

Standard ECMA-383

3rd Edition / December 2010

**Measuring the Energy
Consumption of
Personal Computing
Products**

Standard



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Introduction

Ecma developed and published the world's first environmentally conscious design standard (ECD) for the ICT & CE industries in 2003. ECMA-341 is aimed at the designer and provides pragmatic advice on how to reduce the environmental footprint of a product by taking the right decisions at the design stage. ECMA-341 has been adopted as IEC 62075.

Whilst ECMA-341 includes the definitions of energy saving modes and generic energy saving guidance for designers of ICT & CE products, this Standard complements that guidance by defining a methodology on how to measure the energy consumption of a product whilst providing categorisation criteria that enables energy consumption comparisons of similar products.

Although this Standard's title covers all personal computing products, the scope of this edition is desktop and notebook computers.

The 1st edition of ECMA-383 required the support of a benchmark in order to measure the performance of the product. In order to improve the usability of this Standard the 2nd edition utilises a system of categorisation to enable like for like comparisons of the energy consumption of different products rather than a benchmark. The 3rd edition provides errata corrections, and provides an update to the majority profile study.

This Ecma Standard has been adopted by the General Assembly of December 2010.

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Measuring the Energy Consumption of Personal Computing Products

1 Scope

Although the title is broader in scope, this 3rd edition of the Standard applies to: Desktop and notebook computers as defined in 5.1 that are marketed as final products and that are hereafter referred to as the Equipment Under Test (EUT) or product.

This Standard specifies:

- A test procedure to enable the measurement of the power and/or energy consumption in each of the EUT's power modes.
- Formulas for calculating the TEC (Typical Energy Consumption) for a given period (normally annual).
- A majority profile that should be used with this Standard which enables conversion of average power into energy within the TEC formulas.
- A system of categorisation enabling like for like comparisons of energy consumption between EUT's.
- A pre-defined format for the presentation of results.

This Standard does not set any pass/fail criteria for the EUT. Users of the test results should define such criteria.

2 Conformance

The user of this Standard shall meet all applicable "shall" requirements in 6.

NOTE Based on need a user may implement all or some of the test procedure detailed in 6.2.1 to 6.2.5. For example the user may test only off mode.

3 Normative references

None.

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1

Active Workload

the simulated amount of productive or operative activity that a EUT performs as represented in the P_{work} and T_{work} attributes of the TEC equation

4.2

ACPI

Advanced Configuration & Power Interface

NOTE ACPI specification can be found here <http://www.acpi.info/>

4.3

Category

grouping of EUT configurations

4.4

Duty Cycle

the combined percentage of time a EUT spends in each of its individual power modes

4.5

Energy use

energy used by a EUT measured from the mains power source over a given period of time and measured in kWh

4.6

EPS

External Power Supply

alternating current brick

Power Supply in the same physical enclosure as the EUT

NOTE http://www.efficientpowersupplies.org/pages/External_Power_Supply_Efficiency_Test_Method_8-11-04.pdf outlines testing procedures for measuring EPS efficiencies.

4.7

EUT

Equipment Under Test

NOTE Also referred to as Product in this Standard and sometimes referred to as EUT (Equipment Under Test) in other specifications.

4.8

FB_BW

Frame Buffer Bandwidth

4.9

IPS

Internal Power Supply

Power Supply in the same physical enclosure as the EUT

NOTE http://efficientpowersupplies.epri.com/pages/Latest_Protocol/Generalized_Internal_Power_Supply_Efficiency_Test_Protocol_R6.4.2.pdf outlines the testing procedures for measuring IPS efficiencies.

4.10

LAN

Local Area Network

Examples: IEEE 802.3 Ethernet or Wired LAN, and IEEE 802.11 WiFi or Wireless LAN

4.11

Manufacturer

organization responsible for the design, development and manufacture of a product in view of its being placed on the market, regardless of whether these operations are carried out by that organization itself or on its behalf

4.12

Power Supply

converter of input alternating current to direct current

4.13

RGB

Red Green Blue

primary colours that make-up a pixel on a computer display

4.14

RMS

Root Mean Square

4.15

TEC

Typical Energy Consumption

sum of products of average consumed power and time spent in the power modes

4.16

TEC_{actual}

measured Typical Energy Consumption using P_{work}

4.17

TEC_{estimated}

estimated Typical Energy Consumption substituting P_{idle} for P_{work}

4.18

ULE

Ultra Low Energy

4.19

UPS

Uninterruptible Power Supply

4.20

User of the test results

organisation that will utilise the test results to apply to their needs

NOTE Examples of such an organisation is voluntary agreement owners, regulators, private companies etc.

4.21

WoL

Wake on LAN

NOTE Functionality which allows a computer to wake from sleep or off when directed by a network request via Ethernet.

5 Specifications for EUT

5.1 Computer Descriptions

5.1.1 Desktop computer

Is a computer where the main unit is intended to be located in a permanent location, often on a desk or on the floor? Desktops are not designed for portability and utilize an external computer display, keyboard, and mouse. Desktops are designed for a broad range of home and office applications.

5.1.2 Notebook computer

Is a computer designed specifically for portability and to be operated for extended periods of time either with or without a direct connection to an ac power source? Notebooks must utilize an integrated computer display and be capable of operation off an integrated battery or other portable power source. In addition, most notebooks use an EPS or AC brick and have an integrated keyboard and pointing device. Notebook computers are typically designed to provide similar functionality to desktops, including operation of software similar in functionality as that used in desktops. For the purposes of this Standard, docking stations are considered accessories and therefore, should not be considered as part of the EUT. Tablet PCs, which may use touch-sensitive screens along with or instead of other input devices, are considered Notebook Computers in this Standard.

5.1.3 Integrated desktop computer

Is a desktop computer where the computer and computer display function as a single unit receiving its AC power through a single cable? Integrated desktop computers come in one of two possible forms: (1) a product where the computer display and computer are physically combined into a single unit; or (2) a product packaged as a single product where the computer display is separate but is connected to the main chassis by a DC power cord and both the computer and computer display are powered from a single power supply. As a subset of desktop computers, integrated desktop computers are typically designed to provide similar functionality as desktop computers.

NOTE An integrated desktop computer may also be referred to as an all-in-one computer.

5.2 Power modes

5.2.1 Off Mode (P_{off})

The lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the EUT is connected to the main electricity supply and used in accordance with the manufacturer's instructions. For products where ACPI standards are applicable, off mode correlates to ACPI system level S5 state. P_{off} represents the average power measured in the off mode.

NOTE Some international regulations may also refer to this mode as standby mode.

5.2.2 Sleep Mode (P_{sleep})

The lowest power mode that the EUT is capable of entering automatically after a period of inactivity or by manual selection. A EUT with sleep capability can quickly wake in response to network connections or user interface devices with a latency of ≤ 5 seconds from initiation of wake event to product becoming fully usable including rendering of display. For products where ACPI standards are applicable sleep mode most commonly correlates to ACPI system level S3 (suspend to RAM). When the EUT is tested with the WoL capability disabled in the sleep state it is referred to as Sleep Mode. P_{sleep} represents the average power measured in the Sleep mode with the WoL capability disabled.

