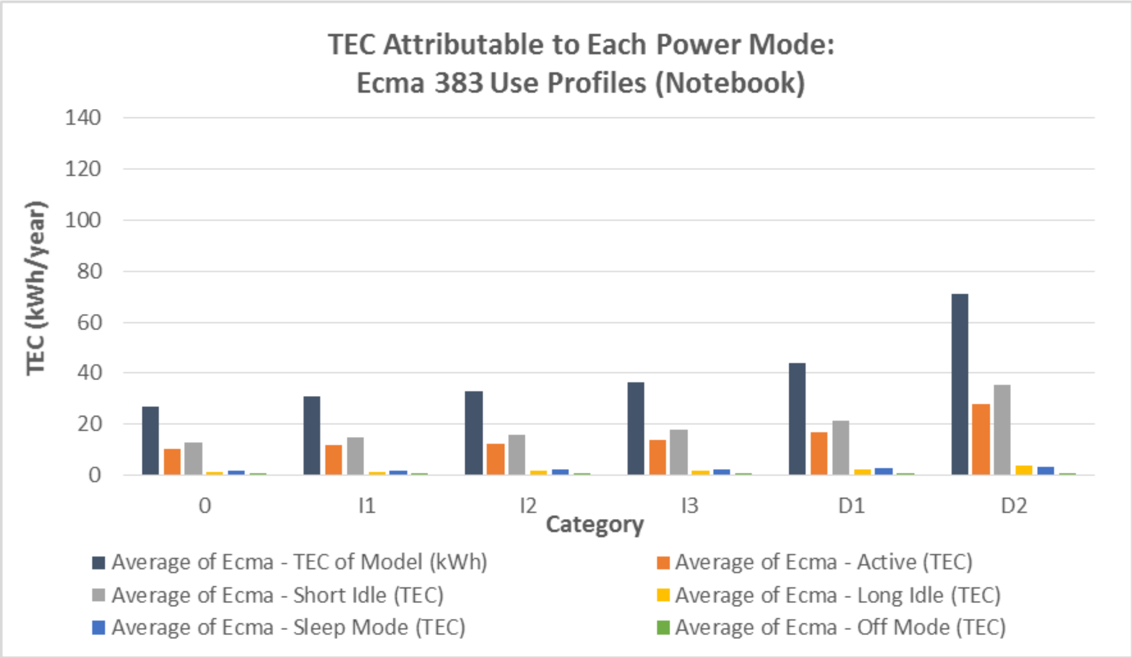

Figure 13 – Average TEC for Notebook Computers in the EU ENERGY STAR database over time compared to the EU Ecodesign Requirements

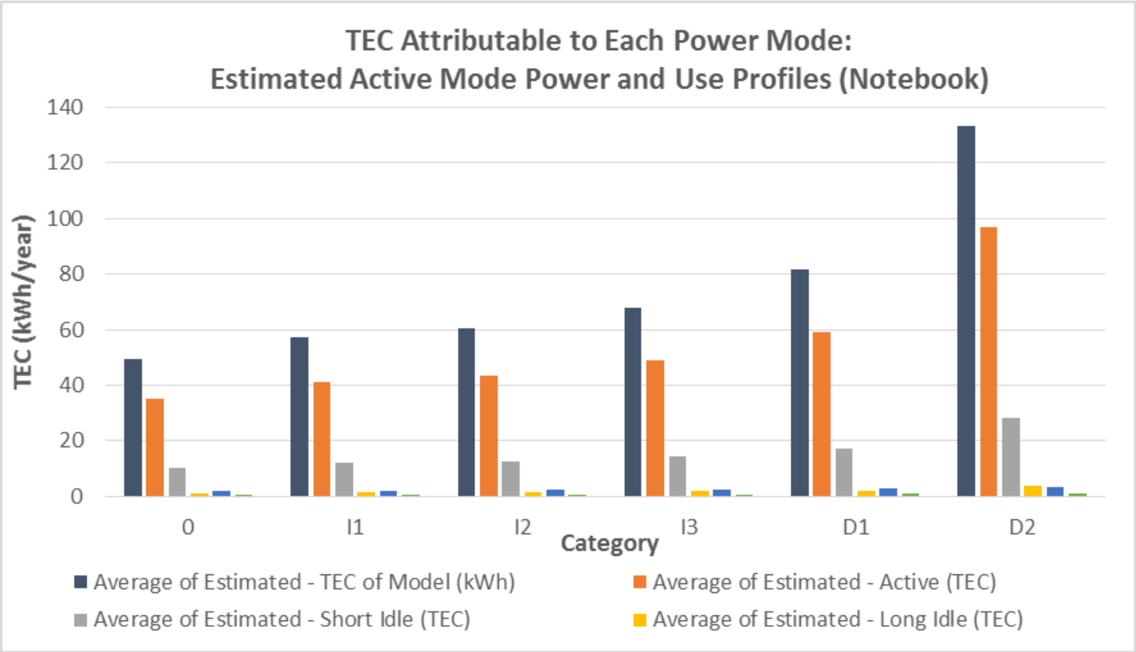

Figure 14 – Average TEC for Notebook Computers in the EU ENERGY STAR database over time compared to the EU Ecodesign Requirements

