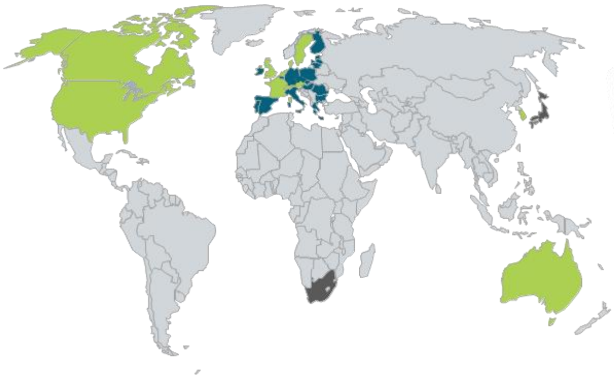
Technology: Notebook Personal Computers



Participating countries:
Australia, Republic of Korea, Switzerland. Canada & USA (ENERGY STAR data)

Other funding countries:
Austria, Denmark, France, Japan, Netherlands, South Africa, Sweden, UK

Other regions covered:
EU (ENERGY STAR and whole market data)

Draft benchmarking report for Notebook Personal Computers

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***For further information refer to* http://mappingandbenchmarking.iea-4e.org/matrix**
***or email* operating.agent@mapping.iea-4e.org**

1 Summary for policy makers

This report covers notebook PCs with screen sizes over 7 inches[1] and is the result of analysis carried out between July and November 2011. Data was provided by Republic of Korea, Switzerland and EU (whole market data); US and EU ENERGY STAR and Australia (partial market data). The ENERGY STAR databases for US and EU provided by far the most comprehensive and detailed datasets with performance data covering well over 3,000 products per year for 2009 up to the first half of 2011. Market average data covering 2002 to 2009 was available for Switzerland and the EU.

The main metric used for comparison of consumption is defined in the ENERGY STAR specification for computers as Typical Energy Consumption (TEC). This approximates the annual consumption of a computer used according to an assumed office usage pattern[2] based on idle, sleep and off mode power.

Important cautions

Firstly, trends should not be viewed as robust (as defined in Annex 3) as the detailed analysis only covers 2 to 4 years of data. Secondly, data is not fully representative of actual consumption in use (screen energy and active mode consumption are excluded). Thirdly, detailed analysis is possible for only a part of the market (ENERGY STAR), although these products accounted for over 50% of the US and EU markets.

Energy performance

Data implies that the market for notebooks is fairly uniform over major economies with similar performance seen in participating regions, which is a view supported by market experts.

Whole market sales weighted data implies an average TEC of 55 kWh/year for the EU (2008) and 36 kWh/year for Switzerland (2009) with both showing a decreasing TEC (i.e. improving) trend of around 10% per year (see Figure S1). Idle mode power almost directly reflects the TEC trend, with average idle mode power being 12 W for Switzerland (2009) and 18 W for the EU (2008). Average off mode power has shown the most significant

[1] The specific scope is: notebook PCs (also called laptops), netbooks (small format notebooks) and tablet PCs. Products with screen sizes less than 7 inches are excluded. For a full definition of scope and performance metrics considered, see *Product Definition: Notebook PCs, Version 2.0: 27th April 2010.*

[2] The ENERGY STAR TEC metric approximates the consumption of an office computer used predominantly for e-mail, word processing and similar basic tasks. US EPA determined that the conventional duty cycle described in Section 3.2 is representative of such products in typical use.

proportional improvement, having dropped by over 50% in 3 years to 0.7 W by 2009 for Switzerland and the Republic of Korea, but remaining just above 1 W for the EU in 2008. Improvement in sleep mode power has slowed, with the average just above 1 W for Switzerland and the Republic of Korea (2009) and 1.7 W for the EU (2008).

EU and US ENERGY STAR partial market data shows almost identical average performance and average TEC was just over 30% better than the whole market average in 2008 for the EU. Around half of ENERGY STAR products are category A (lower specification notebooks) and just under half B (mid-specification notebooks); very few category C (high specification) notebooks meet the relevant ENERGY STAR specification.

ENERGY STAR notebooks (partial market data - only more efficient products) and the Australian sample testing show a fall in TEC averaging 8% per year between 2008 and 2011. The fall totals 23% over 3 years to reach 28 kWh/year in 2011(see Figure S2). Idle mode has improved to an average of just over 9 W in 2011. Sleep mode averages 1.1 W in 2011, which the US products reached in 2010, a year before EU products. Off mode averages less than 0.6 W for EU and US ENERGY STAR and was effectively level 2010-2011. The sleep/off figures may increase again due to added networking functionality. Considering ENERGY STAR categories individually (A, B, C[3]), all appear to be improving at significant rates, although category B has shown particularly large performance improvements of over 20% to 2011.

Comparing consumption (TEC) of similar products, year on year

Three bands of products were analysed in isolation, where each band contained only products with very similar levels of computing capability (low, average and high levels), in consecutive years. Comparable products appear to be consuming less energy year on year, with 2011 products consuming less than two thirds the energy per year of comparable products from 2009 (for TEC measured according to the ENERGY STAR test methodology).

Sample notebooks from low, average and high computing capability bands have converged into a range of TEC with averages between 20 and 30 kWh/year. This convergence implies that power management is succeeding in reducing consumption of most types of processor chip down to similar idle/sleep/off consumption levels. This convergence may merit further investigation in the context of whether it remains justified to separate ENERGY STAR categories A and B, and perhaps C.

[3] The ENERGY STAR criteria define classes of product in terms of computing power base upon presence or not of certain central and graphics processor types and sizes – these are called Category A, B, C (or D for some products). See Table 7 on page 64.

Scope for improvement

Analysis by computing capability band also revealed that the worst to best range of annual consumption of notebooks with average computing capability has halved between 2009 and 2011. This could imply that the easily accessible savings have largely been taken up for average capability products. The scope for improvement (worst to best) is similar for low computing capability notebooks; more scope appears to remain for higher capability products.

The ranges of consumption best to worst have also converged in each of these bands: the average and low capability notebooks with a range of 20 to 30 kWh/year, and high capability notebooks from 17 to 38 kWh/year (best to worst).

Energy performance of brands

The analysis focused on 6 major brands and whilst conclusions should be treated with extreme caution, 2009-2010 data implies that all six brands appear to be reducing average annual consumptions. The average improvement was just over 10% between 2009 and 2010. But the best performing brand has annual consumption 30% lower than the worst performing brand. The best has TEC almost 20% lower than the average. Some brands appear to be reducing annual consumption faster and further than others: one brand achieved a 30% cut in average consumption 2009-2010 and in so doing moved from the worst to the best of these six brands. One brand made only 1% improvement 2009-2010. Reasons for this have not been investigated.

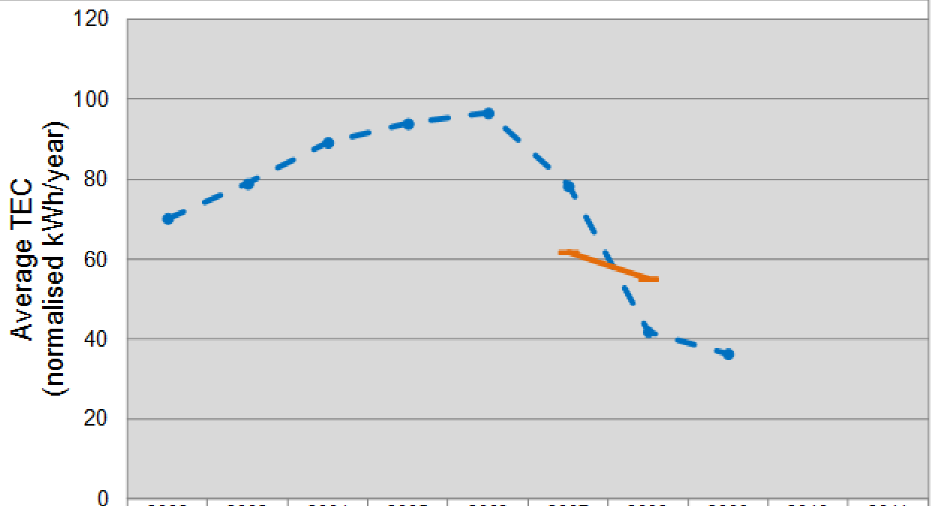
Policies

The ENERGY STAR voluntary labelling scheme for higher efficiency products provides the primary global test methodology for energy consumption and framework for performance improvement. The market (mostly) moves rapidly to meet the ENERGY STAR specification soon after its release. Policy focus on standby/off mode in USA, Canada and Republic of Korea may have helped to drive improvement in these aspects of performance.

EU and Australian Minimum Energy Performance Standards (MEPS) measures being drafted are likely to be based upon ENERGY STAR Version 5 levels (5.2 in the case of Australia) with additional allowances to account for wider specifications not always accounted for under the ENERGY STAR scheme. No other MEPS are in place across participating countries.

A significant revision to the ENERGY STAR test methodology is underway for V6 which could usefully find more effective ways to differentiate performance in line with most likely consumption in real use. Unfortunately this may result in the TEC and other metrics for V6 being non-comparable with Version 5 and earlier, for example with introduction of newly defined long idle and short idle modes (instead of the single idle mode). This means that longer term trends would be very difficult to ascertain, unless the previously defined idle mode (for example) continued to be reported.

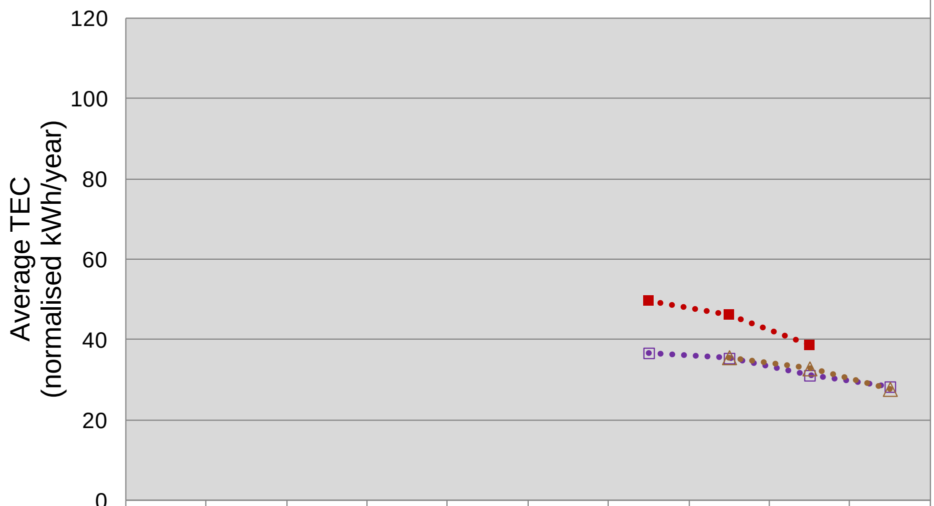
Figure S1. Normalised annual consumption (TEC in kWh/year) for datasets representing whole market.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Republic Of Korea										
Switzerland (Sales Weighted)	70.2	78.9	89.2	93.9	96.6	78.3	41.9	36.4		
EU whole market (IDC)						61.7	55.0			

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure S2. Normalised annual consumption (TEC) with data representing only partial market.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							49.7	46.2	38.6	
USA ENERGY STAR							36.7	35.4	31.1	28.3
EU ENERGY STAR								35.6	32.8	27.7

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Contents

Annexes

2 Introduction

This report is the result of analysis carried out between July and November 2011. Initial results from data collection and preliminary analysis during 2010 have been amalgamated with a later set of data from July 2011.

This work covers notebook PCs (also called laptops), netbooks (small format notebooks) and tablet PCs. Products with screen sizes less than 7 inches are excluded. For a full definition of scope and performance metrics considered, see *Product Definition: Notebook PCs, Version 2.0: 27th April 2010*[4].

Data was submitted by Australia, the Republic of Korea, Switzerland, USA and the EU. The datasets submitted include individual product data for products that were on the market between 2008 and the first half of 2011, plus market average data covering 2002 to 2009. The majority of analysis was carried out on data from the US and EU ENERGY STAR programs as these provided by far the most comprehensive and detailed datasets.

[4] See http://mappingandbenchmarking.iea-4e.org/matrix.

3 About the data used and analysis method

Data was invited from 11 IEA 4E Mapping and Benchmarking Annex participating countries in mid-2010. The request yielded data representing 5 countries/regions (with data of two separate types for the EU). Following initial analysis in early 2011, a second invitation to submit data was issued. This resulted in the datasets listed in Table 1 which were used in the final analysis. The nature of datasets for each country is described in the following sections. Details of each dataset and results for that country alone are included in the individual country mapping documents (available from http://mappingandbenchmarking.iea-4e.org/matrix).

3.1 Important cautions for interpreting and using mapping and benchmarking information

Considerable efforts have been taken to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. The generic approaches are detailed in the overall Mapping and Benchmarking Framework[5] and in the Notebook PCs Product Definition[6]. However, to ensure that readers are fully aware of the reliability of particular sets of data and any associated assumptions or transformations that have been necessary, a *Framework for Grading Mapping and Benchmarking Outputs* has been developed that is used across all of this project's outputs. These gradings are based on a scale as follows:

- **Robust**: Datasets are representative of the full market and there is significant confidence in the transformation used to make the dataset comparable with others. Comparisons within and between such datasets are as reliable as reasonably possible within limits outlined in section 3.4 Limitations and weaknesses in the data and/or approach.
- **Indicative**: Datasets are not fully representative of the market and/or there are minor concerns with the reliability of the transformation used to make the dataset comparable with others. Hence indicative data provides meaningful but qualified comparisons.
- **Illustrative**: Datasets poorly represent the market and/or there is significant concern with the reliability of the transformation used to make the dataset comparable with others. Hence any associated results and conclusions must be treated with caution.

Full details of the system for grading are provided in Annex 2. The specific gradings allocated to each dataset are summarised in Table 1 with explanations of each dataset and its assigned quality rating provided in sections that follow.

[5] Refer to Annex framework at http://mappingandbenchmarking.iea-4e.org/, accessed 2 April 2012
[6] Refer to detailed product definition at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=7, accessed 2 April 2012.

Note that adjustments for normalisation were minimal in this analysis and so are considered not to introduce significant additional degradation of data quality, hence quality gradings are the same for declared and normalised data.

Table 1. Summary of the type and assigned quality for each dataset.

Country	Assigned quality	Source
Australia	**Illustrative**	Independent lab testing of 129 product samples over three years
Republic of Korea	**Robust**	Government register with sales data (but low product numbers and only off mode and sleep mode)
Switzerland	**Indicative**	Government model based on industry declared sales and performance data
USA ENERGY STAR	**Illustrative**	Manufacturer declarations within government managed register of only better performing products; no sales data; may not capture all types of notebooks on the market, especially very high specification domestic products; only first half of 2011 included. (Third-party testing required from 2011)
EU - ENERGY STAR	**Illustrative**	Manufacturer declarations within government-managed register of only better performing products; no sales data; may not capture all types of notebooks on the market especially very high specification domestic products; only first half of 2011 included
EU - whole market	**Robust**	Independent market research report for the European Commission, based on whole market sales data

3.2 Test methodologies and metrics

The ENERGY STAR[7] specification for computers provides an almost globally accepted test methodology and this has been adopted as the basis for this analysis. Its history of versions is summarised in Table 4 on page 50.

ENERGY STAR Version 5.0 came into effect in July 2009 and defined the main metric adopted for this analysis, **Typical Energy Consumption (TEC),** as:

> *A method of testing and comparing the energy performance of computers, which focuses on the typical electricity consumed by a product while in normal operation during a representative period of time. For Desktops and Notebooks, the key criterion of the TEC approach is a value for typical annual electricity use, measured in kilowatt-hours (kWh), using measurements of average operational mode power levels scaled by an assumed typical usage model (duty cycle).*

[7] See http://www.energystar.gov/index.cfm?c=products.pr_find_es_products.

The assumed TEC duty cycle (proportion of hours spent in each mode) has five possible patterns for notebook network connectivity: 'Conventional', '(full) proxying' (Version 5.0/Version 5.2) or various 'full network connectivity' modes (Version 5.2). For this analysis the ENERGY STAR **conventional duty cycle** was adopted which consists of 60% of the time in off mode, 10% in sleep mode and 30% in idle mode for notebooks. This duty cycle does not include any time spent in active state[8] and is based upon computers typically used in office situations.

Performance data prior to specification Version 5.0 (July 2009) was based only on reporting idle mode, sleep mode and off mode powers. A comparable TEC value can be calculated for any dataset that includes sleep mode, idle mode and off mode consumption figures.

Definitions of operational modes (quoted from ENERGY STAR specification Version 5.2):

a) ***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.*
b) ***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.*
c) ***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 Sleep Mode.*
d) ***Active State*** *(not included in TEC): The power state in which the computer is carrying out useful work in response to a) prior or concurrent user input or b) prior or concurrent instruction over the network. Active State includes active processing, seeking data from storage, memory, or cache, including Idle State time while awaiting further user input and before entering low power modes.*

Power for off mode, sleep mode and idle state is measured with the screen blank.