5.2.3 WoL Sleep Mode (P_{sleepWoL})

WoL sleep mode is the lowest power mode that the EUT is capable of entering automatically after a period of inactivity or by manual selection. A EUT with sleep capability can quickly wake in response to network connections or user interface devices with a latency of ≤ 5 seconds from initiation of wake event to product becoming fully usable including rendering of display. For products where ACPI standards are applicable sleep mode most commonly correlates to ACPI system level S3 (suspend to RAM). When the EUT is tested with the WoL capability enabled in the sleep state it is referred to as Wake on LAN Sleep Mode. P_{sleepWoL} represents the average power measured in the Sleep mode with the WoL capability enabled.

5.2.4 On Mode (P_{on})

The on mode represents the mode the EUT is in when not in the sleep or off modes. The on mode has several sub-modes that include the long idle mode, the short idle mode and the active (work) mode. P_{on} represents the average power measured when in the on mode.

5.2.5 Idle Modes

The modes in which the operating system and other software have completed loading, the product is not in sleep mode, and activity is limited to those basic applications that the product starts by default. There are two forms of idle that comprise the idle modes, they are:

5.2.5.1 Short Idle (P_{side})

The mode where the EUT has reached an idle condition (e.g. 5 minutes after OS boot or after completing an active workload or after resuming from sleep), the screen is on and set to as shipped brightness and long idle power management features should not have engaged (e.g. HDD is spinning and the EUT is prevented from entering sleep mode). P_{side} represents the average power measured when in the short idle mode.

5.2.5.2 Long Idle (P_{idle})

The mode where the EUT has reached an idle condition (e.g. 15 minutes after OS boot or after completing an active workload or after resuming from sleep), the screen has just blanked but remains in the working mode (ACPI G0/S0). Power management features if configured as shipped should have engaged (e.g. display is on, HDD may have spun-down) but the EUT is prevented from entering sleep mode. P_{idle} represents the average power measured when in the long idle mode.

NOTE "the screen has just blanked" refers to the main computer display (integrated panel or external display) has entered a low power state where the screen contents can't be observed (e.g. backlight has been turned off turning the screen black).

5.2.6 Active (Work) Mode (P_{work})

The mode in which the EUT is carrying out work in response to a) prior or concurrent user input or b) prior or concurrent instruction over the network. This mode includes active processing, seeking data from storage, memory, or cache, while awaiting further user input and before entering other power modes. In this mode, the screen is on and set to as shipped brightness. P_{work} represents the average power measured when in the active mode.

5.3 Duty Cycle Attributes

The duty cycle of a product is determined by understanding the percentage of time a EUT spends in each of its individual power modes. The attributes associated with the duty cycle are:

5.3.1 Off component of Duty Cycle (T_{off})

The percentage of time a EUT is in the off mode.

5.3.2 Sleep component of Duty Cycle (T_{sleep} & $T_{sleepWoL}$)

The percentage of time a EUT is in the sleep modes.

5.3.3 On components of Duty Cycle (T_{on})

The percentage of time the EUT is in the on mode. The T_{on} duty cycle is equal to the sum of the $T_{work} + T_{side} + T_{idle}$.

5.3.3.1 Short Idle component of Duty Cycle: (T_{idle})

The percentage of time the EUT is in the short idle mode.

5.3.3.2 Long Idle component of Duty Cycle (T_{idle})

The percentage of time the EUT is in the long idle mode.

5.3.3.3 Active (Work) component of Duty Cycle (T_{work})

The percentage of time the EUT is in the active mode.

5.4 Profile Attributes

NOTE Refer to Annex A, Annex B and Annex C for further information on profiles.

5.4.1 Profile

A profile is a combination of duty cycle attributes and a given use case (e.g. office users, home users, gamers).

5.4.2 Majority Profile

The majority profile is the most common profile of users for desktop and notebook computers.

The majority profile should be used with this Standard and is documented in Annex B. It provides the duty cycle attributes and the profile TEC error which is used to determine the TEC equation to be used in 6.5.

5.4.3 Minority Profile

The minority profiles represent less common profiles of users of desktop and notebook computers that are not represented in the majority profile. As an example, extreme gamers represent a very specific profile but are a very small percentage of computer users.

5.4.4 Profile Study

Study performed to create a new profile for this Standard. The study shall generate, together with supporting data, the following:

- All the duty cycle attributes.
- The profile active power ratio.
- The profile TEC error.
- The Profile Active Workload Ratio.

All data shall be derived from a statistically significant sample size that is representative of the user population as a whole. Annex C provides guidance on how to conduct a profile study.

5.4.5 Product Active Power Ratio

The ratio of $P_{\text{on}}/P_{\text{idle}}$, or the average on power divided by short idle power for an individual product within a profile study.

5.4.6 Profile Active Power Ratio (PAPR)

The average of all the product active power ratios recorded in a profile study.

5.4.7 Profile Active Workload Ratio (PAWR)

This represents the average ratio of $P_{\text{work}}/P_{\text{idle}}$ conducted on profile study products and is used to validate that the active workload closely matches the profile study (through its Profile Active Power Ratio).

5.4.8 Product TEC Error

The percent error calculation used in a profile study to evaluate how much error exists for an individual product when directly measuring TEC versus estimating TEC by substituting the static “short idle” power measurement for the measured P_{work} power.

5.4.9 Profile TEC Error

The average of the product TEC error in a profile study.

5.5 Categorisation attributes

Below are some examples of categorisation attributes, additional examples should be found in the category registry, see 6.4.

5.5.1 Cores

The number of physical CPU cores in the EUT.

5.5.2 Channels of memory

Expressed by the total number the EUT is capable of supporting (they do not have to be populated). Each channel has a separate data path.

5.5.3 System memory

The amount of memory measured in GB.

5.5.4 System fan

Any fan used in the EUT excluding fans integrated into the power supply.

5.5.5 TEC Adders

A TEC adder is a power allowance expressed in kWh/year that when added / configured to the EUT will increase its Typical Energy Consumption (TEC) by some amount.

Examples could be:

- Graphics cards, memory, TV tuners, sound cards, hard disk drives, solid state disk drives, etc.
- For an integrated desktop computer, the screen shall be treated as an adder.

6 Test procedure and conditions, categorisation, TEC formula, meter specifications and results reporting

The following procedure shall be used when measuring the power or energy consumption of the EUT.

The user of this Standard shall measure a sample of the EUT. The size of the sample shall be appropriate to demonstrate compliance to the requirements set by the user of the test results.