4. Measuring Active Mode

The previous sections of the report identified that current environmental initiatives are not addressing the active mode of desktop or notebook computers but also noted that the active mode of these types of computers could account for the greatest share of overall energy use. However, it was also noted that the estimates surrounding the active mode power ratio for notebook computers could have been overestimated in the analysis.

Power Mode/State	Notebook (external display attached)	Notebook (no external display attached)	Ratio of Active Power to Short Idle (no external display attached)
Average Active Mode (W)	24.1	23.1	1.63
Game Starcraft II (Active gaming) (W)	40.0	39.4	2.77
HD Youtube Video (HD Test Pattern) (Edge) (W)	19.2	18.8	1.32
HD Youtube Video (HD Test Pattern) (Chrome) (W)	25.0	24.3	1.71
HD Youtube Video (HD Living Planet) (Edge) (W)	19.2	18.8	1.32
HD Youtube Video (HD Living Planet) (Chrome) (W)	25.3	24.8	1.75
HD Youtube Video (HD White Screen) (Edge) (W)	19.8	18.3	1.85
HD Youtube Video (HD White Screen) (Chrome) (W)	27.5	26.2	1.29
HD Youtube Video (HD Test Pattern) (Edge) (W)	20.0	16.0	1.13
HD Youtube Video (HD Test Pattern) (Chrome) (W)	25.7	24.8	1.75
Excel File (64MB) during Opening (W)	28.2	27.8	1.96
Excel File (64MB) (W)	15.4	15.2	1.07
Short Idle (W)	14.7	14.2	n/a
Long Idle (W)	9.6	9.6	n/a
Sleep Mode (W)	1.2	1.2	n/a
Hibernate Mode (W)	0.7	0.7	n/a
Off Mode (W)	0.7	0.7	n/a

Table 7 – Results of power demand tests for an ENERGY STAR registered notebook computer

In an attempt to assess the multiplier for notebook computers, power testing was conducted on a notebook computer.[4] The testing consisted of measuring power demand in a range of different power modes including several active modes. The test results can be seen in Table 7 and summarised in Figure 15. It is clear that power demand during active mode can vary significantly, dependent not only on what computing functionality is being provided (e.g. gaming versus watching a video) but also varying by which software programme (e.g. watching HD videos through Chrome compared to Edge) is providing the functionality. It can also be seen that at the lowest level of active mode (running an Excel file) the active power demand ratio is 1.07, which is only slightly higher than Ecma value of 1.04. However, the active mode ratio is significantly higher when other more computational intensive tasks are running.