One additional metric has been examined:

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[8] The ECMA-383 Standard 'Measuring the Energy Consumption of Personal Computing Products', 3rd Edition, December 2010, supports the non-inclusion of active state in typical usage profiles based upon measurements taken on 500 computers in office environments. This profile study showed less than 1% of time spent in the active state for these users (p21). Users in different environments and with different types of computer may produce different usage profiles. This ECMA Standard recommends an enterprise usage profile of 25% in off mode; 35% sleep mode and 40% idle mode, but was published after the ENERGY STAR criteria update.

Default time to sleep (minutes) for **screen** and **computer**: This is the number of minutes of user inactivity after which the sleep mode is initiated, as preset in the product before user intervention.

It was noted that Standard ECMA-383 *Measuring the Energy Consumption of Personal Computing Products*[9] defines ‘short idle’ and ‘long idle’ active modes, although these are not yet incorporated into the ENERGY STAR programme and will not be analysed for this project. Short and long idle are the idle modes before and after the screen has blanked respectively.

3.3 Overview of datasets used

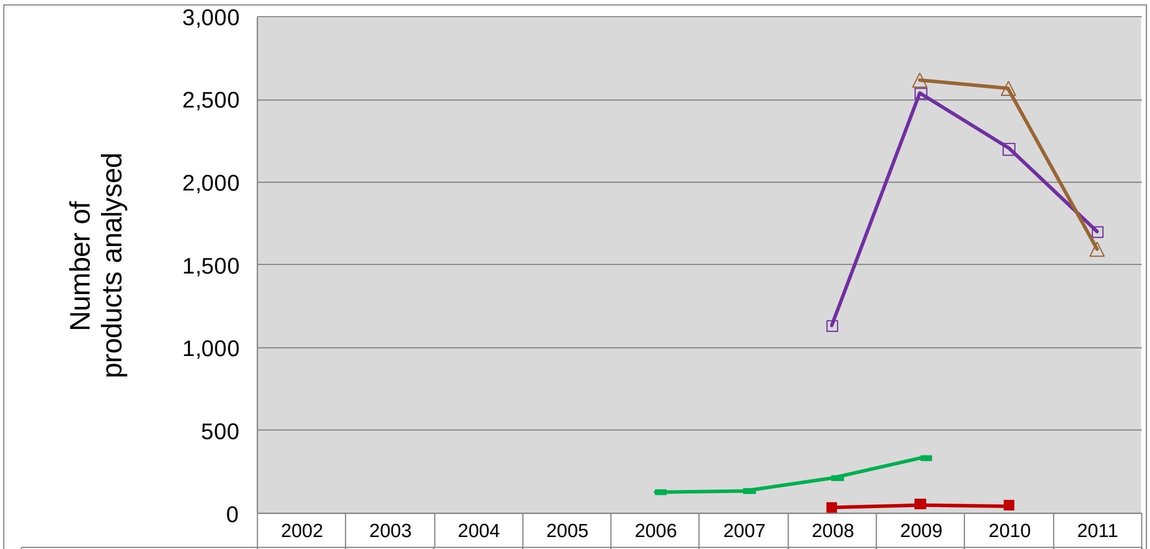
Table 1 provides an overview of the datasets and Figure 1 shows the count of individual products for which data was available in each year. The totals shown against the two ENERGY STAR datasets include the products stated as available on the USA and EU markets respectively, regardless of whether the product was registered on the USA or the EU programme[10]. Further details on each dataset are given in Annex 2 *Descriptions of each country* .

The analysis in this report presents data that is assumed to be representative of the full market separately to partial market data. Thus, Republic of Korea, Switzerland and EU whole market data is in section 5.1 *Whole market data*; US and EU ENERGY STAR and Australian data is plotted in graphs in section 5.2 *Partial market data*.

[9] See http://www.ecma-international.org/publications/standards/Ecma-383.htm

[10] The USA ENERGY STAR database includes some products available on both the US and EU markets; the EU ENERGY STAR database includes only products not available on the US market. The relevant products were copied from the US to the EU dataset, and so appear in both.

Figure 1 Count of individual notebook products from each country for which data was analysed.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							33	52	44	
Republic Of Korea					127	136	212	336		
Switzerland	Market average data only			Market average data only				Market average data		
USA ENERGY STAR							1134	2539	2203	1700
EU ENERGY STAR								2617	2567	1593
EU whole market (IDC)						Market ave only				

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

3.4 Limitations and weaknesses in the data and/or approach

The following overall limitations and weaknesses have been identified as inherent in the data provided, or as a result of the approach taken in the analysis. Further weaknesses and limitations specific to certain aspects of analysis are highlighted in Annex 4 *Analysis approach*:

1. The detailed analysis **only covers 2 to 4 years of data** and so trends cannot be viewed as robust.
2. **Data is not representative of actual consumption in use.** Firstly, power measured during the ENERGY STAR test methodology is done with the screen blank. Secondly, typical energy consumption (TEC) is calculated according to an assumed usage pattern of hours per day in each mode which may not reflect actual usage and, for example, does not include any 'active mode' use of the product. In addition, users may alter the power management settings which could significantly change consumption.
3. Much of the detailed data presented in this analysis is derived from **partial market datasets** (ENERGY STAR), albeit accounting for over 50% of the US and EU markets.
4. The wide spread of TEC values reflects a **wide spread of computing capability** of the products (in terms of processor speed, RAM, video card type etc) as well as

differences in the energy efficiency of the components and systems as a whole. For example, a dataset that includes all types of computer might include small netbooks as well as high-end gaming machines and so inevitably show a wide spread of consumption. Even within the ENERGY STAR categories A, B and C, there is still scope for fairly different products to appear side-by-side within a category. The analysis to isolate a narrow average performance band attempts to ensure sets of fully comparable products.

5. The analysis aims to include only products with screen size of 7 inches and above and so includes netbooks but not smart phones and PDAs. **The screen size field in the US dataset was found to be empty** for the majority of products in the more recent dataset and so this filter could not be applied. However, the numbers of products with screen size less than 7 inches are expected to be very low and so the impact on results very small.

3.5 Summary of approach for energy performance analysis

The aim of the analysis was to present:

- Timeseries of average TEC values for each country, broken down by product categories (ENERGY STAR A, B, C) described below. Also best and worst TEC.
- Timeseries of average idle mode values for each country (all products).
- Timeseries of average sleep mode values for each country (all products).
- Timeseries of average off mode values for each country (all products).
- Timeseries of average TEC values broken down by anonymised brand.

Not all of these analyses were possible for every dataset due to absence of particular data (such as idle mode power or ENERGY STAR category). Details of the analysis process are given in Annex 4 *Analysis approach* on page 61, and summarised below:

1. Datasets were filtered to contain only notebooks with screen sizes over 7 inches.
2. Those with performance figures quoted at 230 V or 100 V were normalised to estimated values at 115 V (see Normalisation of TEC results on page 62).
3. Where no TEC values were quoted, TEC was calculated from the separate off mode, sleep mode and idle mode powers using the ENERGY STAR use profiles.
4. Data was broken down into subsets for various stages of analysis, with the aim of comparing performance of similar products within groups and tracking performance trends over time. The subsets are described briefly below, with more detail in section *Breakdown of data into subsets for analysis* on page 63.

Products for which data was available were broken down into the following sub sets:

a) Into **ENERGY STAR categories A, B and C**. These internationally recognised categories of notebooks (and desktops) define similar products and are useful to an extent, but each category still contains a relatively wide range of computing capability. This breakdown was designed to enable an answer to the question: *'Are notebook PCs within the categories defined by the ENERGY STAR getting more efficient over time?'*

b) By selecting three narrow **bands of similar computing capability** at high, average and low levels (by processor speed, RAM, graphics processor specifications etc). This approach isolated groups with very similar computing capabilities that were constant from year to year. This was designed to enable an answer to the question: *'Are notebook PCs getting more efficient over time, for the same capability?'*
c) Into **anonymised brand groups**, containing products from the same manufacturer, selecting only ENERGY STAR category B products in order to be relatively comparable. This breakdown was designed to enable an answer to the question: *'Does any difference in performance between brands give insight into scope for improvement?'*
d) By defining for each year a narrow band of computing capability representing the most **popular product capability level** in that year. This band was intended to change with market trends for each year and was designed to enable an answer to the question: *'Is the most popular computer type using more energy each year?'* This was not achieved because the 'most popular capability level' could not be defined due many complex and overlapping market trends in subsets of the market.

The rationale and method for dividing into these subsets explained in section *Breakdown of data into subsets for analysis* on page 63.

3.6 Overview of approach to identifying best in class products

Identifying best in class products is intended to bring the following advantages:

- Enables setting realistic current level of ambition as a benchmark for policy purposes.
- If levels are published they could provide incentive benchmarks for manufacturers to aspire to.
- Provides reference benchmarks for best product competitions.

Notebooks were firstly divided into ENERGY STAR categories A, B and C. They were then ranked according to their normalised TEC in kWh per year. The products with lowest TEC were then identified. Internet research was carried out to verify that the best performing notebooks met the product definition, category classification, were commercially available and that performance data published by the manufacturer (or third party source) matched that present in the analysed dataset.

However, it proved difficult to find corroborating evidence for best performing models from the ENERGY STAR database. Few models from the ENERGY STAR database were found on manufacturers' web sites; of those, few had performance data available. It was therefore not possible to identify verified 'best in class' products.

For further information, see section *Best in class products* on page 46.

4 Types of products on the markets and trends

The most detailed data was available from the ENERGY STAR databases, although these represent only the better products on the market and so were graded for quality as illustrative. Most analysis was carried out on these datasets. Whilst the Australian dataset contained comprehensive supplementary data (RAM, processor speed, screen size etc), the dataset included only tens of products and so was not considered comparable to be plotted alongside ENERGY STAR data, which was based upon several thousand products.

4.1 ENERGY STAR category

Figure 2 should not be seen as an accurate reflection of the market situation, except for data from the EU report provided by the European Commission[11], which is sales weighted. ENERGY STAR data is not sales weighted; Australian data only reflects the proportion of categories present in the 129 products bought for testing. However, it does seem clear that categories A and B dominate these markets but without any clear trend in their proportions. The actual count of products analysed in each category is given in Table 6 on page 64.

It is not known if this trend reflects the characteristics of products in the whole market or only the trend in the ENERGY STAR registered products. It is also possible that manufacturers have registered products with the highest energy consuming configuration to cover a family of products and so some members of the product family may qualify for a lower ENERGY STAR category. Thus these figures may overstate the market presence of higher specification products.

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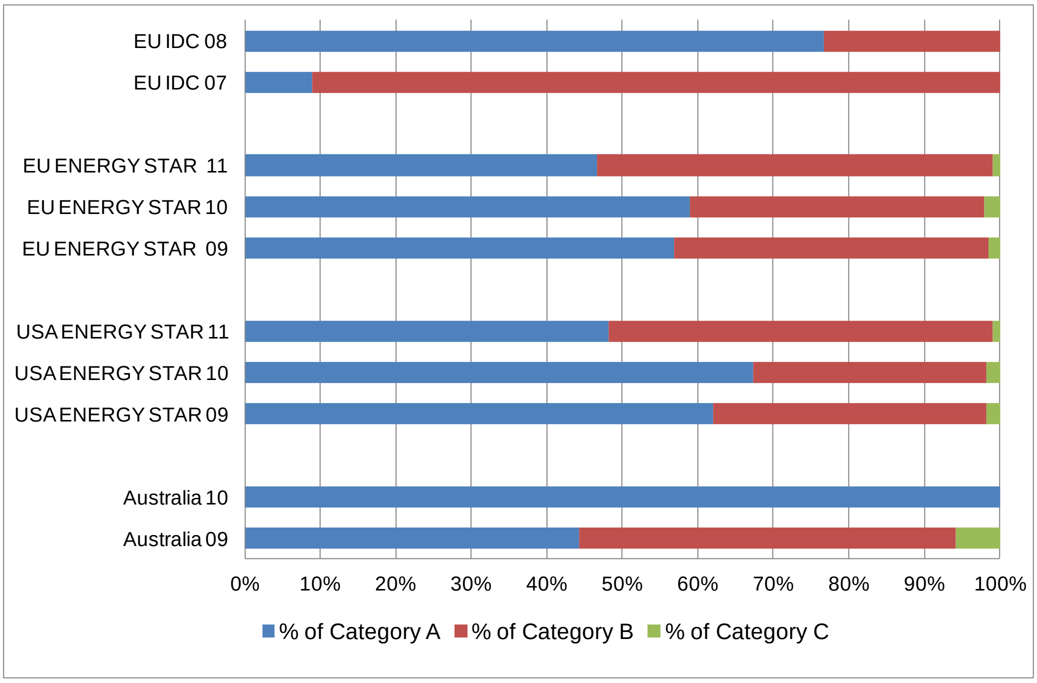
11 Carried out by market research company IDC.

Figure 2. Category breakdown for ENERGY STAR products in each dataset (caution: may not reflect market sales).

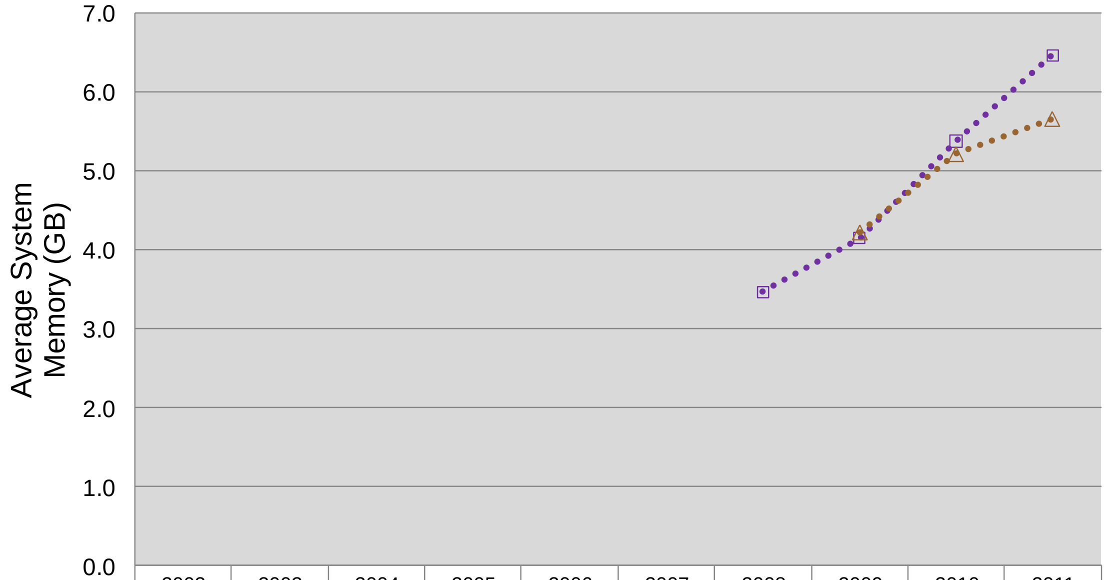


4.2 System memory (RAM)

The trend amongst the specifications registered on the ENERGY STAR programme is shown in Figure 3 and in Figure 4. Data for fewer than 50 products was also available for Australia but these were deemed non-comparable due to small numbers of products. There is a clear trend for rising amounts of system memory, with an average of around 1 GB more RAM added per year.

It is not known if this trend reflects the whole market or only ENERGY STAR registered products. The trend should be treated with caution as it is not sales weighted, and products registered on the ENERGY STAR programme may be those in a family of products which have the highest RAM installed.