6.1 Test Setup

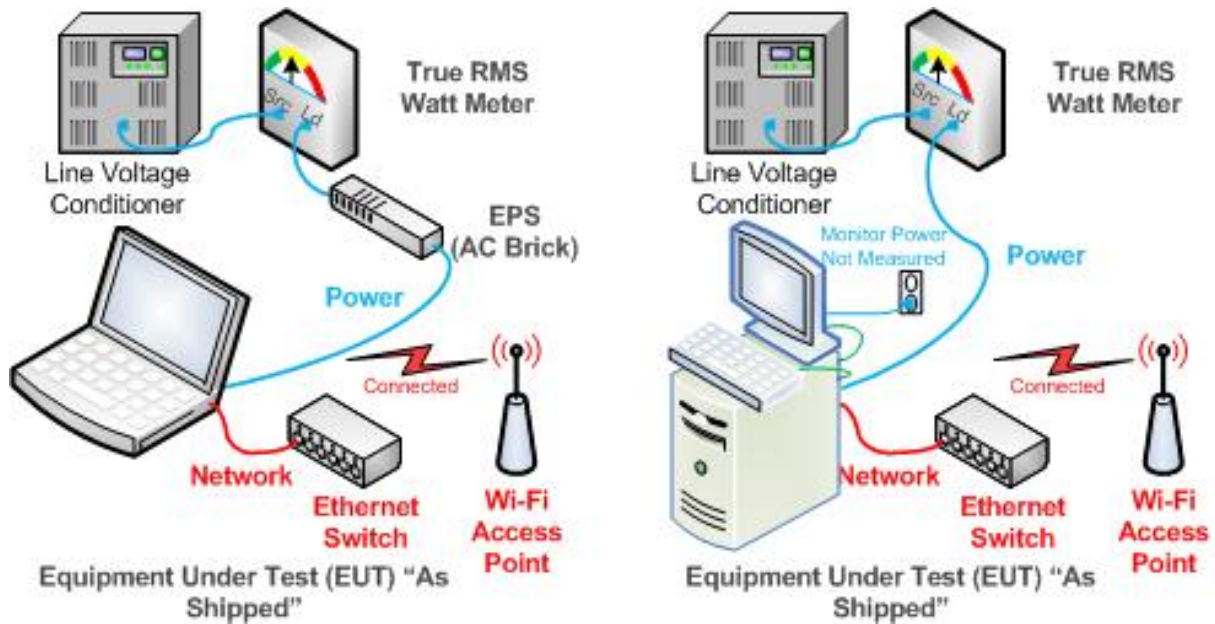
The EUT and test conditions shall be set up as defined below.

1. Ensure that the EUT is configured “as shipped” (unless otherwise stated in this test procedure) including all hardware accessories and software shipped by default. EUT shall also be configured using the following requirements for all tests:
 - a) Desktop and integrated desktop computers shipped without accessories shall be configured with a standard mouse and keyboard. No other external peripherals shall be connected.
 - b) Desktop computers shall be configured with an external computer display (the external display energy consumption is not included as part of the TEC calculation).
 - c) Notebook computers need not include a separate keyboard or mouse when equipped with an integrated pointing device or digitizer.
 - d) Notebook computers shall be connected to the mains power source using the EPS shipped with the product. Battery pack(s) shall be removed for all tests. For EUT where operation without a battery pack is not a supported configuration, the test shall be performed with fully charged battery pack(s) installed, making sure to report this configuration in the test results.
 - e) The screen shall be configured with a “desktop background” (wallpaper) of a solid colour defined by a bitmap set to the RGB values of 130, 130, and 130. The screen brightness shall be set as shipped.
 - f) The sleep timer of the EUT shall be disabled or set to 30 minutes to prevent the EUT from entering the sleep state during the idle or active tests.

NOTE 1 As shipped is defined as the configuration as it leaves the manufacturer.

NOTE 2 The “as shipped” screen brightness is defined as a level the manufacturer deems to be appropriate for an end user to want to use the product.

A typical test setup is illustrated below for a notebook and a desktop computer.



NOTE 3 A notebook and integrated desktop computer shall include the power used by the integrated display in reported results. A desktop computer shall not include the power used by the display device in reported results.

NOTE 4 The illustration shows wired and wireless connections. Only one shall be connected during test per 3 below.

2. A true RMS watt meter that meets the meter requirements in 6.6 is placed between the mains power source and the EUT power supply. No power strips or UPS units shall be connected between the meter and the EUT. The meter shall remain in place until all required power mode data is recorded. The mains power source shall meet the requirements in 6.3.
3. For sleep, long idle, short idle and the optional active measurements, the EUT energy consumption shall be measured with network connectivity in one of the two states described below.
 - a. For EUT with Ethernet support, the EUT shall be connected to an active network switch which supports the highest link speed supported by the EUT (the network switch does not need to be connected to a live network). Only a single network connection needs to be made in the case of a EUT with multiple network connections. It shall also support the minimum requirements needed to support additional power management functions that are supported by the EUT. As an example, the IEEE 802.3az specification supports power management of Ethernet links which must be supported by both the EUT and network switch, to test this function the switch shall also support this function. Power to alternative network devices such as wireless radios shall be turned off for all tests. This applies to wireless network adapters (e.g., 802.11) or device-to-device wireless protocols (e.g. Bluetooth).
 - b. For EUT that do not support Ethernet, but support some other sort of network connectivity, that network shall be turned on and be in a connected state. A live wireless connection to a wireless router or network access point, which supports the highest and lowest data speeds of the client radio, shall be maintained for the duration of testing.
4. Record the EUT description as required in 6.8.
5. Measure the test conditions as defined in 6.3 and record as required in 6.8.
6. If the EUT supports some sort of automatic display luminance control, then the test room's ambient light conditions shall be measured using a meter that meets the requirements in 6.7 and set to the appropriate levels called for in 6.3.

6.2 Test Procedure

The test procedures are listed in order of energy consumption. The specific procedure for measuring each power mode shall be followed. However, the power measurements of each energy mode can be made in any order and, if a TEC result is not required, the user does not need to test all of the power modes.

6.2.1 Measuring Off Mode

1. Place the EUT in off mode which is defined as:
 - The lowest power mode which cannot be switched off (influenced) by the user and that may persist for an indefinite time when the EUT is connected to the main electricity supply and used in accordance with the manufacturer's instructions. For products where ACPI standards are applicable, off mode correlates to ACPI System Level S5 state.
2. Set the meter to begin accumulating true power values at an interval of 1 or more readings per second.
3. Accumulate power values for 5 minutes and record the average (arithmetic mean) value observed during that 5 minute period as P_{off} .

6.2.2 Measuring Sleep Mode

1. Switch the EUT on
2. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed, and place the EUT in sleep mode which is defined as:
 - The lowest power mode that the EUT is capable of entering automatically after a period of inactivity or by manual selection. A EUT with sleep capability can quickly wake in response to network connections or user interface devices with a latency of ≤ 5 seconds from initiation of wake event to product becoming fully usable including rendering of display. For products where ACPI standards are applicable sleep mode most commonly correlates to ACPI system level S3 (suspend to RAM).
3. Reset the meter (if necessary) and begin accumulating true power values at an interval of 1 or more readings per second.
4. Accumulate power values for 5 minutes and record the average (arithmetic mean) value observed during that 5 minute period as P_{sleep} .
5. If testing both WoL enabled and WoL disabled for sleep, wake the EUT and change the WoL from sleep setting through the operating system settings or by other means. Place the EUT back in sleep mode and repeat test, recording sleep power necessary for this alternate configuration as P_{sleepWoL} .