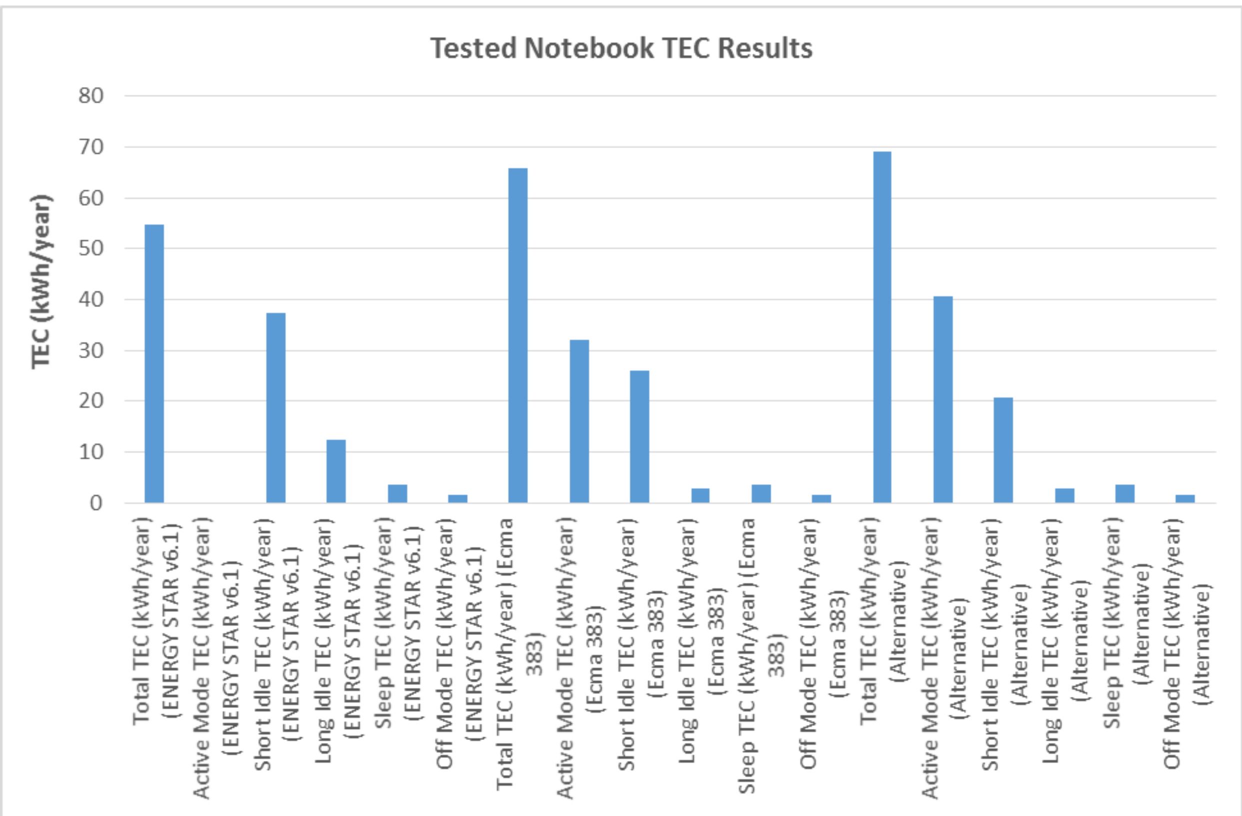

Figure 15 – Results of power demand tests for an ENERGY STAR registered notebook computer

[4] Power testing was conducted using a basic plug in power meter

Figure 16 illustrates the impact that adding the average active mode power ratio from the testing results (1.6) has on overall TEC values for products in the US ENERGY STAR database (illustrated by yellow bars). It is clear that the overall TEC values are significantly below those identified when using the previous estimated active mode ratio (illustrated by grey bars) shown in Table 6. However, as the new TEC total is still above those calculated using the ENERGY STAR and Ecma values, it is clear that active mode power demand is an important consideration when addressing the energy efficiency of notebook computers.

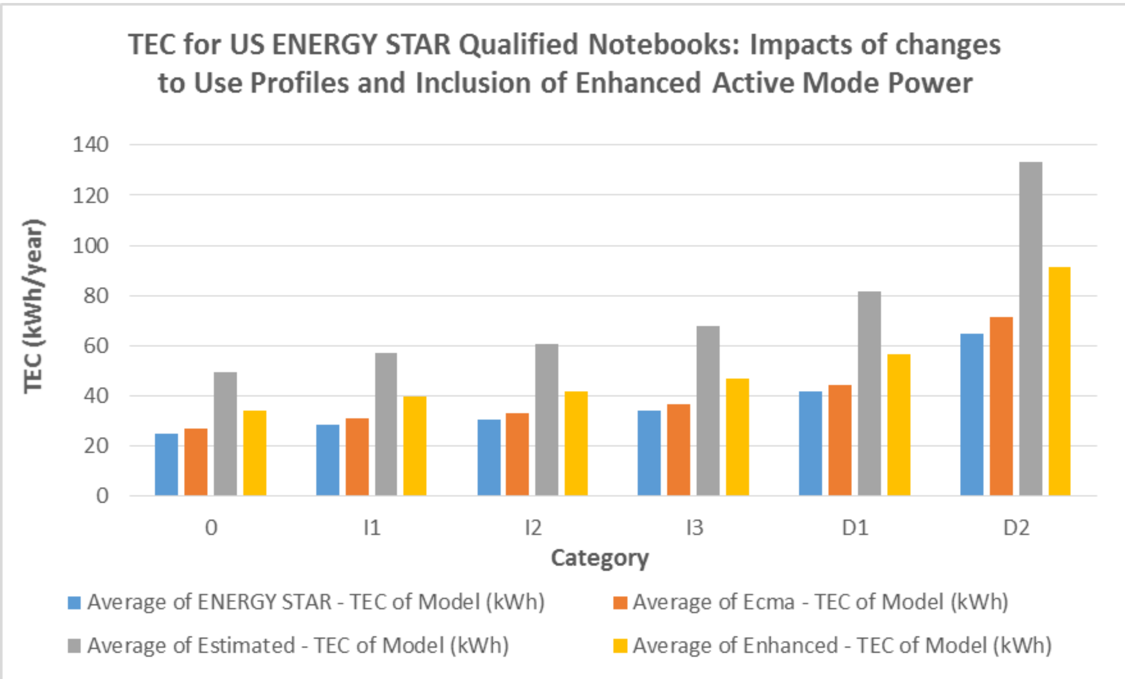

Figure 16 – Average TEC for Notebook Computers in the US ENERGY STAR database based on differing use profiles and inclusion of measured active mode power demands