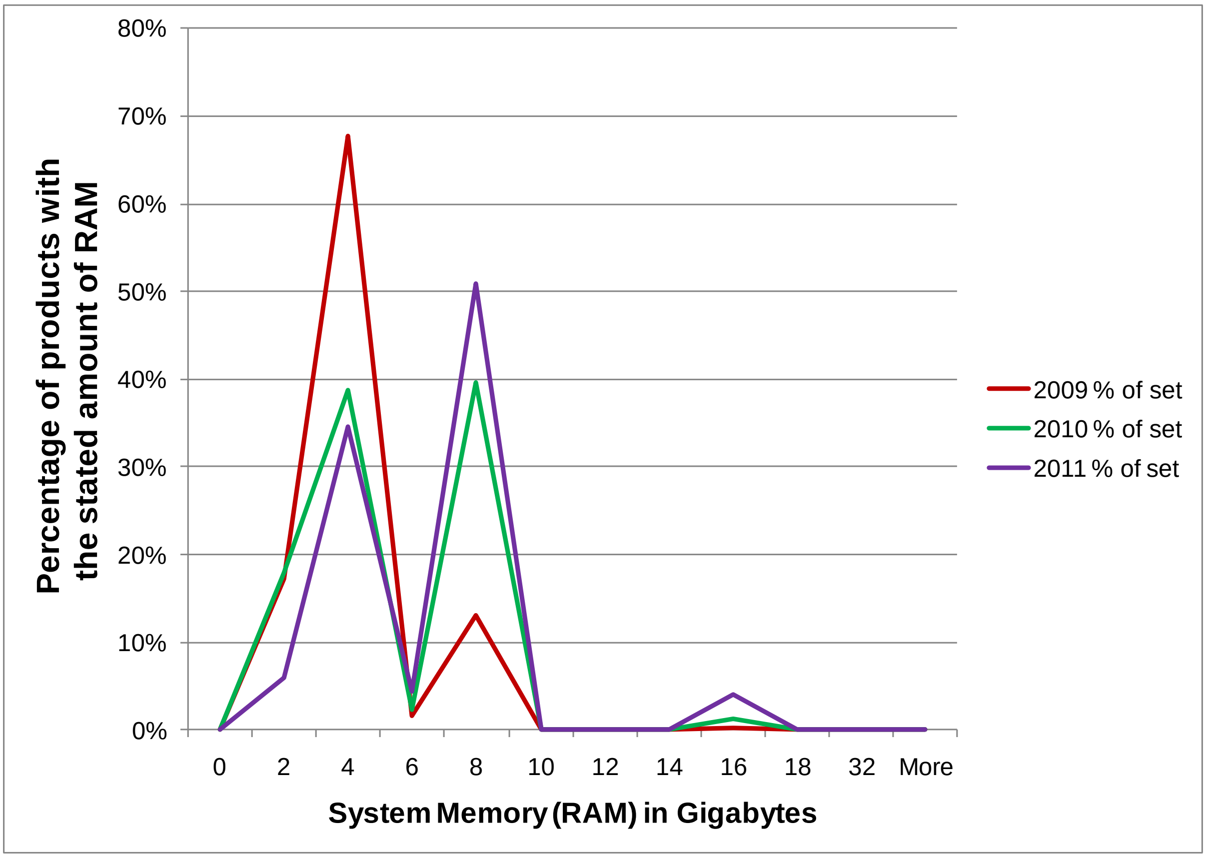
Figure 3. Average system memory (RAM) of ENERGY STAR products in gigabytes (product weighted).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA ENERGY STAR							3.47	4.15	5.38	6.47
EU ENERGY STAR								4.22	5.21	5.66

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 4. Histogram of RAM provided for Category B products only, as a percentage of the whole dataset for each year.



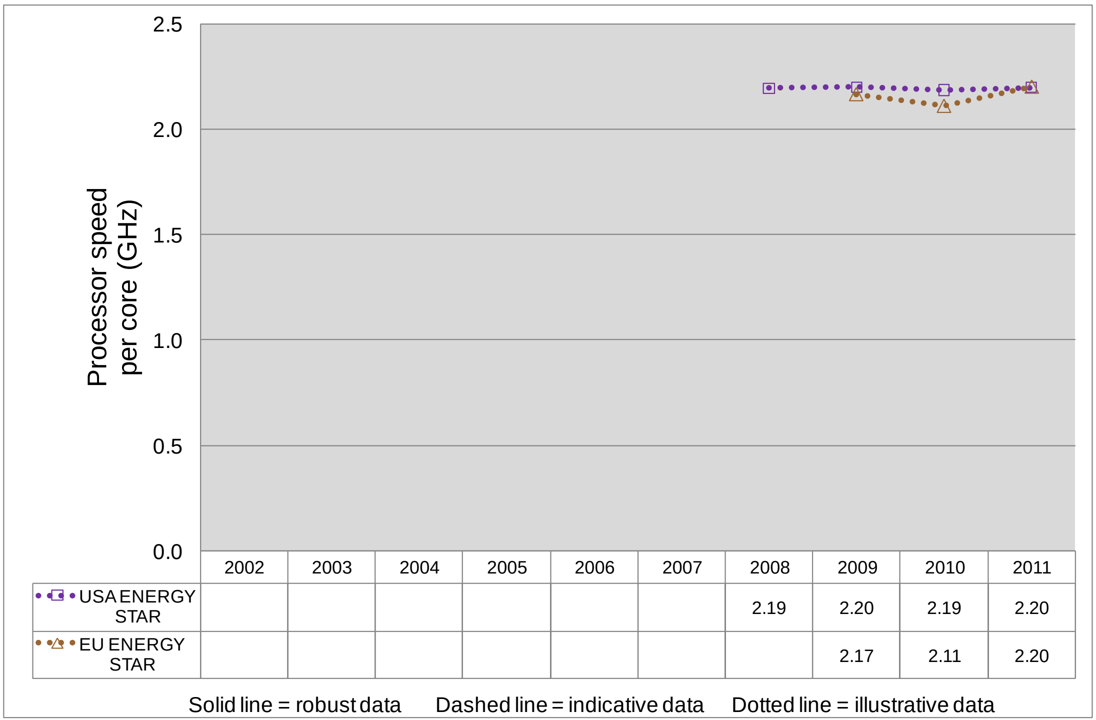
4.3 Processor speed (GHz)

The trend in average processor speed amongst ENERGY STAR products is shown in Figure 5. As previously stated, Australian data was deemed non-comparable due to small numbers of products.

The average processor speed of ENERGY STAR products appears to have stayed constant between 2008 and the first half of 2011 at around 2.2 GHz. However, Figure 6 reveals that although the average processor speed has remained constant, there are complex trends going on. It appears that a large number of products came onto the market in 2011 with slower processor speeds than previous averages and may have replaced a tranche of mid-speed products.

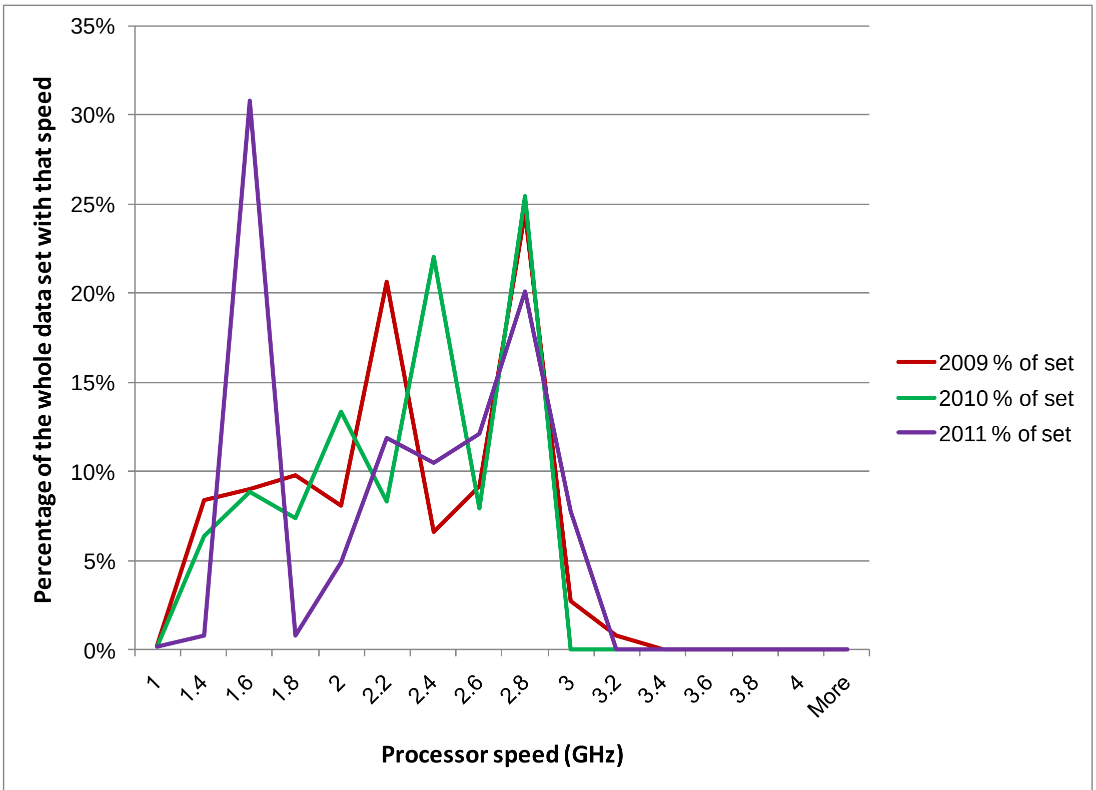
It is not known if this trend reflects the whole market or only ENERGY STAR registered products.

Figure 5. Average processor speed for ENERGY STAR products over time.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA ENERGY STAR							2.19	2.20	2.19	2.20
EU ENERGY STAR								2.17	2.11	2.20

Figure 6. Histogram of processor speed as percentage of the whole dataset for each year.



4.4 Screen size

The trend in screen size amongst ENERGY STAR products is shown in

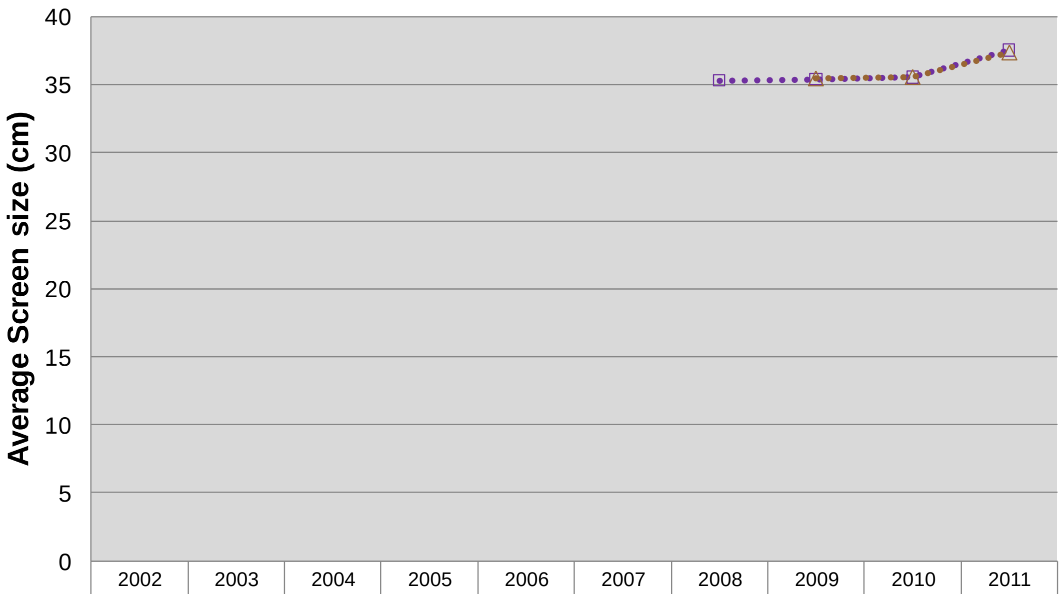
. As stated above, data for Australian products was deemed non-comparable due to small numbers of products.

There appears to have been a rise in average screen size to 37.5 cm (diagonal, 14.8 inches) from 2010 to 2011, following stability at 35.5 cm (14 inches) from 2008 to 2010. Examination of average screen sizes by ENERGY STAR category reveals that 2008 to 2010 show fairly consistent averages for category A of 33 to 34 cm (13.2 inches), whilst category B averages are 39 to 40 cm (15.6 inches). However, in 2011 screen sizes for categories A and B were very similar at 37 and 38 cm respectively (14.6 and 15 inches).

Note that 2011 ENERGY STAR data is only for the first half of the year and so not strictly comparable with previous data.

It is not known if this trend reflects the whole market or only ENERGY STAR registered products.

Figure 7. Average screen size of all ENERGY STAR products over time.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA ENERGY STAR							35.3	35.4	35.6	37.5
EU ENERGY STAR								35.5	35.6	37.4

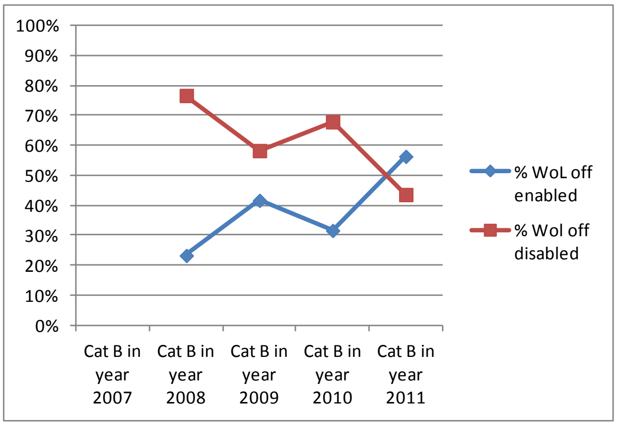
Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

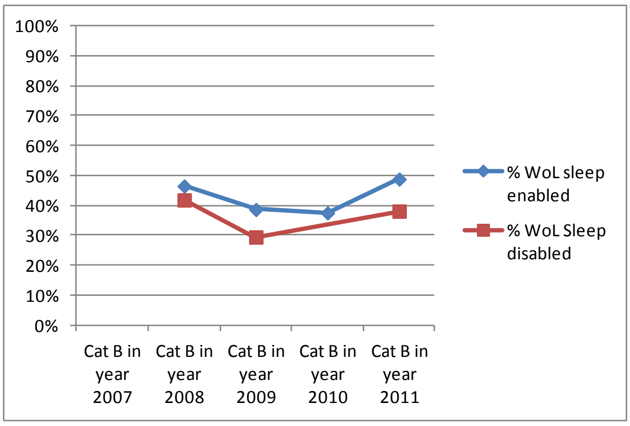
4.5 Wake-on-LAN settings

Enabling Wake-on-LAN (WoL) requires a small additional residual power level (around 0.1 to 0.7 W) to be maintained during sleep mode and/or in off mode. Testing would be carried out in whichever mode is enabled by default (i.e. factory set) and the default mode is declared in the ENERGY STAR database. Because of the additional power demand when WoL is enabled, it is possible that a general change in the proportion of products with WoL enabled could cause an apparent change in the average sleep mode or off mode power. This was therefore examined to check whether or not this was an issue. Figure 8 shows the results for the US ENERGY STAR dataset for Category B, being the largest sub-set of data and deemed representative of general market changes.

There is a general trend for increasing proportion to have WoL disabled for off mode, rising from 20% in 2008 to over 50% in 2011 which could give rise to a reduction in apparent off mode consumption. But no such significant change for WoL settings has occurred for sleep mode from 2008 to 2011[12].

Figure 8. Proportion of Category B notebooks in the USA ENERGY STAR dataset that had WoL enabled/disabled for the declared power demands for off mode (left) and sleep mode (right)





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[12] Note that sleep mode data for 2010 showed a dip to less than 1% which was omitted due to low credibility of the figure (an untraced error).

5 Energy performance

This energy performance analysis section is divided into 2 parts:

- The first part covers available data that reflects the **whole market** in each country/region – showing data for the Republic of Korea, Switzerland and EU (IDC market survey data).
- The second part covers **partial market** data that cannot be considered representative of the full market in that country/region – showing ENERGY STAR for EU & US and Australian registry data.

5.1 Whole market data

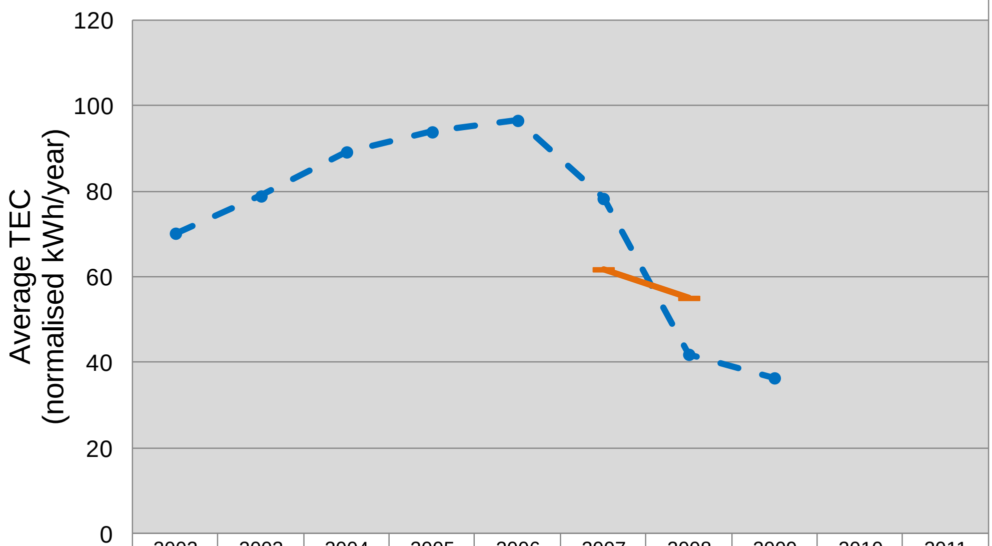
5.1.1 Annual consumption (TEC) for whole market data

Figure 9 shows the only two countries/regions for which data representing the whole market is available for annual consumption (TEC), which are Switzerland and EU (from the EU market research report). The recent TEC trend for both datasets appears to be downward. The more robust dataset indicates a sales-weighted TEC of 55 kWh/year for the EU in 2008 compared to 42 kWh/year for Switzerland in the same year. The Swiss average improved by 13% to reach 36 kWh/year in 2009.