6.2.3 Measuring Long Idle Mode

1. Switch the EUT on.
2. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed, and place the EUT in long idle mode which is defined as:
 - The mode where the EUT has reached an idle condition (e.g. 15 minutes after OS boot or after completing an active workload or after resuming from sleep), the screen has just blanked but remains in the working mode (ACPI G0/S0). Power management features, configured as shipped, should have engaged (e.g. display is on, HDD may have spun-down) but the EUT is prevented from entering sleep mode.

3. Once the EUT has entered the long-idle mode, reset the meter (if necessary) and begin accumulating true power values at an interval of 1 or more readings per second.
4. Accumulate power values for 5 minutes and record the average (arithmetic mean) value observed during that 5 minute period as P_{idle} .

6.2.4 Measuring Short Idle Mode

1. Switch the EUT on
2. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed, and place the EUT in short idle mode which is defined as:
 - The mode where the EUT has reached an idle condition (e.g. 5 minutes after OS boot or after completing an active workload or after resuming from sleep), the screen is on and set to as shipped brightness and long idle power management features should not have engaged (e.g. HDD is spinning and the EUT is prevented from entering sleep mode).
3. Once the EUT has entered short idle mode, reset the meter (if necessary) and begin accumulating true power values at an interval of 1 or more readings per second.
4. Accumulate power values for 5 minutes and record the average (arithmetic mean) value observed during that 5 minute period as P_{sidle} .

6.2.5 Measuring Active Mode (optional see 6.5)

1. Switch the EUT on.
2. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard operational desktop screen or equivalent ready screen is displayed, and place the EUT in short idle mode which is defined as:
 - The mode where the EUT has reached an idle condition (e.g. 5 minutes after OS boot or after completing an active workload or after resuming from sleep), the screen is on and set to as shipped brightness and long idle power management features should not have engaged (e.g. HDD is spinning and the EUT is prevented from entering sleep mode).
3. Load the active workload and prepare it to run.
4. Reset the meter (if necessary) and start the active workload. Begin accumulating true power values at an interval of 1 or more readings per second.
5. When the active workload indicates it has finished, record the average power as P_{work} .

NOTE Criteria for the active workload is defined in 6.5.3.

6.3 Test Conditions

All tests carried out on the EUT shall take place under these conditions:

Supply Voltage:	North America/Taiwan:	120 ($\pm 1\%$) Volts AC, 60 Hz ($\pm 1\%$)
	Europe/Australia/New Zealand/China:	230 ($\pm 1\%$) Volts AC, 50 Hz ($\pm 1\%$)
	Japan:	100 ($\pm 1\%$) Volts AC, 50 Hz ($\pm 1\%$)/60 Hz ($\pm 1\%$)
		For products rated > 1.5 kW maximum power, the voltage range is $\pm 4\%$
Total Harmonic Distortion (THD) (Voltage):	< 2% THD (< 5% for products which are rated for > 1.5 kW maximum power)	
Ambient Temperature:	(23 \pm 5) °C	
Relative Humidity:	10% to 80%	
Ambient Light	(250 \pm 50) Lux	

NOTE 1: The voltage and frequency tolerances defined in the table above can only be achieved through the use of a line conditioner.

NOTE 2 It is recognised that the nominal voltage of some countries vary from the voltages defined above (e.g. China is 220V and India is typically 240V), however this Standard has limited the number of voltages to be tested for worldwide compliance to three in order to minimise test overheads. Whilst the line voltage and frequency will have some impact on the overall TEC score, the variation that will be seen between 230V, 220V and 240V will be minimal and well within the natural variation expected from testing to this Standard.

6.4 Categorisation

Categorisation is a grouping of product configurations enabling their relative energy use to be compared.

To be responsive to market and technology changes the categories that shall be use with this Standard are posted on this publicly available web site:

http://www.ecma-international.org/publications/standards/Categories_to_be_used_with_Ecma-383.htm

6.4.1 ULE Category

This category identifies products that have very low energy consumption which are EUTs with an annualised TEC calculation below a certain KWh target with no other attributes or adders. Once a product qualifies as being in the ULE category, it does not qualify to fit within any of the other categories. If a product does not meet the ULE criteria it will fall within one of the other categories.

NOTE Refer to the category web site defined in 6.4 for the current annualised energy consumption target for a product to qualify as an ULE.

6.4.2 TEC Adders

Since the configurations of base EUT's as defined in 6.5 can be altered with additional features; the Standard provides for TEC adders. TEC adders are intended to increment the TEC limit (provided by the user of the test results) for a given category of EUT's which include the attribute identified by the TEC adder.

TEC adders may be provided for items such as: Memory, graphics, TV Tuners, additional HDD, use of an SSD, discrete sound cards, discrete network cards etc. The user of the test results should provide the energy adders to be applied.

Where the discrete graphics component is treated as an adder, the FB_BW shall be used to determine the adder value.

In the case of an integrated desktop computer, the screen shall be treated as an adder.

To calculate the TEC adder energy consumption:

- Determine which TEC adders apply and based on the allowances provided by the user of the test results calculate the TEC adder value in KWh per TEC adder.
- Apply any appropriate weighting that the user of the test results provides.
- Report the overall TEC adder energy as defined in 6.8.

NOTE 1 Adders are defined in KWh/adder/year. The user of the test results should provide the energy adder information. Annex D provides examples on how adders are included in a TEC calculation.

NOTE 2 The ULE category does not use adders.

6.5 Annualised energy consumption formulas

Typical Energy Consumption (TEC) is a weighted average of measured average power in specific EUT power modes: Off, sleep/WoL sleep, long idle, short idle and active.

It is recommended that the majority profile found in Annex B is used with this Standard.

Should the user of this Standard choose to use a different profile, a profile study shall be completed (5.4.4) and the profile TEC error determined.

- If the profile TEC error is $\leq 15\%$ the user of this Standard shall use 6.5.1.
- If the profile TEC error is $>15\%$ the user of this Standard shall use 6.5.2 and an active workload shall be created that meets the criteria in 6.5.3.

NOTE Annex D provides some example TEC calculations.

6.5.1 Estimated Annualised energy consumption formula (estimated active workload)

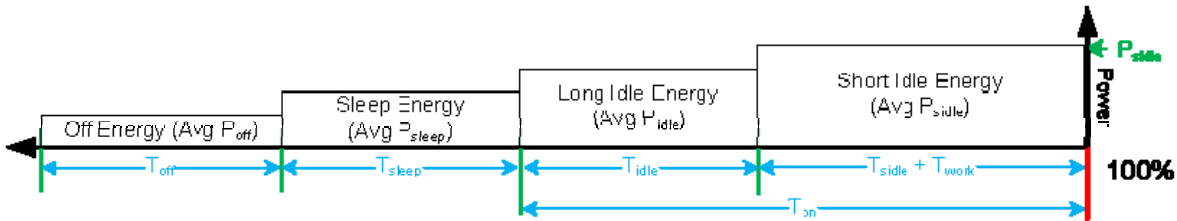
$$TEC_{\text{estimate}} = (8760/1000) * [P_{\text{off}} * T_{\text{off}} + P_{\text{sleep}} * T_{\text{sleep}} + P_{\text{idle}} * T_{\text{idle}} + P_{\text{side}} * (T_{\text{side}} + T_{\text{work}})]$$

$$100\% = T_{\text{off}} + T_{\text{sleep}} + T_{\text{idle}} + T_{\text{side}} + T_{\text{work}}$$

Where T_x are components of the duty cycle and represents the weighted averages of the time spent in each of the P_x power modes.