Figure 17 illustrates that even after accounting for a lower active/short idle ratio active mode remains the dominant power mode in terms of overall energy use.

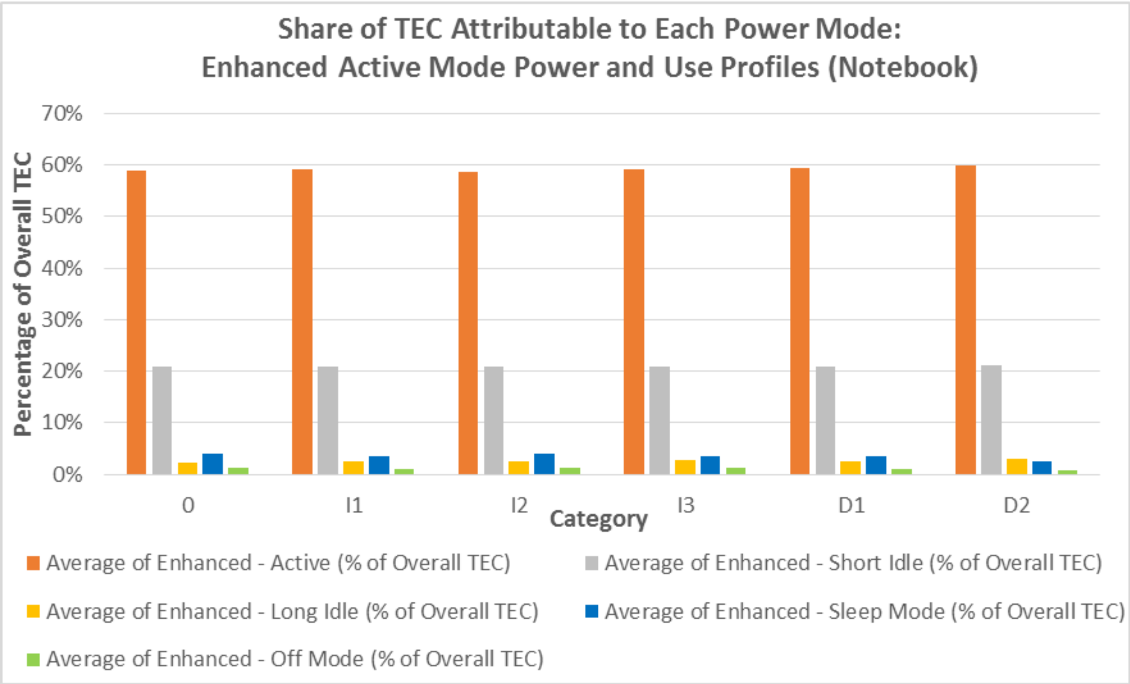

Figure 17 – Average TEC for Notebook Computers in the US ENERGY STAR database based on differing use profiles and inclusion of active mode power demands

5. Inclusion of Active Mode

The previous sections of this report have shown that addressing the active mode of desktop and notebook computers is likely an important consideration. However, there are a number of reasons why the active mode of desktop and notebook computers has not been addressed within most energy efficiency initiatives. These issues are explored in more detail below.

Active Mode Considerations

The lack of coverage of active mode under initiatives such as ENERGY STAR and the EU Ecodesign Regulation is likely largely due to concerns over impacting in use, “real world” computer performance. Concerns surrounding the impact on functionality are partially well founded because computation performance and power demand are still strongly correlated. However, as shown in Table 7, active mode power demand varies with differing computational activities. This suggests that active mode efficiency could be addressed, at some level, without impacting overall computational performance. That is, whilst it may not be possible to limit the maximum amount of power that could be demanded in active mode (since performance is an open ended factor) it may be possible to tackle efficiencies in active mode when a computer is delivering lower levels of functionality. This could take the form of measuring a computers performance, using a predefined metric of performance, measuring the power demand or energy at the same time as the performance testing, and then assign a certain amount of energy or power allowance per unit of performance. Allowances could be staged for different types of computers to reflect that some types of computers may need more or less power/energy per unit of performance.