It was not possible to divide the Swiss data into separate ENERGY STAR category types, but this was possible for the EU IDC dataset. Both categories reflected the same proportional fall in annual consumption as shown in Figure 9; graphs are not included for the EU IDC data as it provides little additional information over that in Figure 9. The EU market research report figures are an average of 54.0 kWh/year for category A and 58.5 kWh/year for category B, both for the year 2008.

Note that data for Switzerland was available covering 1995 to 2009 and showed a fall from 91.5 to 68.8 kWh/year from 1995 to 2001 followed by the rise and fall shown below. The reason for the curved shape for Swiss data is not known.

Figure 9. Normalised annual consumption (TEC in kWh/year) for data representing the full market.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Republic Of Korea										
Switzerland (Sales Weighted)	70.2	78.9	89.2	93.9	96.6	78.3	41.9	36.4		
EU whole market (IDC)						61.7	55.0			

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

5.1.2 Idle, sleep and off mode power for whole market data

Whole market data mostly implies that idle, sleep and off mode power are all reducing significantly when tested under the ENERGY STAR methodology. There are at least two factors that could be contributing to this change, in addition to the inherent efficiency of the components used:

- Firstly, default power management settings could be more effectively powering down the graphics processing chip(s) during idle mode testing. This is a positive step for overall energy efficiency.
- Secondly, the data does not distinguish between products for which Wake-on-LAN has been enabled or disabled; average power is calculated with whichever is the factory default setting. The trends in proportion of US products with WoL enabled/disabled are shown in Figure 8. This showed no significant change in WoL enablement rates for sleep mode (2008 to 2011), but WoL disablement rate for off mode increased from 20% to over 50%. Enablement of WoL increases off mode and sleep mode power by around 0.1 W to 0.7 W.

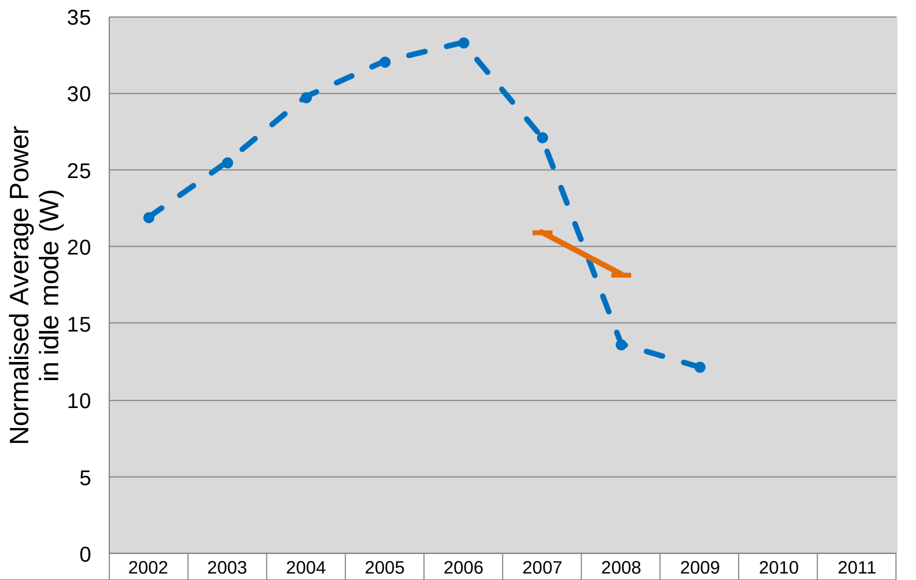
The most significant proportional improvement appears to be shown by off mode power (Figure 12) reduced by over 50% in 3 years to 2009 and 0.75 W (Switzerland and the

Republic of Korea). If these countries showed the same market shift in WoL enablement as the USA, then that could account for around 0.2 W[13] of the overall reduction of 0.75 W, meaning that off mode consumption had indeed decreased. The EU (IDC) data appears to show a slight rise from 2007 to 2008 (unexplained). Improvement in sleep mode appears to be levelling off for Switzerland, the Republic of Korea and EU at a level of just above 1 W (Figure 11). If US trends on WoL enablement are representative of other countries, then this has not significantly affected average sleep mode power.

The most important in terms of average annual consumption is idle mode and the recent trend appears to be significantly downward, with the robust EU (market research) data showing a drop of over 10% from 2007-2008 reaching 18 W; Swiss data implies a drop of over 50% in 3 years to 12 W in 2009 (Figure 10).

Note: Only idle mode power was normalised – sleep and off mode power were left as declared.

Figure 10. Normalised idle mode power for datasets representing whole market.

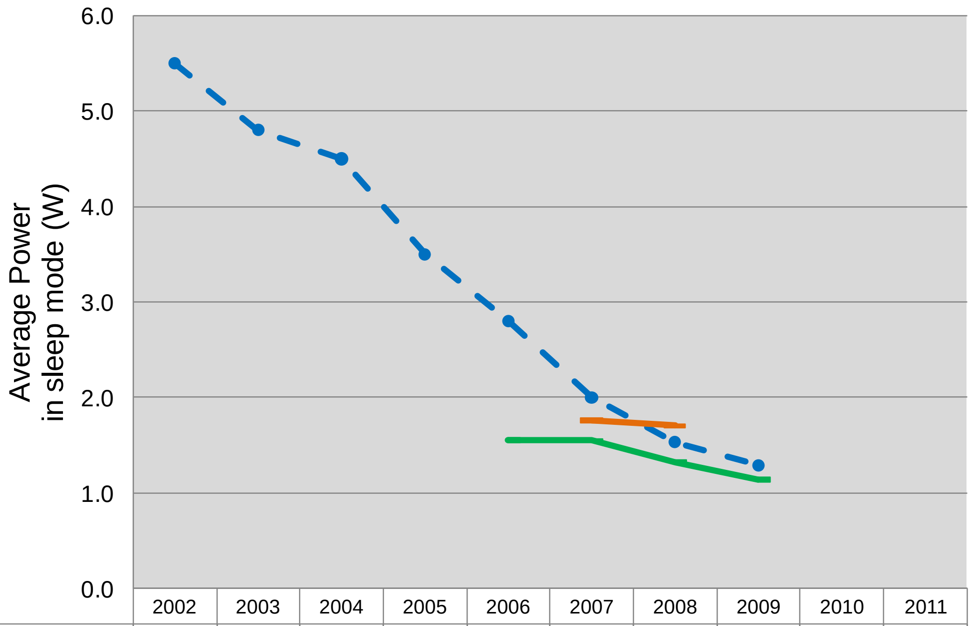


	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Republic Of Korea										
Switzerland	21.9	25.5	29.8	32.1	33.3	27.2	13.6	12.2		
EU whole market (IDC)						20.9	18.2			

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

[13] Assuming a market shift from 20% to 50% of the market for which sleep mode has reduced by 0.5W (assumed typical impact of disabling WoL) – effect on the average is assumed to be 30% x 0.5 W = 0.15 W.

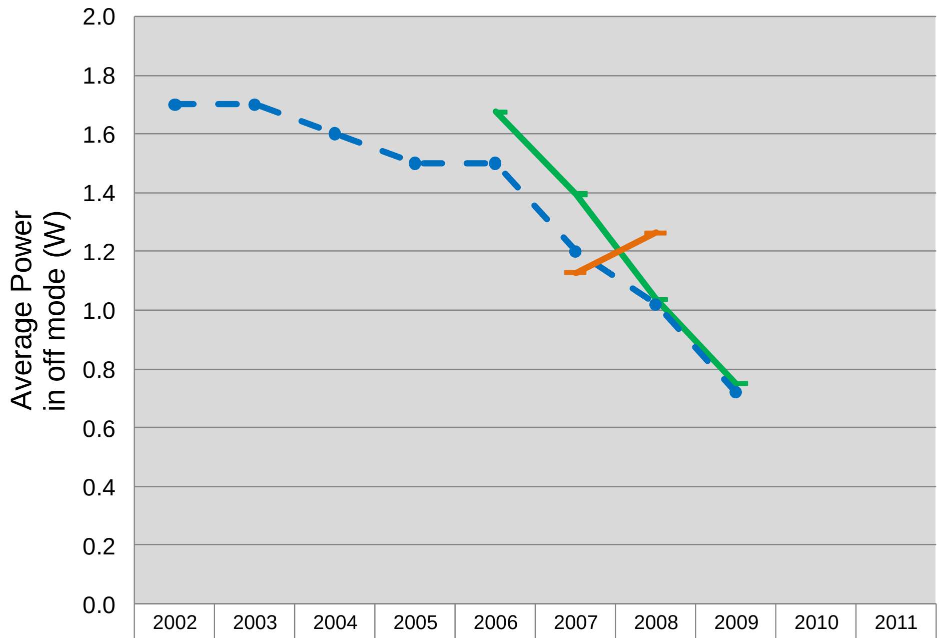
Figure 11. Declared sleep mode power for datasets representing whole market.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Republic Of Korea					1.55	1.55	1.32	1.14		
Switzerland (sales weighted)	5.50	4.80	4.50	3.50	2.80	2.00	1.53	1.29		
EU whole market (IDC)						1.76	1.70			

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 12. Declared off mode power for datasets representing whole market.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Republic Of Korea					1.67	1.39	1.04	0.75		
Switzerland (sales weighted)	1.70	1.70	1.60	1.50	1.50	1.20	1.02	0.72		
EU whole market (IDC)						1.13	1.26			

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

5.2 Partial market data

The graphs in this section are derived from partial market data: EU and US ENERGY STAR datasets: these represent the more efficient top half of the market in 2008, and three quarters of the market in 2009, but probably less than half the market in 2010 following the new Version 5.0 specification coming into force in July 2009. The data from Australia consists of a sample of popular mainstream products with a high proportion of ENERGY STAR compliant products specifically selected for testing.

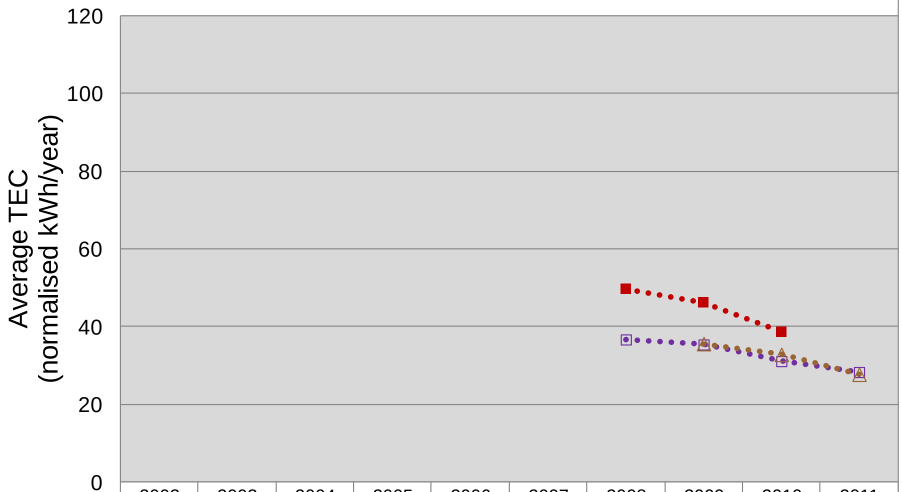
Note that 2011 ENERGY STAR data is only included for the first half of the year and so is not strictly comparable with previous data.

5.2.1 Annual consumption (TEC) for partial market data

5.2.1.1 All product types together

Annual consumption (TEC) data for EU and USA ENERGY STAR is almost identical and shows a fall of around 8% per year 2008 to 2011 – a fall of 23% in 3 years to reach 28 kWh/year in 2011, see Figure 13. The falling trend and approximate rate of change are seen also in the Australian data. Note that although the Australian data implies annual consumption around 20% higher than the EU/USA, this should not be considered valid because these datasets are not comparable, having such widely differing count of products included.

Figure 13. Normalised annual consumption (TEC) with data representing only partial market.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							49.7	46.2	38.6	
USA ENERGY STAR							36.7	35.4	31.1	28.3
EU ENERGY STAR								35.6	32.8	27.7

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

5.2.1.2 ENERGY STAR Categories A, B and C

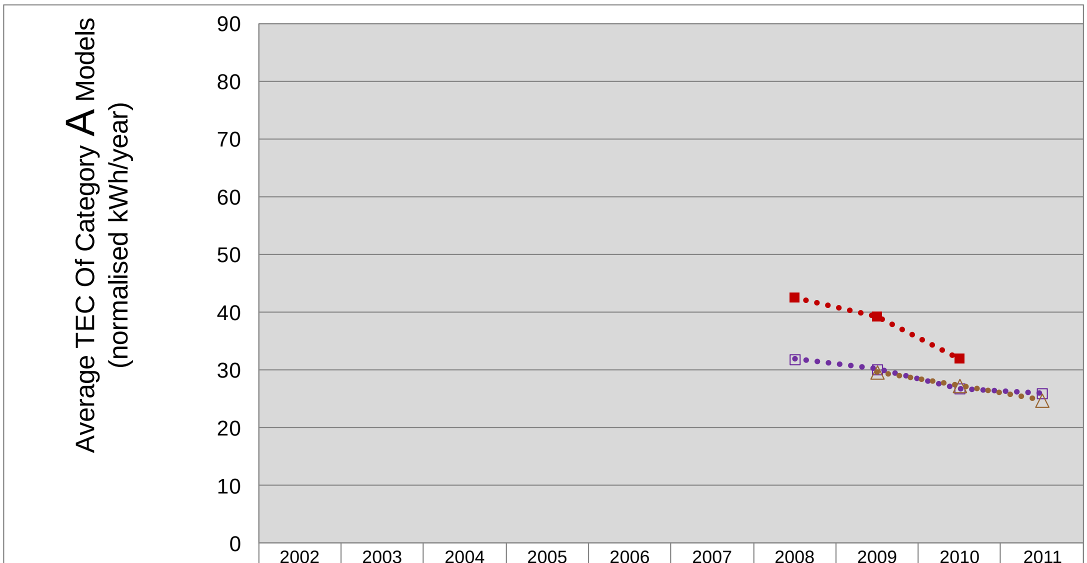
The next three Figures compare average annual consumption (TEC) for the three ENERGY STAR categories of notebook A, B and C (for an explanation of these 3 categories see section ENERGY STAR categories A, B, C on page 63).

Considering firstly the EU and USA data which coincides almost exactly: As might be expected from the rising computing capability inherent in categories A to B to C (Figure 14, Figure 15 and Figure 16) annual consumption in 2011 is 25 (category A); 30 (B); 62 (C) kWh/year. But each category is showing a consistent fall in average annual consumption over time: The falls total 20% (A), 33% (B) for 2008-2011 and 19% (C) for 2009-2011. Note that data was available on relatively few category C products (a few tens of products) compared to B and A (several hundred products), see Table 6.

Table 2 on page 35 summarises the relative performance and most recent improvement rates of the product categories. This table also includes EU whole market data derived from the IDC market report. This EU data should be viewed with caution as it was derived by the authors from the IDC report by implication of relative proportions of category A, B and C products in the market and other pointers.

The Australian data also shows a similar trend to the ENERGY STAR data - of the same magnitude although at a higher level. But this Australian data is not comparable due to the very large differences in product counts on which it is based.