T_{off}	The percent time the product annually spends in the off mode.
T_{sleep}	The percent time the product annually spends in the sleep.
T_{idle}	The percent time the product is annually on and in the long idle mode (screen blanked).
T_{side}	The percent time the product is annually on and in the short idle mode (screen not blanked).
T_{work}	The percent time the product is annually on and in the active mode (screen not blanked).

This is further illustrated in the diagram below (not to scale):



6.5.2 Measured Annualised energy consumption formula (with an active workload)

$$TEC_{actual} = (8760/1000) * (P_{off} * T_{off} + P_{sleep} * T_{sleep} + P_{idle} * T_{idle} + P_{side} * T_{side} + P_{work} * T_{work})$$

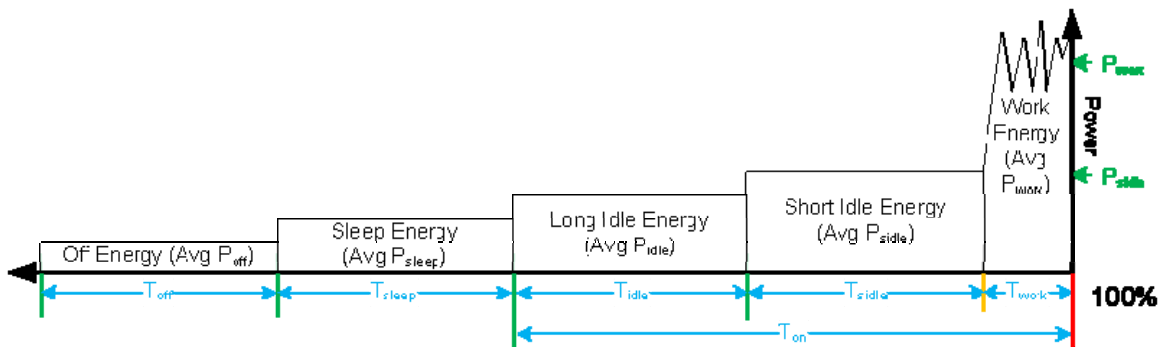
$$100\% = T_{off} + T_{sleep} + T_{idle} + T_{side} + T_{work}$$

Where T_x are components of the duty cycle and represents the weighted averages of the time spent in each of the P_x power modes.

- T_{off} The percent time the product annually spends in the off mode.
- T_{sleep} The percent time the product annually spends in the sleep.
- T_{idle} The percent time the product is annually on and in the long idle mode (screen blanked).
- T_{side} The percent time the product is annually on and in the short idle mode (screen not blanked).
- T_{work} The percent time the product is annually on and in the active mode (screen not blanked).

Where P_{work} is measured using an active workload created based on the criteria in 6.5.3.

This is further illustrated in the diagram below (not to scale):



6.5.3 Criteria to develop an active workload

The workload is required to be created if the error in comparing the actual energy to the estimated energy is greater than 15%, or

$$15\% > |TEC_{act} - TEC_{est}| / TEC_{act}$$

Where,

$$TEC_{act} = 8.76 * (P_{off} * T_{off} + P_{slp} * T_{slp} + P_{idle} * T_{idle} + P_{side} * T_{side} + P_{work} * T_{work})$$

$$TEC_{est} = 8.76 * (P_{off} * T_{off} + P_{slp} * T_{slp} + P_{idle} * T_{idle} + P_{side} * (T_{side} + T_{work}))$$

Which results in the following formulae to qualify the Energy Study for the need of an active workload:

$$15\% > |(P_{\text{work}} * T_{\text{work}} - P_{\text{side}} * T_{\text{work}})| / (P_{\text{off}} * T_{\text{off}} + P_{\text{slp}} * T_{\text{slp}} + P_{\text{idle}} * T_{\text{idle}} + P_{\text{side}} * T_{\text{side}} + P_{\text{work}} * T_{\text{work}})$$

6.5.4 Criteria of the active workload (if needed)

Should the profile TEC error be greater than the error defined in 6.5 an active workload shall be created and the TEC_{actual} formula in 6.5.2 used.

The workload shall be created to ensure that the energy consumed by the workload correlates to the Energy Study such that there is less than a 15% error when comparing the “On Energy” consumed by the work as compared to the true “On Energy” as measured in the energy study.

$$|E_{\text{onwl}} - E_{\text{onstdy}}| / E_{\text{onstdy}}$$

Where E_{onwl} is the “On Energy” calculated from the developed workload, and E_{onstdy} is the “On Energy” calculated from the energy study; or,

$$\begin{aligned} E_{\text{onwl}} &= P_{\text{idle}} * T_{\text{idle}} + P_{\text{side}} * T_{\text{side}} + P_{\text{work}} * T_{\text{work}}, \\ E_{\text{onstdy}} &= P_{\text{on}} * T_{\text{on}}, \\ T_{\text{on}} &= T_{\text{idle}} + T_{\text{side}} + T_{\text{work}}. \end{aligned}$$

Resulting in the equation:

$$15\% > |P_{\text{idle}} * T_{\text{idle}} + P_{\text{side}} * T_{\text{side}} + P_{\text{work}} * T_{\text{work}} - P_{\text{on}} * T_{\text{on}}| / (P_{\text{on}} * T_{\text{on}})$$

6.6 True RMS Watt Meter specification

Approved meters shall include the following attributes:

- Measurements must be reported by the meter with an overall accuracy of 1% or better for the ranges measured during the test. Overall accuracy is the sum of all specified analyzer accuracies for the measurements made during the test.
- An available current crest factor of 3 or more at its rated range value, meters which do not specify the crest factor, the analyzer must be capable of measuring an amperage spike of at least 3 times the maximum amperage measured during any 1-second sample of the measurement.
- Report true RMS power (watts) and at least two of the following measurement units: voltage, amperes and power factor.

The following attributes in addition to those above should be considered:

- Frequency response of at least 3 kHz.
- The meter must be able to be calibrated by a standard traceable to NIST (U.S.A.) (<http://nist.gov>) or a counterpart national metrology institute in other countries. The analyser must have been calibrated within the past year.
- If the meter will be used in an automated setup, it must have an interface that allows its measurements to be read by the SPEC PTDaemon. The reading rate supported by the analyzer must be at least 1 set of measurements per second, where set is defined as watts and at least 2 of the following readings: volts, amps and power factor. The data averaging interval of the analyzer must be either 1 (preferred) or 2 times the reading interval. "Data averaging interval" is defined as the time period over which all samples captured by the high-speed sampling electronics of the analyzer are averaged to provide the measurement set.

It is also desirable for measurement instruments to be able to average power accurately over any user selected time interval (this is usually done with an internal math calculation dividing accumulated energy by time within the meter, which is the most accurate approach). As an alternative, the measurement instrument shall have to be capable of integrating energy over any user selected time interval with an energy resolution of less than or equal to 0.1 mWh and integrating time displayed with a resolution of 1 second or less.