There is another major stumbling block with including active mode requirements in energy efficiency initiatives and that is the lack of a suitable test methodology. Table 7 showed that active mode power demand not only varies with the service being delivered but also with the programme that is delivering that service. As such, any test procedure that aimed to support active mode power demand measurements may need to take account of the impact that different programmes could have on power demand. This could be problematic when the same programme cannot be used on different computers (e.g. different operating systems would impact which programme(s) could be used) so accurate comparisons between products would not be possible. However, it could be possible to focus on the service being delivered irrespective of the actual programme that is delivering the service.

Whilst the energy used during active mode is an important consideration in the overall energy used by desktop and notebook computers, the inability to measure power demand during active mode in a comparable manner limits the opportunity to include active mode in energy efficiency initiatives. The next section of the report investigates whether currently available benchmark software could facilitate the consideration of active mode energy efficiency within energy efficiency initiatives.

Measuring Active Mode - Benchmarks

Developing test procedures which support the measurement of active mode power demand in desktop and notebook computers whilst performing discrete tasks (e.g. video playback) would not be straightforward. There are many programmes available in the market which seek to identify the computational performance of computers. These are known as "Benchmarks". Benchmarks are designed to mimic a particular type of workload on a component or system normally through specially created programs that impose the workload on a computer component (e.g. CPU or GPU) or on the whole computer system. Benchmarks therefore seek to provide a method of comparing the performance of different computers but generally do not also support accurate power demand measurement.

Active mode power demand could be measured with the use of a benchmark to attain a predefined level of computational functionality (i.e. measuring power demand at a point where the computer system is stressed to a predefined level). However, using a bespoke benchmarking tool would necessitate defining exactly how stressed a computer system would need to be at the point of power testing. ENERGY STAR does specify the use of benchmarking tools (Linpack to stress the core system (e.g., processor, memory, etc.) and SPECviewperf® (to stress the system's Graphics Processing Unit (GPU)) for the workstation computer requirement but this is done in order to measure maximum power demand. Maximum power demand in itself is not an indicative measure of how much energy would be used by a computer since they are very unlikely to be fully stressed during operation by the user.

Other benchmark software packages seek to quantify computer performance by testing the performance of different components and then providing an overall performance score. There are many of these types of benchmarks available in the marketplace but each approaches the quantification of computer performance in a slightly different manner. Whilst many of the benchmarks address a wide range of components that, together, define a computer's performance others concentrate on the either the CPU and/or the GPU as these are often seen as the main components. Table 8 includes a summary of some of the main benchmark programmes used to measure computer performance and how each approach the benchmarking of computer performance.

Benchmark	Licence Required	Free Basic Version Available	Common Operating Systems Supported	Overall System Score	Components Tested			
					CPU	GPU	Memory	Storage
PCMark8	Yes	Yes	Windows and Android	Yes	Yes	Yes	Yes	Yes
Novabench	No	Yes	Windows and OS X	Yes	Yes	Yes	Yes	Yes
PassMark Performance Test	Yes	Yes	Windows	Yes	Yes	Yes	Yes	Yes
SiSoftware Sandra 2016	Yes	Yes	Windows	Yes	Yes	Yes	Yes	Yes
Cinebench R15	No	Yes	Windows and OS X	No	Yes	Yes	No	No
Geekbench 3	Yes	Yes	Mac OS X, Windows, Linux, Android, BlackBerry, and iOS	No	Yes	No	No	No

Table 8 – Overview of popular computer benchmarks

In order for a benchmark to support any active mode efficiency testing within an energy efficiency scheme it would be essential that it would cover both a wide range of computers on the market and also address the performance of as many components as possible to ensure a more accurate final performance score. However, it is clear from the details shown in Table 8 that some benchmarks provide a much broader coverage in terms of operating system coverage and in terms of the computer components that are tested. Nevertheless, there is precedent for computer performance benchmarks to be used in

Government procurement contracts which are subject to strict rules governing the reference of suitable test methodologies.[5]

Benchmark	Final Output Metric	Overall Score				Max Difference (%)
		Test 1	Test 2	Test 3	Test 4	
1	Numeric score	2072	2073	2041	2048	1.6%
2 (GPU)	frames per second (fps)	24.37	21.39	22.01	20.88	16.7%
2 (CPU)	Numeric score	226	217	197	216	14.7%
3 [6]	Numeric score	3.31				0.0%
4 (single core)	Numeric score	2331	2329	2243	2313	3.9%
4 (multi core)	Numeric score	4497	4501	4280	4479	5.2%
5	Numeric score	1460.4	1487.9	1474.6	1475.7	1.9%
6	Numeric score	644	641	624	633	3.2%