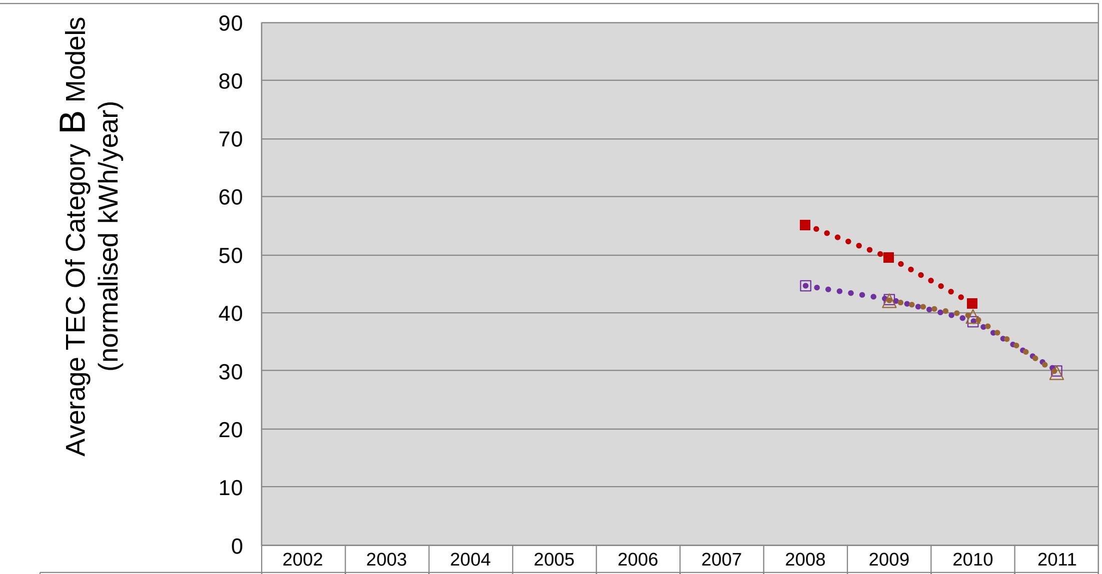
Figure 14. Normalised annual consumption (TEC) for only ENERGY STAR category A products (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							42.5	39.2	31.9	
USA ENERGY STAR							31.8	30.1	26.8	25.9
EU ENERGY STAR								29.6	27.3	24.7

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

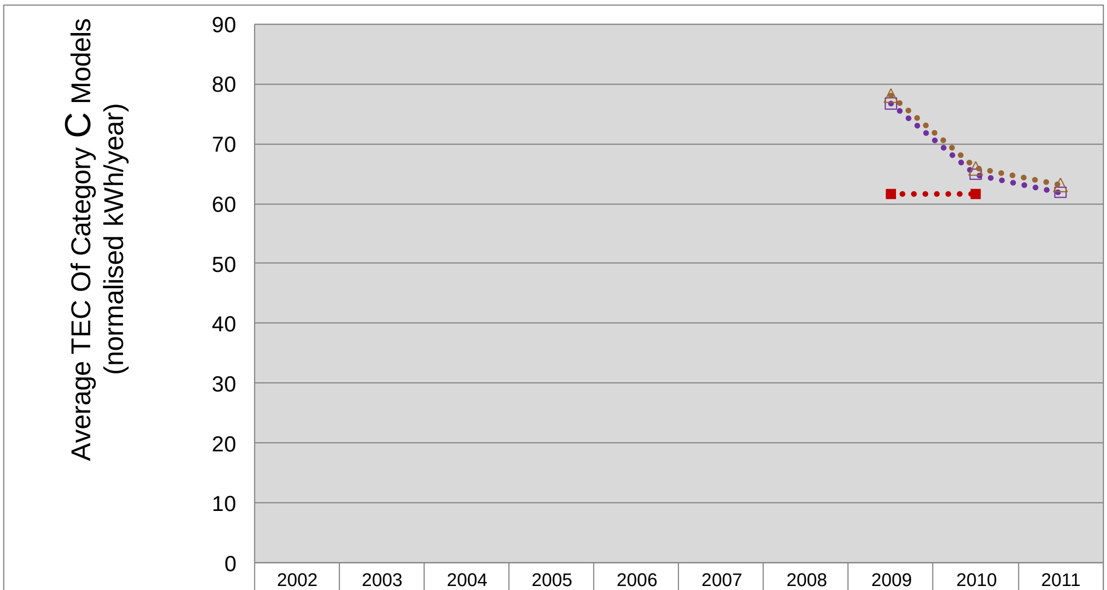
Figure 15. Normalised annual consumption (TEC) for only ENERGY STAR category B products (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							55.1	49.6	41.6	
USA ENERGY STAR							44.7	42.4	38.5	30.1
EU ENERGY STAR								42.2	39.5	29.8

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 16. Normalised annual consumption (TEC) for only ENERGY STAR category C products (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia								61.6	61.6	
USA ENERGY STAR								76.8	64.9	61.9
EU ENERGY STAR								78.1	65.9	63.2

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

5.2.1.3 Variation of TEC with screen size

As shown in Figure 17[14]:

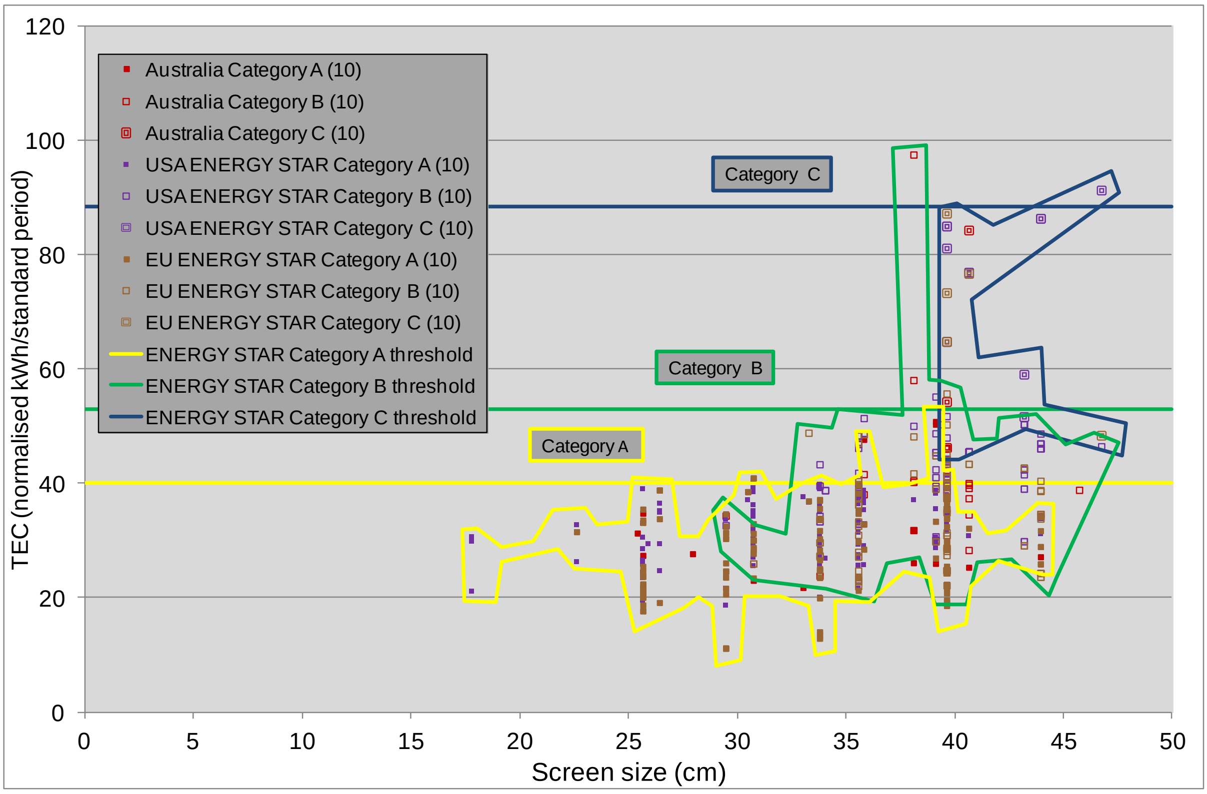
- ENERGY STAR category A notebooks have a wide range of screen sizes from 17 to 45 cm (6.7 to 17.7 inches) but a relatively narrow range of annual consumption compared to other categories of 15 kWh/year up to 40 kWh/year (to 50 kWh/year for Australian non-ENERGY STAR registered products).
- Category B notebooks do not generally have screens less than 30 cm (11.8 inches) in diagonal but extend to slightly larger than category A notebooks at up to 47 cm (18.5 inches). The range of annual consumption is 20 up to 60 kWh/year (with one high consuming exception).
- Category C notebooks only have fairly large screens, 40 to 50 cm diagonal (15.7 to 19.7 inches), and also significantly higher annual consumption ranging from 50 to over 90 kWh/year.

Note that screen size does not influence directly the TEC figure as the screen is off during test. This analysis is merely indicative of the type of product present in each category.

This scatter plot also illustrates that the datasets contain relatively few category C products. 2010 data is shown as this is the most recent full year data and the 2011 dataset contained few US products with screen size data. Note that the Australian products have been categorised according to ENERGY STAR definitions but do not necessarily comply with the ENERGY STAR energy requirements.

[14] Note that the data displayed on this scatter graph is from the 2010 ENERGY STAR (US and EU) databases as they contained more screen size data. The 2011 database for USA (which included 2010 registered products) contained little screen size data.

Figure 17. Annual consumption (TEC) versus screen size for products in ENERGY STAR categories A, B and C (partial market data).

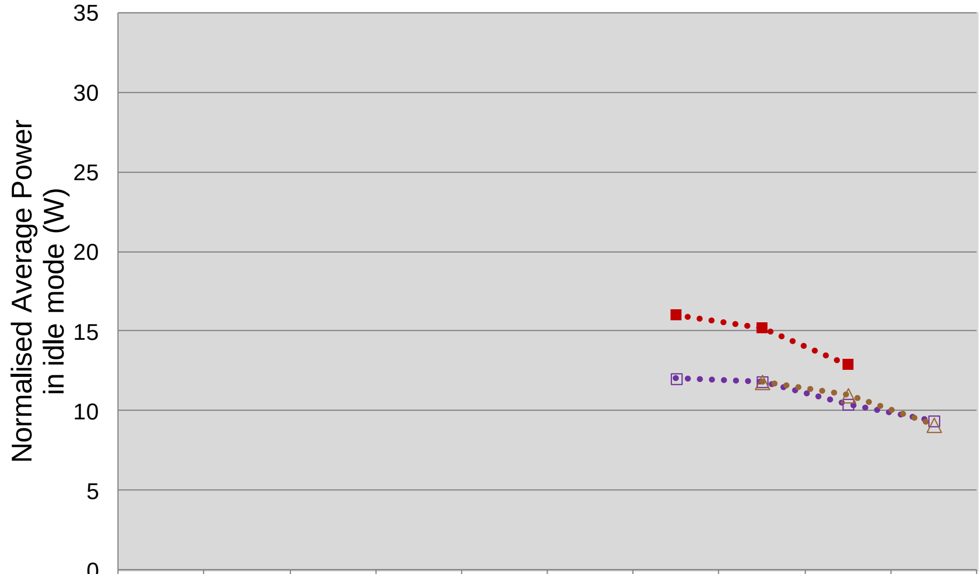


5.2.2 *Idle, sleep and off mode power for partial market data*

The trends evident for annual consumption (TEC) reflect the trends in idle mode, since idle power is the dominant factor in calculating TEC. Equally, the trends in power are similar in each mode and for each category of products. This section therefore only includes a selection of the possible permutations of graphs to illustrate the patterns seen.

Under the ENERGY STAR test procedure, all power modes are showing steady improvement year on year for this partial market data. Idle power has decreased by 22% over 3 years to 2010 for all product types (Figure 18) and by 33% to 10 W in 2011 for category B notebooks alone (Figure 19). Sleep mode has improved by around 20% 2009 to 2011 to reach just under 1 W (Figure 20) for these better performing (partial market set) notebooks. Off mode power has improved by a similar amount to reach 0.5 W in 2011 (Figure 21), although changes in WoL enablement rates (see Figure 8) could account for most of the 0.2 W improvement in off mode power. The Australian dataset shows similar or more rapid improvement but in most cases at a higher power and annual consumption than the EU/US ENERGY STAR average. Table 2 summarises the relative performance and most recent improvement rates of the product categories.

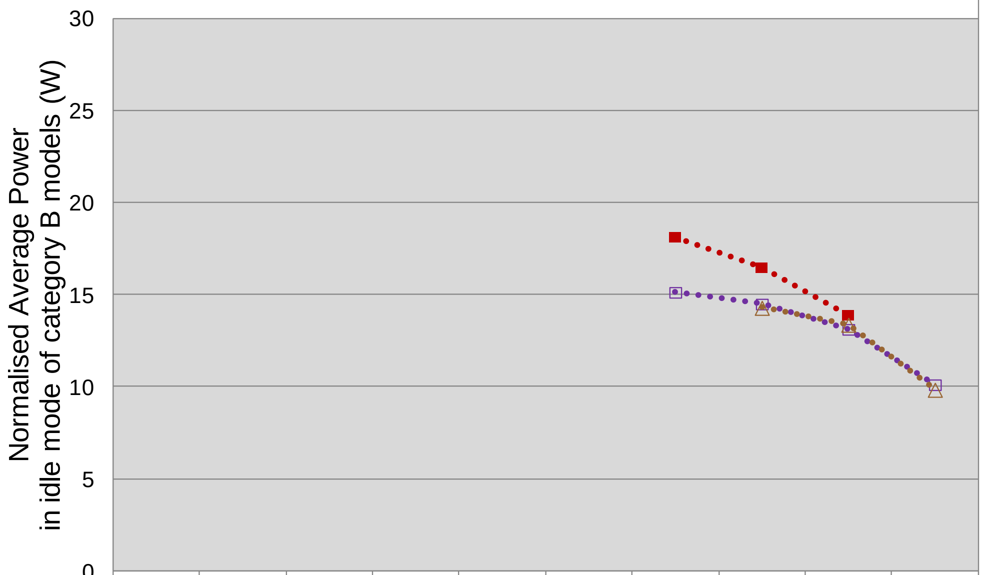
Figure 18. Normalised average power in idle mode for EU/US ENERGY STAR and Australia (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							16.0	15.2	12.9	
USA ENERGY STAR							12.0	11.8	10.4	9.4
EU ENERGY STAR								11.8	11.0	9.1

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

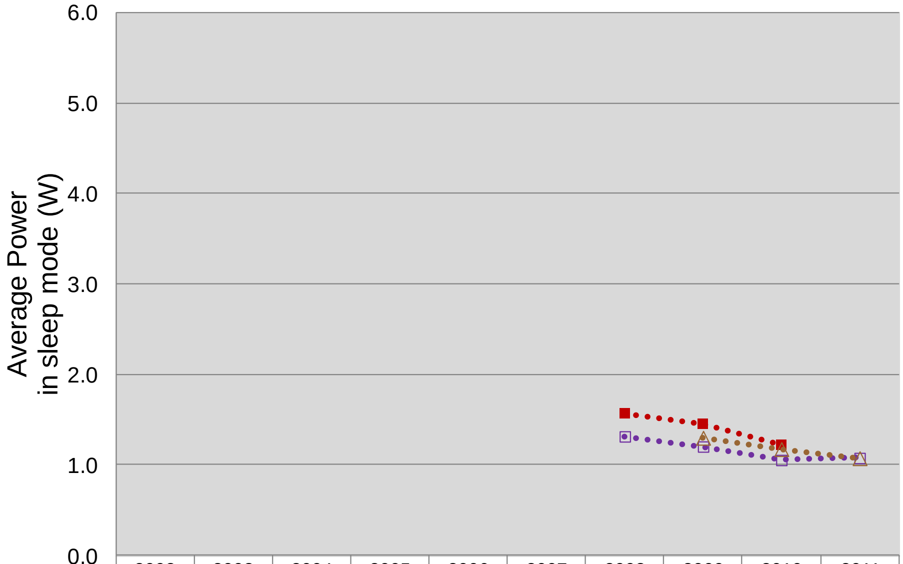
Figure 19. Normalised average power in idle mode for category B notebooks from EU/US ENERGY STAR and Australia (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							18.1	16.5	13.9	
USA ENERGY STAR							15.1	14.5	13.1	10.1
EU ENERGY STAR								14.3	13.4	9.8

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

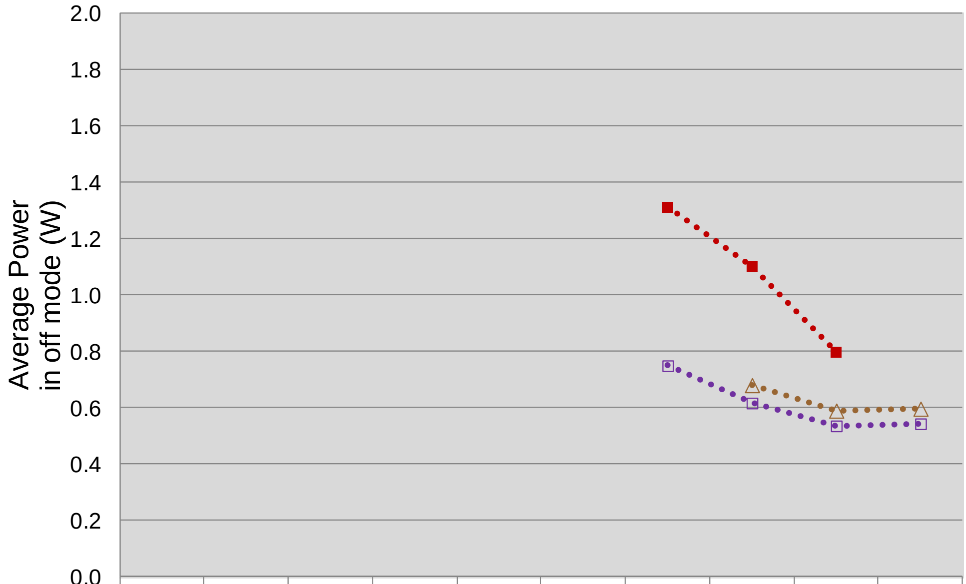
Figure 20. Declared average power in sleep mode for EU/US ENERGY STAR and Australia (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							1.6	1.5	1.2	
USA ENERGY STAR							1.3	1.2	1.1	1.1
EU ENERGY STAR								1.3	1.2	1.1

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 21. Declared average power in off mode for EU/US ENERGY STAR and Australia (partial market data).