6.6.1 True RMS Watt Meter Accuracy

Measurements of power of 0.5 W or greater shall be made with an accuracy of 2% or better at the 95% confidence level. Measurements of power of less than 0.5 W shall be made with an accuracy of 0.01 W or better at the 95% confidence level. The power measurement instrument shall have a resolution of:

- W or better for power measurements of 10 W or less;
- W or better for power measurements of greater than 10 W up to 100 W; and
- W or better for power measurements of greater than 100 W.

All power figures shall be in watts and rounded to the second decimal place. For loads greater than or equal to 10 W, three significant figures shall be reported.

6.7 Ambient Light Meter specification

If the EUT supports some sort of automatic display luminance control, then the EUT shall be tested in an environment that meets the ambient light requirements defined in 6.3.

A meter used to measure the ambient light conditions shall measure illumination and shall meet the following requirements.

Resolution	Accuracy
10 Lux	+/- 5%

6.8 Results reporting format

The following minimum set of information shall be reported. The format is an example format only; the user of the Standard should use the format of his choice.

1. EUT description

Manufacturer _____

EUT Code / Model Number _____

EUT Type: Notebook computer Desktop Computer Integrated Desktop Computer

Operating System: Windows Mac OS Other _____

Operating system version details _____

For Notebook Computers:

Battery pack removed during test Yes No If no then:
 Fully charged battery pack used Yes



Annex A (informative)

Overview of Profile Methodology

Profiles are an important concept in this Standard and the approach taken is to focus on a single (majority) profile for measuring TEC versus supporting multiple profiles. This annex outlines the reasons for this approach, and other approaches explored in the development of this Standard.

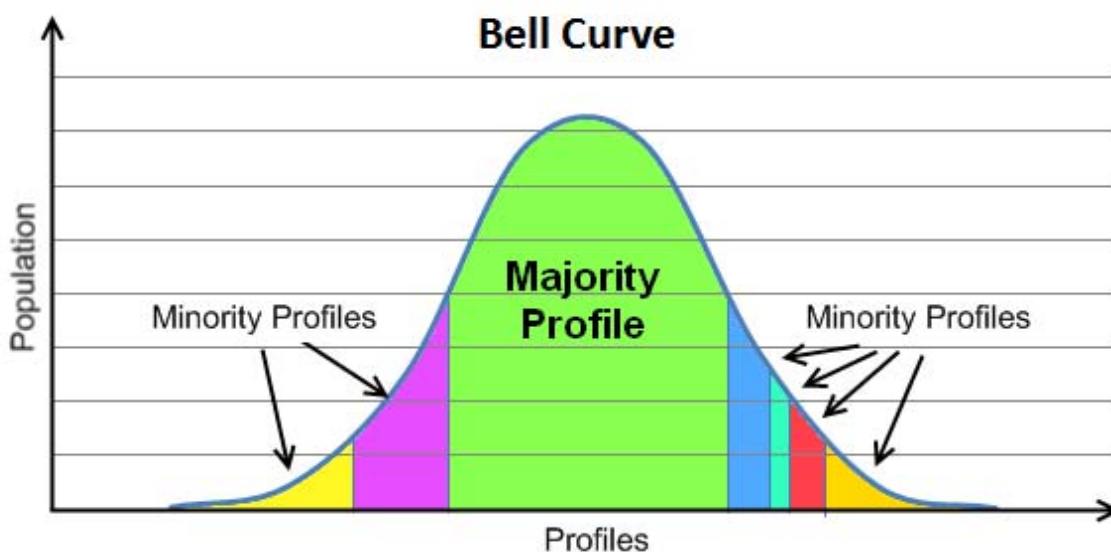
The computer is a general purpose device, and the TEC consumed by that device is very dependent on how it is used. While a computer can be described through categorisation, this only defines the attributes of the computer hardware and software. This computer (defined by a category) can then be used in many ways (defined by a profile) which will result in different TEC values (on the same computer).

For example, a computer “C1” is being purchased by users “U1” and “U2”. U1 works in a large enterprise and primarily uses a suite of office applications over an office day (typically 5 days per week and allowing for holidays) he will get a TEC value of T1. U2 uses the same computer at home for internet access and email with family members and gets a different TEC value of T2. The values of T1 and T2 are different, yet were generated by the same computer. Both TEC results are right, but as this example demonstrates the TEC value is influenced based on the usage profile.

So when trying to get an accurate value of TEC, it is important to not only note the category of the computer but to also describe the profile of how it is used.

Creating a standard which produces multiple TEC estimates for a single computer is confusing, and overly complicated. Therefore the approach taken by this Standard is to focus the TEC value on a single profile which represents a “typical” user and to base the profile attributes (T_{off} , T_{sleep} , T_{idle} , T_{sidle} , T_{work}) around this single typical profile called the majority profile.

What is a typical profile? For this Standard, it is defined as a profile which represents how a majority of users use a computer. Think of the user base as a bell curve where the majority of users fall within the majority profile, and the other minority profiles fall outside this range.



Statistical data for profiles is readily available to determine a majority profile (and the minority profiles). This Standard focuses on the majority profile and creates duty cycle attributes based on that profile to generate the TEC values. It is recognized that users of computers who don't match the majority profile will experience different TEC_{actual} values based on their usage of the computer, however the methodology makes a compromise to reduce the complexity and use of TEC such that a majority of users will experience accurate $TEC_{\text{estimated}}$ values based on their "majority usage".

A similar approach has been taken in other industries such as estimating Litre/100 Kilometres for automobiles. Here there are two profiles of usage (highway and city driving) that are used to describe the efficiency of cars globally. But this represents how a majority of users would use that automobile, and actual mileage will vary based on how that user actually drives. The majority of users will experience fuel mileage close to the estimates, but for a minority of users the mileage will vary.

Annex B (informative)

Majority Profile

5.3 of this Standard defines duty cycle attributes of a profile and 5.4.2 recommends the use of the majority profile. The recommended majority profile is based on enterprise users (people using computers in small to large businesses primarily focused on office productivity applications). A profile study on enterprise users on over 500 computers yielded:

Duty cycle attributes for the Enterprise majority profile duty cycle study

	Desktop Computer	Notebook Computer
T_{off}	45%	25%
$T_{\text{sleep}} + T_{\text{WoLsleep}}$	5%	35%
T_{idle}	15%	10%
T_{sidle}	35%	30%
T_{work}	0%	0%

NOTE The percentages provided above were created through an enterprise profile study conducted in 2010 by the ECMA-383 workgroup. The enterprise duty cycle study from over 500 enterprise machines from various countries (China, Europe, Japan and USA) from several large enterprises companies (Intel, Lenovo, Lexmark, and Sony).