Table 9 – Benchmark results for example notebook computer

To support active mode efficiency requirements in an energy efficiency initiative it would be necessary that a benchmark could produce repeatable and accurate results. Table 9 shows the results of running the different benchmarks on a notebook computer.[7] Each benchmark was run four times in order to identify extent to which the results were accurate and reproducible. After each test the computer was powered down and restarted. After the second test the benchmark software was uninstalled and then reinstalled for the third and fourth tests. Uninstalling and then reinstalling was conducted to ensure that previous results were not informing the results of subsequent tests. It is clear from the results in Table 9 that none of the benchmarks returned the same result on any of the four tests despite no changes being made to the testing conditions. This suggests that there is always some variability in the tests results. However, the degree of variability on the results differs greatly between the benchmarks. The highest difference (between lowest and highest score in the four tests) was 16.7% and the lowest 1.6%. A variance of 16.7% would not be suitable for use in an energy efficiency initiative as it is too large. However, a variance of 1.6%

[5] http://www.futuremark.com/pressreleases/governments-choose-pcmark-to-specify-pc-performance
[6] Only one round of testing could be completed for this benchmark as future attempts (even after uninstall and then reinstall) failed to complete.
[7] The names of the benchmarks are anonymised due to licensing restrictions.

is within normal testing tolerances for power demand and so could be seen as sufficiently robust. It is important to note that this testing was only conducted on a single notebook computer and so further testing into the accuracy of any candidate benchmarks should be conducted by those interested in using benchmarks within energy efficiency initiatives.

Whilst it appears that energy efficiency activities on active mode could be supported by at least some benchmarks currently on the market based on their suggested ability to measure computer performance in an accurate and repeatable manner there are many other issues surrounding the use of benchmarks which need to be explored.

Benchmarks – Further Considerations

The previous section of the report discussed how identifying the performance of computers could assist with addressing the active mode of computers within energy efficiency initiatives.

Firstly, not all energy efficiency initiatives are allowed to prescribe an exact test methodology. For example, under the EU's Ecodesign Directive a suggested test methodology may be identified by the European Commission, in both transitional methods and harmonized procedure documentation, but manufacturers are able to use any other similar test procedures. Market surveillance authorities, on the other hand, need to use the test procedure laid out by the Commission. This means that whilst manufacturers would be free to use any other similar benchmarks to measure the performance of their computers, they would have to ensure that their products are compliant with any mandatory requirements when tested with the test procedure listed by the Commission.

Whilst the results in Table 9 shown that at least some of the benchmarks provide quite a high degree of consistency in their results, even these small differences could have an impact on a product's standing within an energy efficiency initiative. That is, energy efficiency initiatives often include a clear pass/fail metric so any variability could see a product fall either side of this pass/fail line. This variability could be somewhat overcome by requiring that, when any product only narrowly meets any specification limits, manufacturers measure the performance several times to take an average value. ENERGY STAR includes such a process where additional units of the same product are required to be tested when the energy or power values are within 10% of the specification line.

If benchmarks were to be used within an energy efficiency initiative, the measurement would take place before the product had been sold into the market. As such, the computers' performance would be tested as "shipped" or as "placed on the market" and would therefore not account for the upgradability potential of a product. Whilst this is also true when testing for power demand in other power modes, such as idle and sleep mode, the upgradability potential of a computer could have a significant impact on its potential performance. As such, the upgradability of a computer could be considered when developing any active mode efficiency metrics.

Another issue which could prove to be problematic for the use of benchmarks in energy efficiency initiatives is the large amount of configurability found in computers. Many types of computer on the market, especially desktop computers, can be configured with different types and number of components even within the same product family. This configurability means that each different version of a product will often have a different level of performance but it would not be practical or cost effective to request that manufacturers test each and every configuration of a product that they place on the market. Many energy efficiency initiatives recognise the configurability issue within the computer market and allow for representative configurations of any product model to be tested rather than each and every configuration.

Many of the benchmarks on the market are continually updated either in the form of major updates, taking place every two to three years (e.g. to account for changes to the operating systems on the market etc.), to smaller iterative updates (e.g. to account for more minor issues such as software bugs) which are launched as required. This major upgrade cycles seen in many benchmarks could cause some issues within energy efficiency initiatives that last two years or more as the benchmark could be out of sync with changes in the market such as the launch of a new popular operating system. If developers of operating systems (e.g. Microsoft or Apple) could be encouraged to work with the benchmark developers ahead of a placing a new operating system on the market, then there may be less impact on the energy efficiency initiative. The energy efficiency initiative would still require some flexibility in terms of the referenceable test benchmark however to account for both major and minor changes over time.