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							1.3	1.1	0.8	
USA ENERGY STAR							0.7	0.6	0.5	0.5
EU ENERGY STAR								0.7	0.6	0.6

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Table 2. Summary of average TEC, sleep and off mode power, mostly by ENERGY STAR category, with annual improvement rates for the most recent year(s) for which data was available.

Aspect	ENERGY STAR Category	EU whole market (2008 and change 2007-2008)	EU ENERGY STAR (2011 and change 2010-2011)	US ENERGY STAR (2011 and change 2010-2011)
Range of TEC	A	-	15 to 40 kWh/year	
	B	-	20 to 55 kWh/year	
	C	-	40 to 90 kWh/year	
Average TEC (kWh/year)	A	*54*	24.7	25.9
	B	*58.5*	29.8	30.1
	C	-	63.2	61.9
Annual improvement rate for TEC (most recent)	A	8%	9%	3%
	B	6%	25%	22%
	C	-	4%	5%
Average Sleep (W)*	All	1.7	1.1	1.1
Annual improvement rate for sleep mode (most recent)	All	3%	9%	-2%
Average off mode (W)*	All	1.3	0.6	0.5
Annual improvement rate for off mode (most recent)	All	-12%	-1%	-1%

*Mixture of products with WoL enabled and WoL disabled.

Notes on Table 2:

i. A dash (-) denotes that no data was available to quantify.

ii. EU whole market data is 3 years older than ENERGY STAR (partial market) data.

iii. ENERGY STAR specifications include energy allowances for certain product features which mean a product may consume slightly above the basic performance threshold (e.g. due to additional RAM, graphics capability or disks).

iv. These EU whole market data for categories A and B separately was derived by the authors from the European Commission's market research report by implication of relative proportions of category A and B products in the market and other pointers. It should be seen as only illustrative quality. The whole market EU sleep and off mode data is robust.

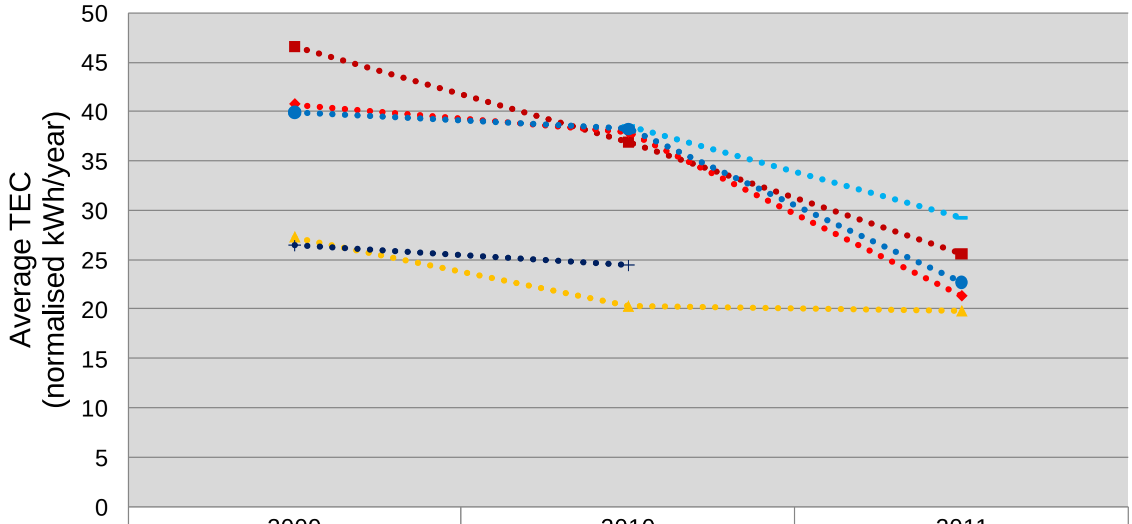
5.2.3 Are comparable products consuming less energy, year on year? For partial market data

This analysis aims to track how consumption of notebooks with highly comparable performance change year on year. The subsets into which data has been divided are described in section 3.5 *Summary of approach for energy performance analysis* and in more detail in Annex 4 *Low, average and high performance bands* on page 65.

Figure 22 shows how the average annual consumption (TEC) of notebooks in each of the high, average, and low computing capability subsets is reducing year on year for USA and EU ENERGY STAR products. This seems to confirm that comparable products are indeed consuming less energy year on year when tested according to the ENERGY STAR procedure, with 2011 products consuming less than two thirds the energy per year of comparable products from 2009. Notebooks from all 3 performance bands have converged into a range of between 20 and 30 kWh/year on average. This convergence implies that power management is succeeding in reducing consumption of most types of chip down to similar idle/sleep/off consumption levels. Differences in active mode consumption could well be diverging, but this is not exposed by the ENERGY STAR test methodology.

High-performance products have reduced average consumption by around 45% in 2 years (USA, 2009 to 2011) and by 24% in one year (EU, 2010 to 2011). Average performance products have reduced consumption by 47% (USA) and 43% (EU) in 2 years. Improvements in low performance products have been significantly less.

Figure 22. Average annual consumption (TEC) for notebooks of comparable computing capability, year on year. HPB = High performance band; APB = average performance band; LPB = low performance band. ENERGY STAR products only.



	2009	2010	2011
USA HPB	46.6	36.9	25.6
USA APB	40.7	37.9	21.4
USA LPB	27.3	20.3	19.8
EU HPB		38.5	29.2
EU APB	39.9	38.3	22.7
EU LPB	26.4	24.4	

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

5.2.4 Scope for improvement in TEC for partial market data

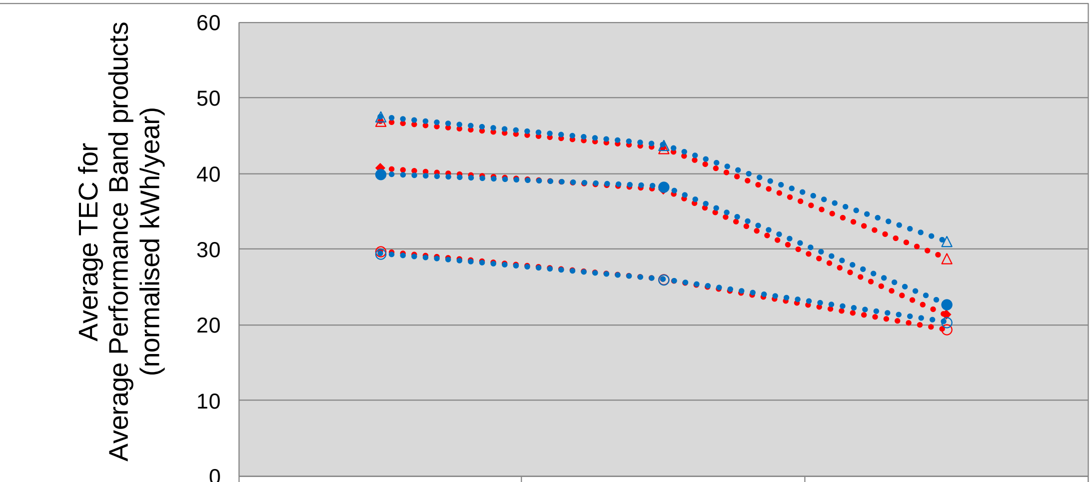
Figure 23 shows how the range of annual consumption in the average computing capability band (average performance band, or APB) has halved between 2009 and 2011 from ±10 kWh/year to ±5 kWh/year, combined with a reduction in consumption for best and worst[15] products. It appears that scope (room) for improvement is being taken up for this average performance level of product when tested according to the ENERGY STAR methodology.

A similar graph for high computing capability notebooks, Figure 24 shows less reduction in consumption, and slight divergence from 2009 to 2011. These products are probably more variable in their actual design (clock speeds, frame buffer widths etc) and power management set up than products in the average performance band, despite their key computing capability metrics (processor speed, RAM etc) being very similar to each other. This could account for the wider range of consumption.

A similar graph for low computing capability products, Figure 25, shows average consumption improving more slowly than for the high and average capability products. The range of best to worst is converging on an almost identical range of values as the average capability products (20 to 30 kWh per year); 2011 best products are nearly 50% worse than the best of preceding years. Possible reasons for this include more functionality, or worse efficiency in the lower capability products which raises their idle power demand and annual consumption.

[15] Note that in order to avoid distortion through outliers or erroneous product data, the graphs show figures for the worst performer of that dataset at the 95th percentile position, not the very worst in the whole dataset. Best performance is taken as the very best in the dataset.

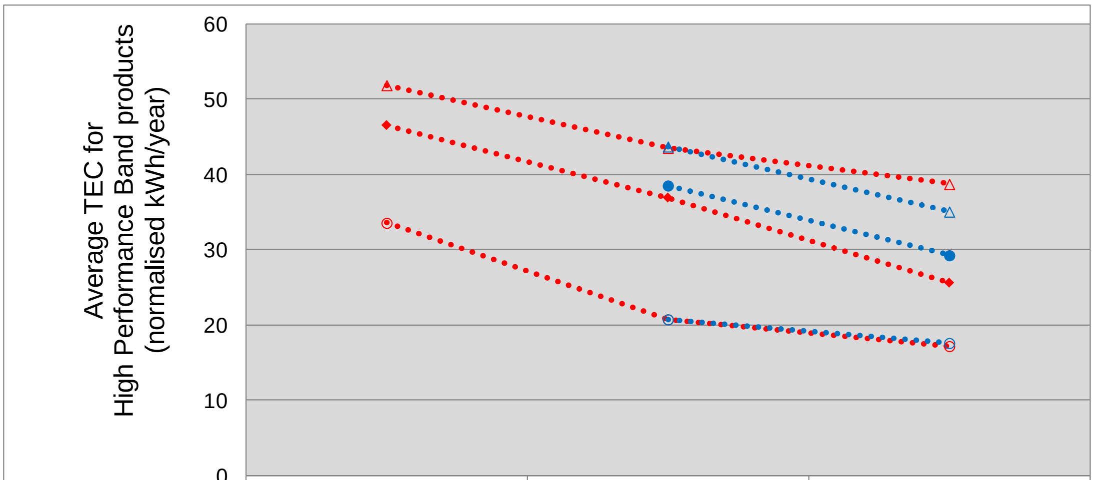
Figure 23. Best, average and worst annual consumption (TEC) for notebooks in the average performance band (APB), US and EU ENERGY STAR data only.



	2009	2010	2011
Best USA APB	29.7	26.0	19.4
Average USA APB	40.7	37.9	21.4
Worst USA APB	47.0	43.4	28.8
Best EU APB	29.4	26.0	20.3
Average EU APB	39.9	38.3	22.7
Worst EU APB	47.6	43.8	31.1

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

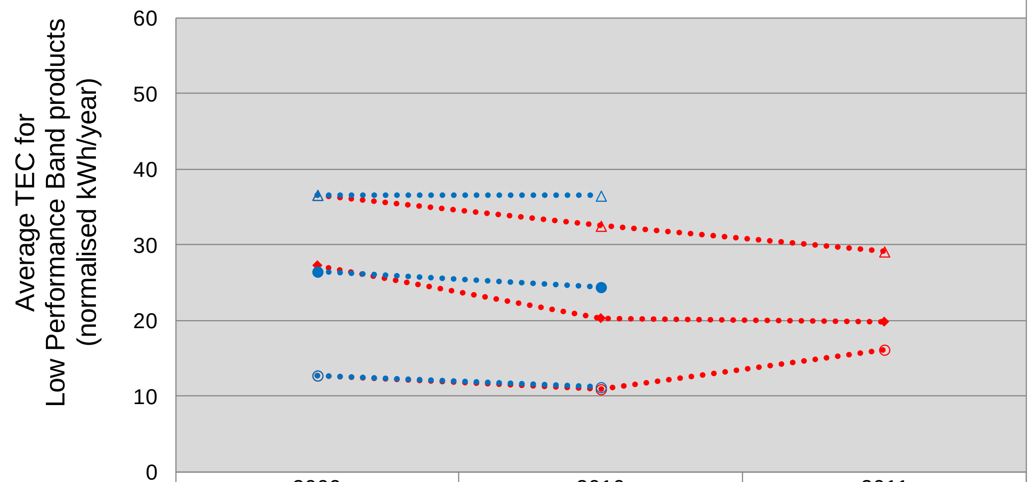
Figure 24. Best, average and worst annual consumption (TEC) for notebooks in the high performance band (HPB), US and EU ENERGY STAR data only.



	2009	2010	2011
Best USA HPB	33.6	20.7	17.2
Average USA HPB	46.6	36.9	25.6
Worst USA HPB	51.9	43.5	38.7
Best EU HPB		20.7	17.6
Average EU HPB		38.5	29.2
Worst EU HPB		43.7	35.0

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 25. Best, average and worst annual consumption (TEC) for notebooks in the low performance band (LPB), US and EU ENERGY STAR data only.



	2009	2010	2011
Best USA LPB	12.7	10.9	16.1
Average USA LPB	27.3	20.3	19.8
Worst USA LPB	36.6	32.5	29.1
Best EU LPB	12.7	11.2	
Average EU LPB	26.4	24.4	
Worst EU LPB	36.6	36.5	

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

5.2.5 Analysis by brand for partial market data

The selection of brands to show on graphs and the rationale for focus on category B products only is explained in the section *Analysis by brand* on page 68. These results should be treated with extreme caution due to several reasons, for example:

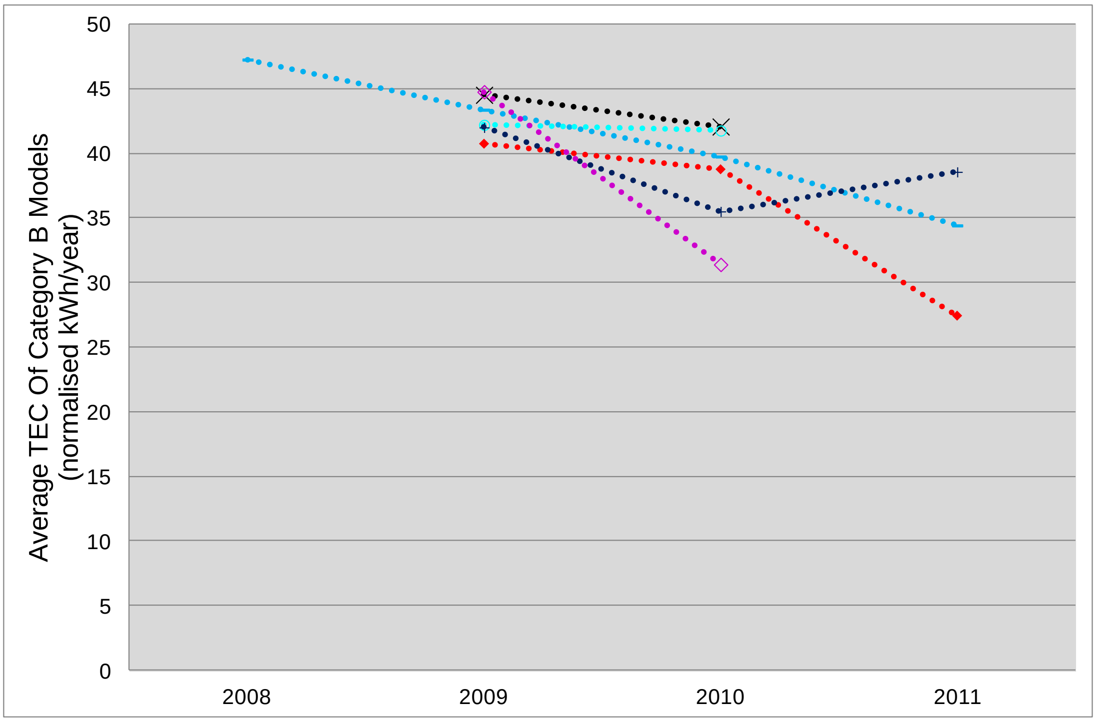
- It appears that some brands with less reduction in consumption have raised the average system memory (gigabytes of RAM) over the same period.
- Whilst all averages derived from fewer than 10 products have been omitted from the graph, brands have different representation in each year and different counts of products analysed ranging from 13 to 87. Comparability is thus not robust.
- There may be other changes in specification or product range that have not been detected in this analysis that could explain changes in average consumption.

For these and further cautions, see the section *Known limitations and weaknesses in the division of products by brand:* on page 71.

Figure 26 shows the average consumption by brand and the range of improvement achieved by each between 2008 and 2011. Note that 2011 data covers only half of the year, and so most analysis is focused on the two complete years of data 2009 to 2010. The following observations can be made:

- All brands appear to be reducing average annual consumption for category B products, with an average improvement of just over 10% 2009-2010.
- The best performing brand in 2010 (the most recent full year data) has annual consumption just under 30% lower than the worst; the best has annual consumption almost 20% lower than the average.
- Some brands appear to be reducing annual consumption faster and further than others: one brand achieved a 30% cut in average consumption 2009 to 2010 and in so doing leapt from the worst to the best of these six brands.
- One brand made only 1% improvement 2009-2010.