Additionally the energy study was performed on 17 machines which conclusively showed that no active workload is needed for the Enterprise profile, as the average TEC error across all machines averaged to be about 1.2% (see the energy study data summary below); well below the 15% error criteria for requiring an active workload:

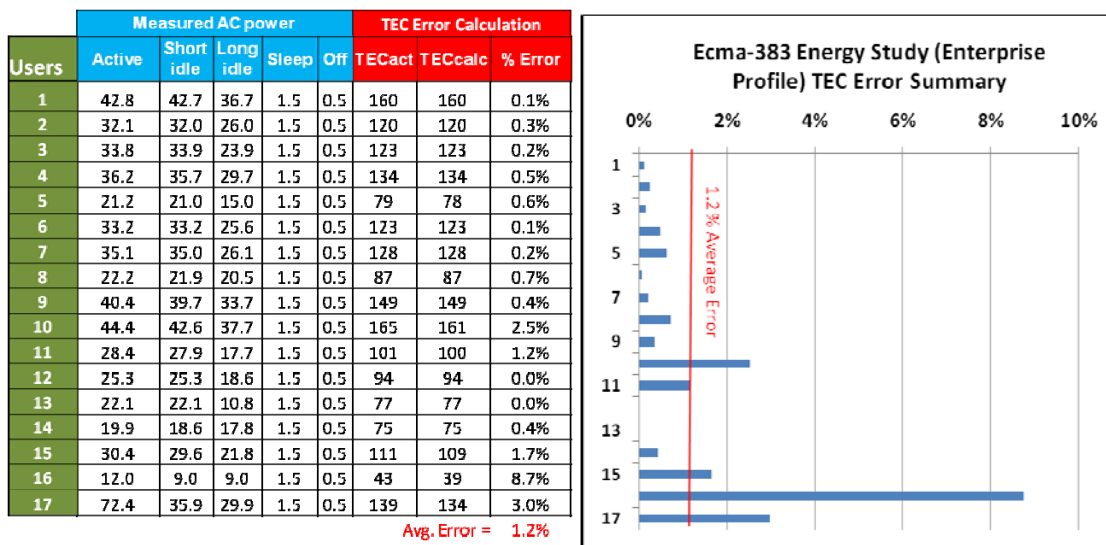


Figure 1 — Summary of the Enterprise Energy Study

This results in the following TEC equations for the Enterprise majority profile:

$$\text{Desktop TEC}_{\text{estimate}} = 8.76 \cdot (P_{\text{off}} \cdot 45\% + P_{\text{sleep}} \cdot 5\% + P_{\text{idle}} \cdot 15\% + P_{\text{side}} \cdot 35\%),$$

$$\text{Notebook TEC}_{\text{estimate}} = 8.76 \cdot (P_{\text{off}} \cdot 25\% + P_{\text{sleep}} \cdot 35\% + P_{\text{idle}} \cdot 10\% + P_{\text{side}} \cdot 30\%).$$

These numbers will be further validated for future editions of this Standard through additional profile studies.

Annex C (informative)

How to conduct a profile study

If the majority profile is not used with this Standard the user shall ensure that the profile used has been created through a profile study.

An example profile study:

A majority of client users of computers consist of enterprise (e.g. office) users, so a profile study is performed around “enterprise users” as the majority profile.

A large statistically significant number of computers are instrumented to gather utilisation data based around how the computers are used. The duty cycle attributes T_{off} , T_{sleep} , and T_{on} are recorded. This study is performed for a minimum of 1 year. The average value of T_{off} , T_{sleep} and T_{on} are then reported as part of the study along with the sample time and number of samples.

The second stage of the study requires computers to be instrumented and used by users that fit within the study profile to measure their on power and capture on utilisation (T_{idle} , T_{sidle} and T_{work}). While this sample of computers can't be as large as the first sample (cost reasons), it should be a large enough sample to draw a number of conclusions with a mix of different computers from different client computer categories:

- What is the average T_{idle} , T_{sidle} and T_{work} ratios for this given profile
- What is the profile active power ratio
- What is the profile TEC Error.

The profile study should provide a description and attributes of the computers used in the study including how the data was collected and calculated.

The example below illustrates some data from a profile study and shows 8 computers with measured P_{idle} , P_{sidle} and P_{on} . The product active power ratio is calculated for each computer (P_{on}/P_{sidle}) and then the profile active power ratio is calculated by taking the average of all of the product active power ratios.

Measurement	NB1	NB2	NB3	DT1	DT2	DT3	DT4	DT5
P_{off}	1	1	1	1.6	1.6	1.6	1.6	1.6
P_{sleep}	1.5	1.5	1.5	2.8	2.8	2.8	2.8	2.8
P_{idle}	22.7	19.3	22	39.3	55	120.9	210.5	168.1
P_{sidle}	32.8	28.2	28.1	39.3	55	120.9	210.5	168.1
P_{on}	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
Profile active power ratio	1.04							

The product active power ratio is a good way of representing the computers active power and shows how much higher it is than when the product is in a short idle state. Because this is a ratio, it allows various

products with different absolute power values to be examined together (notice the ratios for desktops which are in the 100W range can be combined with notebook ratios which are in the 20-30W range).

The profile active power ratio is then used as an attribute to describe what the active workload should look like (if needed). In the case of this profile, the active workload is very close to the short idle power measurement.

Additionally the profile study needs to provide duty cycle attributes for the profile. This can be done in two parts, the first to determine the duty cycle attributes of off, sleep and on modes for the computer (T_{off} , T_{sleep} and T_{on}), and the second to determine the components of the on mode duty cycles (T_{idle} , T_{sidle} and T_{work}).

In this example an existing study used for the ENERGY STAR V5 specification will be used to determine the off, sleep and on mode duty cycle attributes:

ENERGY STAR® V5 Computer Study		
	Desktop Computer	Notebook Computer
T_{off}	55%	60%
T_{sleep}	5%	10%
T_{on}	40%	30%

The T_{on} components of the duty cycle attributes will be created through the profile study. Continuing the example from above the data shows how the duty cycle attributes break down for each of the computers used in the profile study, the profile T_{idle} , T_{sidle} and T_{work} is then calculated from the averages of the sample products (in this case the profile has separated desktop and notebooks).

Measurement	NB1	NB2	NB3	DT1	DT2	DT3	DT4	DT5
T_{idle}	1.6%	4.6%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%
T_{sidle}	15.9%	19.9%	11.2%	37.2%	21.3%	26.7%	6.3%	36.5%
T_{work}	12.6%	5.5%	17.5%	2.8%	18.7%	13.3%	33.7%	3.5%
	NB	DT						
Profile T_{idle}	2.5%	0.0%						
Profile T_{sidle}	15.7%	25.6%						
Profile T_{work}	11.9%	14.4%						

With this data, the TEC_{actual} and $TEC_{estimated}$ values can then be calculated. The TEC_{actual} is calculated by using the P_{on} for the average on power, while the $TEC_{estimated}$ is calculated using the measured P_{idle} , P_{sidle} , T_{idle} , T_{sidle} , T_{work} and using P_{sidle} as an approximation of the P_{work} power. This is summarized in the table below.