Computer benchmarks can be complex software programmes which can take considerable resources to develop. For this reason, many of the currently available computer benchmarks are commercial products (often marketed with truncated free trial versions) that require users to purchase a licence. These licences are not always inexpensive, so requiring that manufacturers purchase benchmarks could add considerable costs. These costs could be offset by negotiation with benchmark owners for reduced pricing in reflection of the large scale use of the benchmark as a result of referencing it within an energy efficiency initiative. These negotiations are unlikely to be a quick process which could cause delays in the finalisation of any energy efficiency initiative. Alternatively, energy efficiency initiative owners could negotiate with developers of free benchmark software to facilitate open use outside of existing terms and conditions (i.e. current terms and conditions even within free benchmarks may be too restrictive for use in an energy efficiency initiative). Another option would be for energy efficiency owners to commission the development of a bespoke benchmark, although it is recognised that this may be a costly endeavour.

Whilst using a more complex benchmark may provide the most robust solution for the inclusion of computer active mode within energy efficiency initiatives there are more simplistic approaches that could be developed.

Measuring Active Mode – Simple Benchmark

A more simplistic approach could be taken to give an indication of active mode energy use during normal usage.

Table 10 illustrates a simple test procedure that could be used to measure active mode energy use in desktop and notebook computers. Whilst measuring active mode power in this way would not capture the full range of active power demands found in desktop and notebook computers it would give an indication. That is, the test procedure would be unlikely to stress many systems but instead provide an indication of active mode power demand during light usage. This would have the added benefit of encouraging manufacturers to further enhance the scalability of power within their computers. That is to say, manufacturers have made considerable efforts to reduce power demand in idle mode but there has been little incentive to reduce power demand during use. Whilst, it is important to point out that increased efficiency in idle mode would likely have some impact on efficiency in active mode due to the power demand scalability technologies added to the computer components (i.e. idle mode power demands have been reduced due to better control of power demand during periods when full computational power is not required). However, this scalability could be further encouraged by including lower computational intensive active mode tasks into the efficiency requirements of environmental initiatives.

		Test Parameters				
Active Mode Elements	Loaded Common WebPage	Duration 5 mins	Defined file size	Defined content	Sized to full display	Integrated or external display on
	Loaded Word Processing Document	Duration 5 mins	Defined file size	Defined content	Sized to full display	Integrated or external display on
	Loaded Common spreadsheet	Duration 5 mins	Defined file size	Defined content	Sized to full display	Integrated or external display on
	Playing HD Video	Duration 5 mins	Defined video (size and content)		Sized to full display	Integrated or external display on
	Combined: Loaded Common WebPage (x5), loaded word processing document (x5), loaded common spreadsheet (x5), Playing HD Video (x1)	Duration 5 mins	All files of defined size and content with defined video			Integrated or external display on

Table 10 – Simple active mode test procedure

Table 11 illustrates how an active mode TEC value could be calculated from the measured active mode power values. Within the example, it is assumed that computers would spend 20% of their time in an active mode. It is further assumed that during use most computers would be running multiple applications and so 50% of the annual active quota is given to an instance where multiple programmes are running.

		Maximum power demand (W)	Percentage of time in each active state	Hours Per Year in each active state	Total Active Energy Consumption (kWh)
Active Mode Elements	Loaded Common WebPage	15.0	12.5%	219	3.3
	Loaded Word Processing Document	16.0	12.5%	219	3.5
	Loaded Common spreadsheet	17.0	12.5%	219	3.7

	Playing HD Video	25.0	12.5%	219	5.5
	Combined: Loaded Common WebPage (x5), loaded word processing document (x5), loaded common spreadsheet (x5), Playing HD Video (x1)	28.0	50.0%	876	24.5
			Total	1752	40.5

Table 11 – Example calculation of active mode TEC

As previously mentioned, the ENERGY STAR v6.1 specification for desktop and notebook computers is based on a typical energy consumption (TEC) approach measured in kWh/year. This TEC is calculated for desktop and notebook computers using the following formula:

$$TEC = \frac{8760}{1000} \times (P_{OFF} \times T_{OFF} + P_{SLEEP} \times T_{SLEEP} + P_{LONG\_IDLE} \times T_{LONG\_IDLE} + P_{SHORT\_IDLE} \times T_{SHORT\_IDLE})$$

Where:

- P_{OFF} = Measured power consumption in Off Mode (W);
- P_{SLEEP} = Measured power consumption in Sleep Mode (W);
- P_{LONG_IDLE} = Measured power consumption in Long Idle Mode (W);
- P_{SHORT_IDLE} = Measured power consumption in Short Idle Mode (W); and
- T_{OFF}, T_{SLEEP}, T_{LONG_IDLE}, and T_{SHORT_IDLE} are mode time weightings (i.e. share of the annual 8760 hours) as specified in Table 2.