Figure 26. Average annual consumption (TEC) for products in ENERGY STAR category B for 6 global brands of product. Each line represents a different brand.

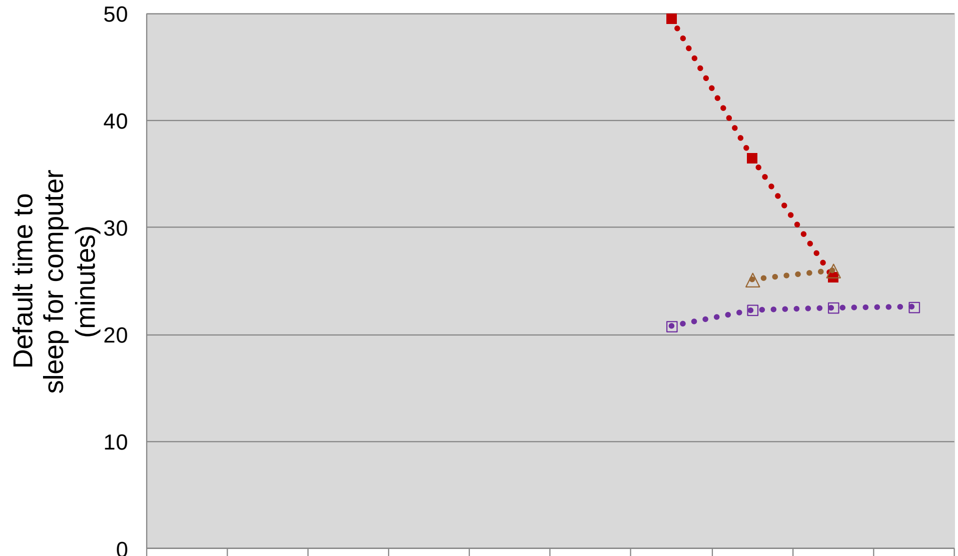


5.2.6 Default time to sleep for partial market data

Figure 27 shows how the average default time before the computer goes into sleep mode is preset at around 25 minutes for both EU and USA. Figure 28 shows similar data for the screen (time to sleep) with values between 10 and 15 min. The values for EU and USA appear relatively static over time. The data for Australia is based on a relatively small sample of products and should be treated with caution.

Whole market data was only available for the Republic of Korea on the average default time before the computer goes into sleep mode, which stayed at 22 minutes between 2006 and 2009.

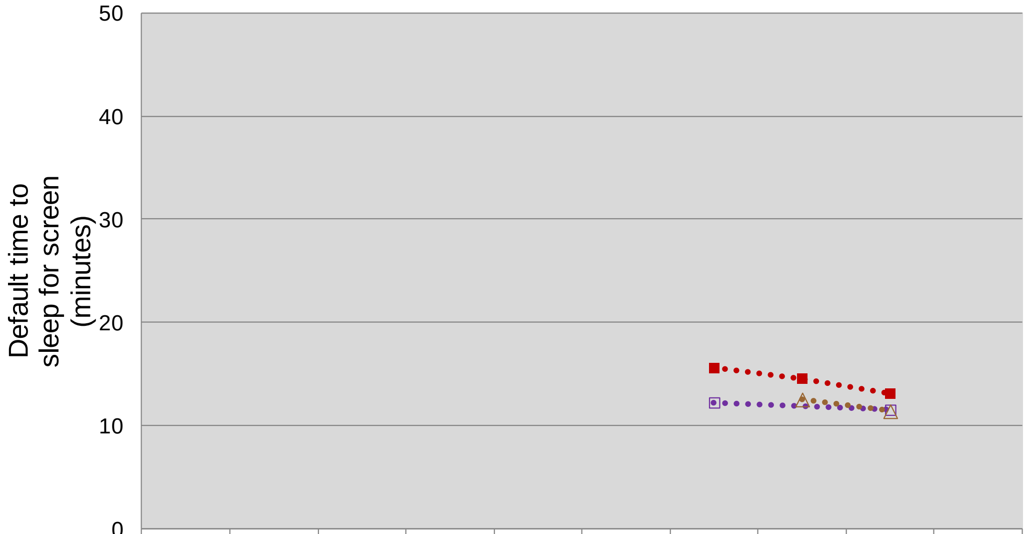
Figure 27. Average default time after which the computer is preset to go to sleep, showing partial market datasets only.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							50	36	25	
USA ENERGY STAR							21	22	23	23
EU ENERGY STAR								25	26	

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 28. Average default time after which the screen is preset to go to sleep, showing partial market datasets only.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Australia							16	15	13	
USA ENERGY STAR							12		12	
EU ENERGY STAR								13	11	

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

6 Stock of products and consumption

Australia, Switzerland and the Republic of Korea provided data on stock which is presented in Figure 29. The 3 countries for which data is available show significantly different ownership levels per head of population but the rate of growth of stock appeared to follow a similar pattern of doubling in 4 to 5 years between 2005 and 2011. This data does not appear to show any signs of saturation being reached.

Australia and Switzerland provided data on national consumption of notebooks, as shown in Figure 30. This has been quoted exactly as reported by the national government and is not based on a calculation using ENERGY STAR TEC values.

Figure 29. Installed stock of notebooks in each country, and number of notebooks per head of population expressed as a percentage.

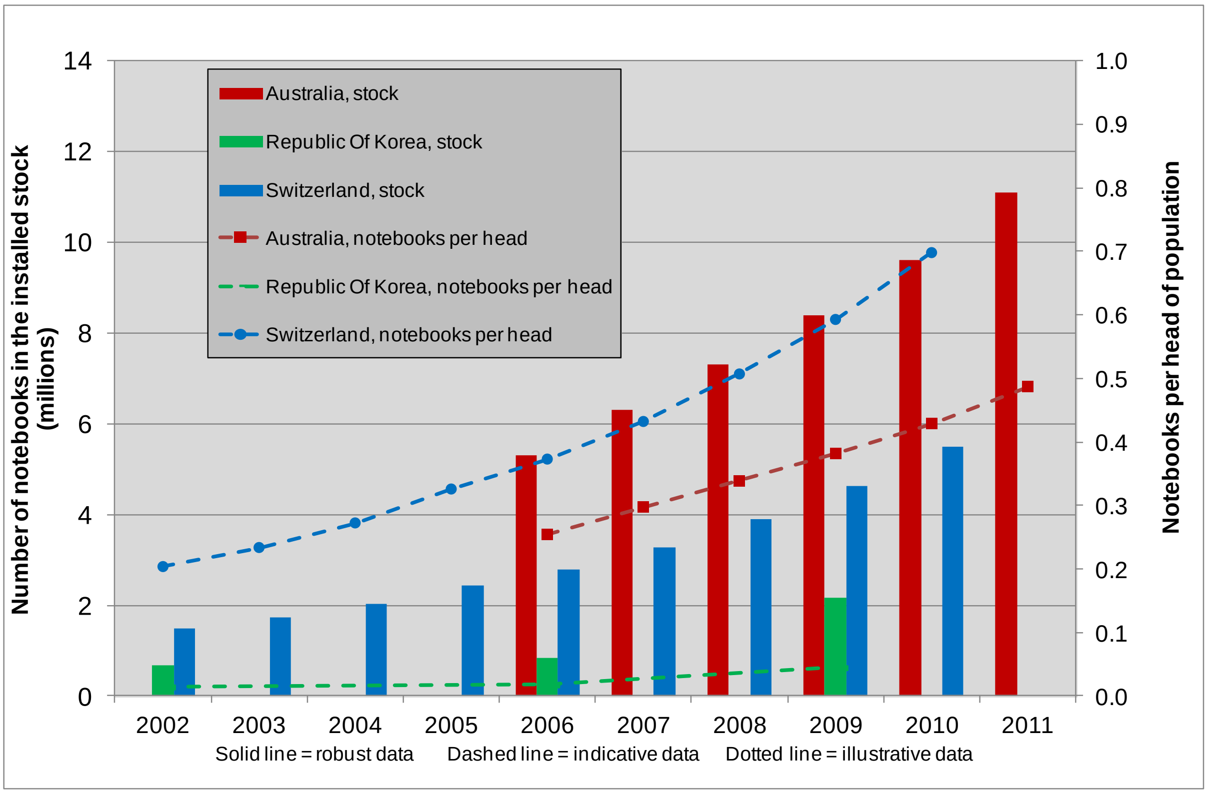
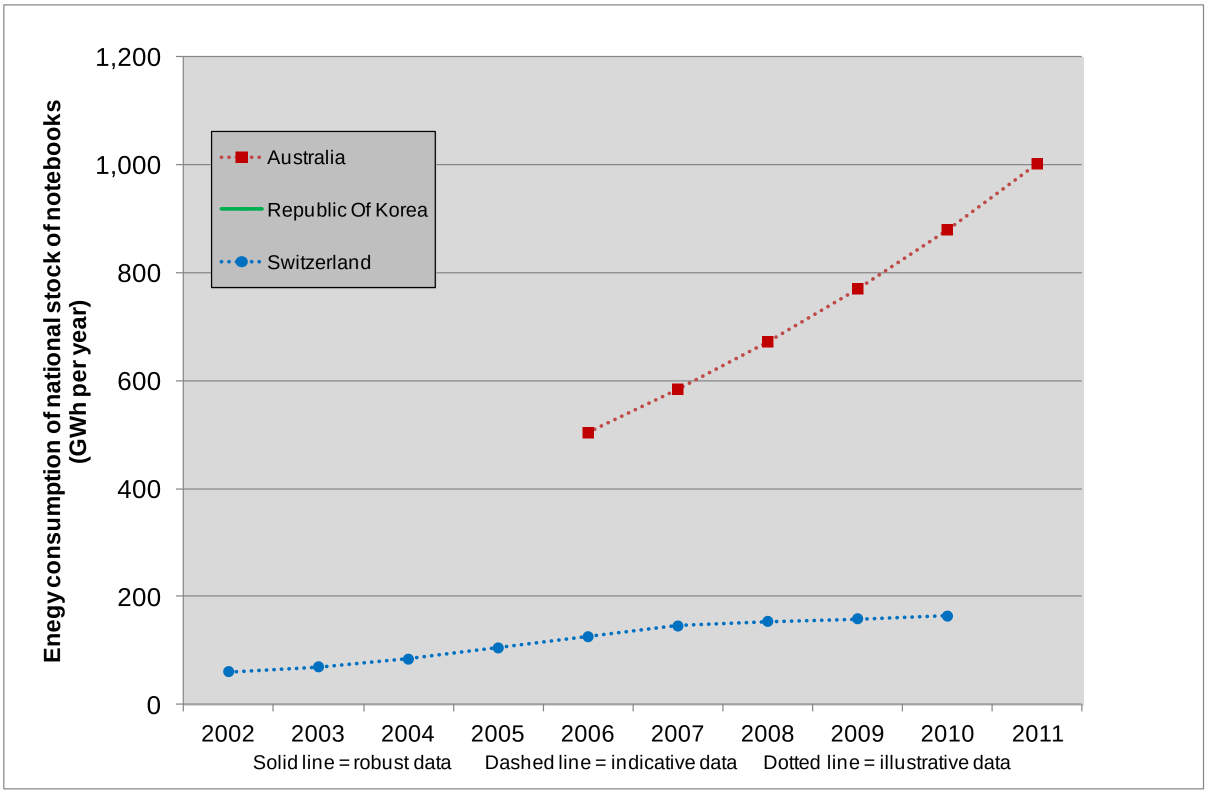


Figure 30. Consumption of national stock of notebooks for Australia and Switzerland.



7 Best in class products

The intention of this analysis was to establish benchmark performance levels for the lowest annual consumption (TEC) in each ENERGY STAR category (A, B, C) that had been validated by confirming the same energy data as quoted on a manufacturer's data sheet (or other reliable source, e.g. Topten type site[16]) for products that are currently available for sale. The process, as used for several products under Mapping and Benchmarking analysis, is described in Annex 3 on page 59.

However, representative performance levels could not be adequately verified. This was because:

a) Energy performance data is not directly accessible from most suppliers[17]: Apple, Dell and HP did have data on some models, but even for these there were some models which were still for sale for which no data was available; no energy data was found for 16 other brands. This absence was not due to rapid product churn (i.e. removal of data for older products) since similar levels of absence were found for best products in an ENERGY STAR database downloaded on the day of the research (rather than that from July 2011 used in the main analysis).

b) Model numbers are complex making it sometimes impossible to know for sure if the registered model coincides with the data sheet found on the manufacturer's site. Also some models appear to have multiple entries – it is not clear if these are sub-models or if they are models with the same number but different release dates.

c) Some updated products appeared to retain the same model numbers, further reducing confidence in declared data. In some cases the replacement product appeared to have lower TEC than the predecessor, in some cases significantly higher.

d) For five products, the data from the manufacturer showed a TEC of between 5% and 43% higher than that quoted in the ENERGY STAR database (It is possible that the product specification had been updated since submission to the ENERGY STAR scheme).

e) Even the ENERGY STAR database downloaded fresh at the time of this research contained many out-of-date products – including that ranked as the most efficient one which appeared to be no longer available, judging from the manufacturer's web site.

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16 www.topten.info.

17 Data on energy performance was searched for on the manufacturers' sites and via Internet search engines. Data were found for some models from three manufacturers in this way. On receipt of guidance from an ICT expert, information for some models of a further 5 manufacturers were found on their web sites. However, this data would not be obvious to a consumer - it was not found by search engines or referenced from the manufacturer's web page of the model giving the normal specification.

For category A, the first three products verifiable from any third party source were ranked 3rd, 5th and 79th in the set. For category B, the first three were ranked 683rd, 714th and 949th. For category C the first three were ranked 8th, 15th and 76th. Thus the verified products were (except for category A) far from the best; the best according to the ENERGY STAR database remained un-verified. It was not, therefore, deemed meaningful to report these results in this report.

Experience in this research implies that manufacturers make energy data available for the ENERGY STAR database, but few provide much (if any) direct to consumers. And furthermore it implies that consumers seeking to identify a highly efficient notebook computer may have to check through many ENERGY STAR listed products before finding one that is still available on the market.

8 Policies

The policies in place in the participating countries are summarised in Table 3, with the timeline of ENERGY STAR specification versions summarised in Table 4.

In the Republic of Korea, products with standby power over 1 W carry a mandatory warning label. Products carrying the standby warning label accounted for 40% of sales amongst the 20 included product categories in 2008, but this fell to only 1.4% by 2010[18]. Only 0.3% of computer sales in the Republic of Korea fail to meet the 1 W requirement. The horizontal standby regulation in the EU places minimum requirements on off mode for computers but does not cover sleep mode. The EU also has a regulation restricting the efficiency and no-load power for external power supplies.

In addition, the USA, EU and Australia have mandatory minimum procurement standards for government purchases aligned with ENERGY STAR specification[19].

Several countries also operate voluntary labelling or rating schemes that cover the wider environmental impacts of computing products. The most prominent of those is probably the EPEAT scheme[20] which registers products in 41 countries around the world. The EPEAT specification is derived from the IEEE 1680.1 standard and reflects several categories of environmental attributes that cover the full lifecycle of electronic products. Products earn bronze, silver or gold levels depending upon how many of the optional extra specifications are met, over and above the mandatory minimum. The IEEE 1680.1 PC and Display standard addresses:

- Reduction/elimination of environmentally sensitive materials;
- Material selection;
- Design for end of life;
- Product longevity/life extension;
- Energy conservation (requires compliance with ENERGY STAR specification);
- End-of-life management;
- Corporate performance;
- Packaging.

[18] Source: Korea's Energy Standards and Labelling – Market Transformation, Performance Improvements during the First 19 years and a Vision for the Future, Ministry of Knowledge Economy and Korea Energy Management Corporation, 2010, page 60.
[19] Applies to central government only in EU; in US a certain percentage of purchases have to be ENERGY STAR compliant.
[20] http://www.epeat.net/. The name is derived from Electronic Product Environmental Assessment Tool.

Table 3. Summary of policies for notebooks amongst participating countries.

Country/ region	MEPS regulation	Label regulation	Outline label requirement
Australia	None. (Consultation held for possible MEPS based on ENERGY STAR Version 5.2 plus functional adders[21]; no decision taken at November 2011)	ENERGY STAR voluntary label - same criteria as USA but with 12 month lag.	Maximum limits for Typical Energy Consumption over a year.
EU	None specific for computers (draft measure is under discussion in 2011/2012 based on ENERGY STAR, plus functional adders). Computers are covered by a horizontal regulation for standby covering off mode[22] of 1 W (2010) and 0.5 W (2013). Also for external power supplies[23] with requirements for efficiency and no-load power.	ENERGY STAR voluntary label - same criteria as USA. Version 6 under development, likely in 2012.	Maximum limits for Typical Energy Consumption over a year.
Republic of Korea	None	Mandatory standby label if threshold not met; voluntary label if met.	Thresholds for standby power are published for both labels.
Switzerland	None	ENERGY STAR voluntary label - same criteria as USA.	Maximum limits for Typical Energy Consumption over a year.
USA – federal	None	ENERGY STAR voluntary label, Version 5. Version 6 under development, likely in 2012.	Maximum limits for Typical Energy Consumption over a year; 3rd party testing since Jan 2011.