Measurement	NB1	NB2	NB3	DT1	DT2	DT3	DT4	DT5
TEC_{actual}	96.0	82.1	86.3	149.1	206.9	439.2	805.4	600.1
$TEC_{estimated}$	90.7	78.8	79.2	146.6	201.7	432.6	746.5	598.0
Product TEC Error	5.6%	4.0%	8.3%	1.6%	2.5%	1.5%	7.3%	0.4%
Profile active power ratio	3.9%							

An example TEC_{actual} and $TEC_{estimated}$ calculations are shown below for the NB1 data:

$$TEC_{actual} = 8.76 * (T_{off} * P_{off} + T_{sleep} * P_{sleep} + (T_{idle} + T_{side} + T_{work}) * P_{on})$$

$$TEC_{actual} = 8.76 * (60\% * 1W + 10\% * 1.5W + (2.5\% + 15.7\% + 11.9\%) * 34W)$$

$$TEC_{actual} = 96.2 \text{ KW*Hr}$$

The TEC_{actual} is calculated by using the measured P_{on} which is the average power of the computer measured over the time for which the computer was on (hence the weighting factor was the sum of all of the active weightings: T_{idle} , T_{side} and T_{work}).

$TEC_{estimated}$ uses the measured T_{idle} and T_{side} with the appropriate weighting factors, but then substituting P_{side} , which is statically measured, with the P_{work} value:

$$TEC_{estimated} = 8.76 * (T_{off} * P_{off} + T_{sleep} * P_{sleep} + T_{idle} * P_{idle} + (T_{side} + T_{work}) * P_{side})$$

$$TEC_{estimated} = 8.76 * (60\% * 1W + 10\% * 1.5W + 2.5\% * 22.7W + (15.7\% + 11.9\%) * 32.8W)$$

$$TEC_{estimated} = 90.8 \text{ KWh}$$

To understand how the estimated value (which doesn't require the testing of an actual workload) impacts the product TEC error the following calculation is used:

$$[(TEC_{actual}) - (TEC_{estimated})] / (TEC_{actual})$$

$$(96.2 - 90.8) / 96.2 = 5.6\% \text{ error}$$

These same calculations are done for all of the products, and then the product TEC error is averaged to give the profile TEC error of 3.9%.

In this case the profile study would recommend that for this profile the TEC does not require an active workload and all submitted TEC values for this profile can be estimated using the short idle TEC estimation.

For the case where the profile study showed a much higher profile TEC error, then the active workload would have to be created to allow the P_{work} attribute to be measured. The active workload would have to be created from code fragments represented by the profile usages, but shall also guarantee that the profile active power ratio (PAPR) is within 15% of the profile active work ratio (PAWR), as shown in section 6.5.3.

- $PAPR = P_{on} / P_{side}$
- $PAWR = P_{work} / P_{side}$
- $15\% > |(PAPR - PAWR)| / PAPR$ (absolute values).



Annex D (informative)

Sample TEC Calculations

This section will go through two TEC calculation examples.

Notebook computer Example

A notebook computer is to measure its TEC value, and has a configuration as follows:

- 2 Core CPU
- 15" display
- 2 Memory channel capability
- 4 Gbytes of memory
- Integrated Graphics controller

The user then takes the notebook computer and performs the tests outlined in section 6 and summarizes the results below:

$$P_{\text{off}} = 1.4W$$

$$P_{\text{sleep}} = 4.3W$$

$$P_{\text{idle}} = 8.7W$$

$$P_{\text{sidle}} = 13.2W$$

The majority profile dictates the use of the TEC formulae:

$$\text{Notebook TEC}_{\text{estimate}} = 8.76 * (P_{\text{off}} * 25\% + P_{\text{sleep}} * 35\% + P_{\text{idle}} * 10\% + P_{\text{sidle}} * 30\%)$$

And filling in the measured values:

$$\text{Notebook TEC}_{\text{estimate}} = 8.76 * (1.4 * 25\% + 4.3 * 35\% + 8.7 * 10\% + 13.2 * 30\%)$$

Therefore,

$$\text{Notebook TEC}_{\text{estimate}} = 58.6 \text{ kWh / Year}$$

For users who want to then compare this TEC value to some specified limit associated with the category, there might be a need to apply adders to the limit (the value of these adders is provided by the user of the test results).

In accessing the category registry (6.4), it shows that this product falls into the “NBX category” which, by way of an example, is defined as (note this is an example not based on an actual category from the registry, the real category registry will change over time):

- ≤ 2 CPU cores, ≥ 1 Channel memory, ≥ 2 Gbytes memory, integrated graphics and a screen size ≤ 13.3 ”

Additionally the registry states that the TEC limit would have an adder of x kWh / Gbyte of memory above the base (2Gbytes). So the user of this specification would then take the category limit and add this to the adder ($2 \times$ kWh / Gbyte since there were 2 Gbytes of memory over the base category definition).

In this case the user of the specification would determine if the TEC value passed or failed depending on the value of the calculated limit:

Pass: $58.6 \text{ kWh} \leq [\text{TEC Limit} + 2 \times x]$

Fail: $58.6 \text{ kWh} > [\text{TEC Limit} + 2 \times x]$

Desktop Computer Example

An all-in-one desktop computer is to measure its TEC value, and has a configuration as follows:

- 3 Core CPU
- 20” display
- 3 Memory channel capability
- 4 Gbytes of memory
- Integrated Graphics controller

The user then takes the all-in-one desktop computer and performs the tests outlined in section 6 and summarizes the results below:

$$P_{\text{off}} = 2.2W$$

$$P_{\text{sleep}} = 4.1W$$

$$P_{\text{idle}} = 25.7W$$

$$P_{\text{sidle}} = 33.6W$$

The majority profile dictates the use of the TEC formulae:

$$\text{Desktop TEC}_{\text{estimate}} = 8.76 \times (P_{\text{off}} \times 45\% + P_{\text{sleep}} \times 5\% + P_{\text{idle}} \times 15\% + P_{\text{sidle}} \times 35\%),$$

and filling in the measured values:

$$\text{Desktop TEC}_{\text{estimate}} = 8.76 \times (2.2 \times 45\% + 4.1 \times 5\% + 25.7 \times 15\% + 33.6 \times 35\%)$$

Therefore,

$$\text{Desktop TEC}_{\text{estimate}} = 147.3 \text{ kWh / Year}$$

For users who want to then compare this TEC value to some specified limit associated with the category, there might be a need to apply adders to the limit (the value of these adders is provided by the user of the test results).

In accessing the category registry (6.4), it shows that this product falls into the “DTX category” which, by way of example, is defined as (note this is an example not based on an actual category from the registry, the real category registry will change over time):

- ≥ 2 CPU cores, ≥ 2 Channel memory, ≥ 2 Gbytes memory

Additionally the registry states that the TEC limit would have an adder of x kWh / Gbyte of memory above the base (2Gbytes). So the user of this specification would then take the category limit and add this to the adder ($2 \cdot x$ kWh / Gbyte since there were 2 Gbytes of memory over the base category definition).

Additionally the registry states that the TEC limit would have an adder of y kWh for the integrated display.

In this case the user of the specification would determine if the TEC value passed or failed depending on the value of the calculated limit:

Pass: $147.3 \text{ kWh} \leq [\text{TEC Limit} + 2 \cdot x + y]$

Fail: $147.3 \text{ kWh} > [\text{TEC Limit} + 2 \cdot x + y]$.



Bibliography

- [1] IEC 62301: "Household electrical appliance – measurement of standby power"
- [2] IEC 62018: "Power consumption of information technology equipment - Measurement methods"
- [3] ENERGY STAR V5.0 specification for computers.