A simple change could be made to this formula to account for time in active mode:

$$TEC = \frac{8760}{1000} \times (P_{OFF} \times T_{OFF} + P_{SLEEP} \times T_{SLEEP} + P_{LONG\_IDLE} \times T_{LONG\_IDLE} + P_{SHORT\_IDLE} \times T_{SHORT\_IDLE} + P_{ACTIVE} \times P_{TIME})$$

The ENERGY STAR requirements (i.e. the maximum amount of energy that a computer can use) are also therefore formulated in terms of TEC as illustrated below:

$TEC\_MAX = (1+ALLOWANCE_{PSU}) \times (TEC_{BASE} + TEC_{MEMORY} + TEC_{GRAPHICS} + TEC_{STORAGE} + TEC_{INT\_DISPLAY} + TEC_{SWITCHABLE} + TEC_{EEE})$

Where:

- $ALLOWANCE_{PSU}$ is an allowance provided to power supplies that meet optional more stringent efficiency levels
- TEC_{BASE} is the Base allowance specified in Table 6; and,
- $TEC_{GRAPHICS}$ is the discrete graphics allowance as specified in Table 7, with the exception of systems with integrated graphics, which do not receive an allowance, or Desktops and Integrated Desktops with switchable graphics enabled by default, which receive an allowance through TECSWITCHABLE; and
- TEC_{MEMORY}, $TEC_{STORAGE}$, $TEC_{INT\_DISPLAY}$, $TEC_{SWITCHABLE}$, and TEC_{EEE} are additional allowances given for individual components

Again a simple change to this formula could be made in order to account for energy use in active mode:

$TEC\_MAX = (1+ALLOWANCE_{PSU}) \times (TEC_{ACTIVE} + TEC_{BASE} + TEC_{MEMORY} + TEC_{GRAPHICS} + TEC_{STORAGE} + TEC_{INT\_DISPLAY} + TEC_{SWITCHABLE} + TEC_{EEE})$

The amount of energy allowed under "TEC_{ACTIVE}" would need to be defined during development of any environmental initiative requirements. Given the very simplistic nature of the suggested active mode test procedure, manufacturers could be asked to provide this data during the development stage of a new specification for an initiative such as ENERGY STAR. Provision of this data would then allow development of suitable TEC_{ACTIVE} levels for different types of desktop and notebook computers (following the same approach as used for the development of the TEC_{BASE} allowances).

6. Conclusion

This SEAD report has shown that the energy used during the active modes of desktop and notebook computers plays a significant factor in overall computer energy use. However, none of the main environmental initiatives which address the energy efficiency of computers is currently addressing this important power mode. The exclusion of active mode within these major environmental initiatives is a multi-faceted issue but one which is likely based on a fear of impacting computational performance and the lack of suitable test procedures.

The report showed that there are software applications on the market that may be able to accurately measure the performance of computers in a consistent and accurate manner. The use of these benchmarks, along with power measurements taken during performance testing, could provide a route for including active mode efficiency within energy efficiency initiatives. However, it was also shown that further testing needs to be conducted to ensure that currently available benchmarks provide accurate and repeatable results across a range of computers. In addition, there are a number of other considerations that need to be explored in further detail before benchmarks could be adopted by energy efficiency initiatives. These other issues include understanding how commercial, or even free benchmarks, currently available in the market could be used within energy efficiency initiatives without breaking established terms and conditions. These negotiations will likely be initiative specific considerations. Given the fast moving nature of the computer industry it would also be necessary to understand how energy efficiency initiatives could include references to a benchmark that would likely need to be updated during the life of an initiative.

An alternative approach would be to use a simplistic test procedure which tackled active power demand in some commonly used but low computational intensive tasks. Without the need to delve into significant detail during testing of active mode power it may be possible to include at least some active mode requirements in major environmental initiatives, allowing comparisons between products based on how energy efficiently they deliver commonly used applications. A simple test procedure which addressed some common functionalities, which would be unlikely to become outdated during the life of an energy efficiency initiative, may offer a better alternative for addressing computer active mode energy efficiency.

It is recognised that, due to the inherent complexities, this SEAD report does not answer all of the questions surrounding the use of benchmarks to support active mode energy efficiency considerations in energy efficiency initiatives. However, the report makes it clear that there are options available to support the consideration of active mode energy efficiency within energy efficiency initiatives but that further research is required.