[21] A 'functional adder' is an allowance (for example in extra Watts power consumption over and above the basic criteria requirement) made for products that incorporate certain features or capabilities. A product may qualify for none, one or several adders for different reasons and so some may consume a stipulated total number of Watts above the basic criteria but still qualify for the ENERGY STAR label.

[22] COMMISSION REGULATION (EC) No 1275/2008 of 17 December 2008, Ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment. The requirements on standby for computers in this regulation are likely to be superseded by the specific regulation for eco-design of computers expected during 2012/2013.

[23] COMMISSION REGULATION (EC) No 278/2009 of April 2009: Eco-design requirements for no-load condition electric power consumption and average active efficiency of external power supplies.

Table 4. Timeline of the development of ENERGY STAR specifications.

Specification version	Effective date	Expired date	Key Requirements (outline only – see full specification for details)
Version 1.0	June 92	Sept 95	**No requirements for notebooks.** A desktop in sleep mode must use <30 W; Integrated systems must use <60 W. Specified that a computer must go to 'sleep' after a period of time or through user enabling.
Version 2.0	October 95	June 99	**No requirements for notebooks.** A desktop in sleep mode must use <30 W; Integrated systems must use <60 W. Power management must send the computer into sleep mode after 15 to 30 minutes. Include wording about sleep mode. Must be able to send monitor into sleep mode.
Version 3.0 – Tier 1	July 99	July 00	**No requirements for notebooks.** A desktop with a power supply rating <200 W must use <30 W in sleep mode; power supply rating >200 W must use no more than 15% of the power supply rated value in sleep mode. Integrated computer systems must use <45 W in sleep mode. Must have the ability to sleep when connected to a network.
Version 3.0 – Tier 2	July 2000	July 2007	**No requirements for notebooks.** Standalone desktop (not for network) with a power supply rating <200 W must use <15 W in sleep mode, plus rising requirements for higher power supply ratings. Computers for networks cannot consume more than 15% of their power supply rated output power when in sleep mode. Integrated computer systems must use <35 W in sleep mode.
Version 4.0	July 2007	July 2009	Notebook PCs covered for first time, with division into Categories A and B (plus C for desktops). Basic requirements for notebooks[24]: Off mode <1.0 W; Sleep <1.7 W; Idle Cat A <14 W, Cat B <22 W; WoL allowance of 0.7 W for sleep/off; plus power management requirements.
Version 5.0	July 2009	Superseded by Version 5.2 in US only	Introduced two TEC calculations for 'conventional' and 'proxying' modes. Basic requirements for notebooks in 'conventional' mode[25]: TEC Cat A<40 kWh/year; Cat B <53; Cat C <88.5. Allowances for memory, GPU and storage, plus power management requirements.
Version 5.2 (US only)	July 2009	Not yet expired	Basic requirements for notebooks[26]: No change to 'conventional' mode from Version 5.0; replacement of 'proxying' mode TEC for various 'networked' modes; presentational changes (plus technical changes for other products).
Version 6.0	To be announced		(In consultation during 2011/2012[27]).

[24] For full specification see http://www.energystar.gov/index.cfm?c=archives.computer_spec_version_4_0
[25] For full specification see http://www.energystar.gov/index.cfm?c=archives.computer_spec_version_5_0
[26] For full specification see http://www.energystar.gov/index.cfm?c=archives.computer_spec_version_5_0
[27] For development process see http://www.energystar.gov/index.cfm?c=revisions.computer_spec

9 Conclusions

Important caution: *The majority of data analysed is from EU and US ENERGY STAR programmes, which consist of only better products, and also only a half year dataset for 2011. The US ENERGY STAR* product *data accounted for 50% (2008) and 75% (2009) of US sales; EU ENERGY STAR data accounted for 46% (2010) of the EU27 market.*

9.1 TEC, idle, sleep and off mode power

Whole market sales weighted data implies an average TEC of 55 kWh/year for the EU (2008) and 36 kWh/year for Switzerland (2009) with both showing a decreasing (i.e. improving) trend of around 10% per year. Idle mode power almost directly reflects the TEC trend, with average idle mode power 12 W for Switzerland (2009) and 18 W for the EU (2008). Average off mode power has shown the most significant proportional improvement having dropped by over 50% in 3 years to 0.7 W by 2009 for Switzerland and the Republic of Korea, but remaining just above 1 W for the EU in 2008. The EU standby regulation came into force in 2010 which should ensure EU average off mode of below 1 W. Improvement in sleep mode power has slowed, with the average just above 1 W for Switzerland and the Republic of Korea (2009) and 1.7 W for the EU (2008). If whole market trends follow those seen in the US ENERGY STAR data (see Figure 8 on page 23) then market changes in Wake-on-LAN (WoL) enablement rates could explain most of the average off mode improvement, but not the sleep mode improvement.

Product-weighted partial market data (ENERGY STAR better products and Australian sample testing) shows a fall in TEC averaging 8% per year 2008 to 2011, totalling 23% over 3 years to reach 28 kWh/year in 2011. Idle mode has improved at the same rate as TEC to reach an all product average of just over 9 W in 2011. Sleep mode averages 1.1 W in 2011[28] which the US products reached in 2010, a year before EU products. Off mode averages less than 0.6 W for EU and US ENERGY STAR and was effectively level 2010 to 2011. The sleep/off figures may increase again due to added networking functionality. (See Table 2 on page 35).

[28] The sleep mode figure includes a mix of products with Wake-on-LAN (WoL) enabled and disabled.

9.2 ENERGY STAR data

EU and US ENERGY STAR data shows almost identical average performance. ENERGY STAR average TEC was just over 30% better than the whole market average in 2008[29]. Just over half of the ENERGY STAR market has been category A (lower specification notebooks) and just under half B (mid-specification notebooks); very few category C (high specification) notebooks meet the relevant ENERGY STAR specification.

Whilst all categories appear to be improving at significant rates, category B in US/EU ENERGY STAR has shown very large performance improvements of over 20% to 2011.

Unfortunately no contemporary data (2010-2011) was available for EU whole market, but the 2007-2008 EU whole market data showed only a 6% improvement in average TEC for category B. This could be due to lower rates of improvement at that time, poorer power management, different WoL enablement rates being prevalent, or due to the poorer performing products (which are excluded from ENERGY STAR) dragging down the improvement rate.

9.3 Notebooks of similar specification over time

Comparable products are consuming less energy year on year for consumption measured according to the ENERGY STAR test methodology, with 2011 products consuming less than two thirds the energy per year of comparable products from 2009. Note that this may not accurately reflect actual usage in homes/offices.

High-capability and average-capability products have reduced average consumption by over 20% per recent year. Improvements in low capability products have been slower at around 10% per recent year.

There is also a convergence of consumption for products in each of these capability bands into very similar ranges of best to worst. The average and low capability notebooks of 2011 have an almost identical range of annual consumption (20 to 30 kWh per year), and high capability notebooks extend from 17 to 38 kWh per year.

9.4 Energy performance of brands

The results of analysis by brand should be treated with extreme caution for several reasons. For example, brands have different representation in each year and different counts of products analysed, and there are some known changes in specification or product range over time that could contribute to differences in average consumption, plus other changes in

[29] Ratio calculated for 2008, the most recent year with data in common assuming that EU and US ENERGY STAR averages were as similar in 2008 as they were in 2009 to 2011 (no EU ENERGY STAR data were available for comparison with the 2008 EU whole market average).

product line-up that are not known. However, data implies the following cautious observations about 2009 to 2010 data:

- All brands appear to be reducing average annual consumption for category B products, with an average improvement of just over 10% 2009-2010.
- The best performing brand has annual consumption just under 30% lower than the worst; the best has annual consumption almost 20% lower than the average.
- Some brands appear to be reducing annual consumption faster and further than others: one brand achieved a 30% cut in average consumption 2009-2010 and in so doing leapt from the worst to the best of these six brands.
- One brand made only 1% improvement 2009-2010.

9.5 Scope for improvement

The spread of performance data between best to worst annual consumption across all notebooks, and even across notebooks within ENERGY STAR categories (A, B and C) is largely explained by differences in their computing capability, rather than their efficiency. However, the best to worst range of annual consumption of notebooks with average computing capability has halved between 2009 and 2011, with an associated drop in the level of consumption as noted earlier. This could imply that the easily accessible savings have largely been taken up for average capability products, with little remaining headroom. The scope for improvement of low computing capability notebooks appears similarly constrained to an identical range.

Similar analysis for high capability notebooks shows slight divergence in best to worst from 2009 to 2011, probably as these are more variable in their actual design than products in the average performance band. This implies that there remains scope for improvement in the higher computing capability products.

9.6 Policies

The ENERGY STAR voluntary labelling scheme for higher efficiency products provides the primary global test methodology for energy consumption and framework for performance improvement. The market (mostly) moves rapidly to meet the ENERGY STAR specification soon after its release.

Policy focus on standby/off mode in USA, Canada, Republic of Korea and EU may have helped to drive improvement in these aspects of performance.

EU and Australian MEPS measures being drafted are likely to be based upon ENERGY STAR Version 5 levels (5.2 in the case of Australia) with additional allowances to account for wider specifications not always accounted for under the ENERGY STAR scheme. No other MEPS are in place across participating countries.

9.7 Key issues for policy makers

The following issues have been identified from the foregoing analysis that may be of particular interest to policy makers:

i. Overall average and category average annual consumption (TEC), as measured under the ENERGY STAR test methodology, has improved fairly consistently and significantly year on year. However, this may not accurately reflect actual consumption in homes and offices. Improvement is not step-wise with ENERGY STAR specification, perhaps being driven largely by the need for good battery life and other technological changes such as optional power management of discrete GPUs.

ii. ENERGY STAR average TEC appeared some 30% better than the whole market average for the EU in 2008 (most recent year for which data is available).

iii. EU and USA ENERGY STAR performance levels appear very similar, as do the available trends and performance levels of Australia, Switzerland and the Republic of Korea. This implies that the market for notebooks is fairly uniform over major economies; a view supported by market experts.

iv. The wide spread of performance ('best' to 'worst') overall and within each ENERGY STAR category reflects differing functionality and not necessarily differing efficiency.

v. However, three bands of products were analysed in isolation, where each band contained only products with very similar levels of computing capability (low, average and high levels). This analysis showed significant reduction in average annual consumption was achieved within each band from 2008 to 2011, particularly in the high and average computing capability bands.

vi. Consumption levels for these bands of similar products have also converged – such that typical products with low, average and high computing capability have a very similar range of consumption (low and average bands have identical ranges). This convergence may merit further investigation in the context of whether it remains justified to separate ENERGY STAR categories A and B, and perhaps C.

vii. It should be borne in mind that TEC does not necessarily reflect actual annual consumption in both homes and offices. The standard TEC calculation (annual usage profile) is based only upon office based operation[30] and so does not take account of high active mode usage such as gaming, audio and video etc becoming more common in homes, nor does it include screen energy consumption.

[30] Implied by standard ECMA 383 Measuring the Energy Consumption of Personal Computing Products, 3rd Edition, December 2010 p21.

viii. A significant revision to the ENERGY STAR test methodology is under way for V6 which could usefully find more effective ways to differentiate performance in line with most likely consumption in real use. Unfortunately this may result in the TEC and other metrics for V6 being non-comparable with Version 5 and earlier, for example with the introduction of newly defined long idle and short idle modes (instead of the single idle mode). This means that longer term trends would be very difficult to ascertain, unless the previously defined idle mode (for example) continued to be reported.

Annex 1 Terminology used

The following lists some of the terminology used within this benchmarking document. It does not attempt to provide a full listing of all terminology, but rather to provide a summary of terminology most frequently used and/or terminology used with a meaning different to its more common usage. Most definitions are from ENERGY STAR Version 5.2 criteria.

Active state/mode	*The power state in which the computer is carrying out useful work in response to a) prior or concurrent user input or b) prior or concurrent instruction over the network. Active state includes active processing, seeking data from storage, memory, or cache, including idle state time while awaiting further user input and before entering low power modes.*
Category A, B, C	*ENERGY STAR classifications of product type by computing capability. Category A includes basic computing capabilities; B most average capability notebooks; C higher capability notebooks (and a small proportion of ENERGY STAR registrations).*
Idle state/mode	*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 sleep mode*
(Discrete) GPU	*Discrete Graphics Processing Unit (GPU): A graphics processor with a local memory controller interface and local graphics-specific memory.*
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.*
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.*
WoL	*Wake-on-LAN. Functionality which allows a computer to transition from sleep mode or off mode to an active state of operation when directed by a network wake event via Ethernet.*

Annex 2 Descriptions of each country dataset

Data for Australia

Government-sponsored independent test report data on 129 notebooks was made available, covering notebook purchases made between 2008 and June 2010. Tests were made in six batches by three different test laboratories and during that period also provided comprehensive supplementary data for most products. Products were selected as representative of mainstream products on the Australian market, although four of the batches targeted products that were marketed as compliant with the ENERGY STAR specification of the time. A TEC value could be calculated for over 85% of the models in the source database for use in the analysis. No sales data was available. Data quality assigned as **illustrative** due to small market sample and no sales weighting.

Data for the EU

Two separate datasets were made available for the EU:

- Whole market average figures for 2007 and 2008 extracted from a market research report[31] commissioned by the European Commission. This included figures for average performance of both ENERGY STAR registered products and non-registered products (i.e. whole market). This data is sales weighted and are claimed (according to report authors) to be derived from datasets that cover 62% of the market, and are assumed to cover a fairly random selection of the market and so not skewed. Data quality is assigned as **robust** due to being based on a random sample of 62% of the whole market and sales weighted.

- EU ENERGY STAR datasets for the whole of 2009 and 2010 and for the first half of 2011. The sets included between 1,600 and 2,600 products for different years. The datasets consist of products registered in the USA ENERGY STAR scheme as being available in the EU, combined with the products registered solely in EU. No sales data for these is available. The ENERGY STAR specification changed in July 2009 to adopt Version 5. ENERGY STAR registered products accounted for 46% of 2010 EU

[31] SPECIAL STUDY Energy Modelling for EU Office Equipment, Section 2.1, IDC Analyst Team, second Energy Modelling report in a series of reports prepared by IDC and AEA Technology for the EU under the contract TREN/D3/441-2006, first report dated November 2008 (2007 data), second report dated October 2009 (2008 data).

sales[32]. Data quality assigned as **illustrative** due to partial market coverage (only better products) and no sales weighting.

Data for Switzerland

The data for Swiss notebooks was provided from government modelling of the national stock and sales of home and office products. This included sales weighted figures for sleep, off and idle modes from which figures for TEC were calculated. Data quality assigned as **indicative** due to being based on model data derived from manufacturer declarations, with indicative sales weighting.

Data for Republic of Korea

Data was provided from a government database that included sleep mode and off mode power only, covering 2006 to 2009 inclusive. A total of 1,350 products was included, of which 811 provided usable energy data. TEC energy consumption could not be calculated from these figures due to the absence of idle mode power. Sales data was provided, from which sales weighted figures for off mode and sleep mode could be calculated. Data quality assigned as **robust** due to having sales data and assumed whole market coverage (best to worst), although there were relatively low numbers of products, indicating that the database may not have included all products on the market, particularly in earlier years.

Data for USA

A comprehensive database was provided of all notebook products registered on the ENERGY STAR programme from 2008 to 2011, and so represents the better products available on the market. The US Environmental Protection Agency (EPA) estimates that ENERGY STAR registered notebook PCs accounted for 49% of all USA notebook sales in 2008 and 74% of all sales in 2009[33] (no similar data available for 2010 and 2011). The ENERGY STAR specification changed in July 2009 to adopt Version 5. Data quality assigned as **illustrative** due to having no sales data and having only partial market coverage (better products).

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[32] SPECIAL STUDY Survey of the Market Penetration of Energy Efficient Office Equipment under the ENERGY STAR Programme Report 1.5, IDC and AEA Technology for the European Commission under the contract TREN/D3/441-2006, table 2 page 4.

[33] Quoted from ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2008 Summary and ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2009 Summary, available from www.energystar.gov/index.cfm?c=partners.unit_shipment_data

Annex 3 Framework for grading mapping and benchmarking outputs

In order for the Mapping and Benchmarking Annex to provide transparency regarding the degree of 'reliability' that can be attributed to the results produced by the Annex, a framework has been developed that allows the *grading* of benchmarking outputs. This grading is based on a three part 'scale' of robust, indicative and illustrative. This grading is applied to both the initial data input and any manipulations that are required to present the data in a consistent form in the country mappings, and to the subsequent manipulations of that data in order to make it comparable with datasets from other countries/regions during the benchmarking process. While expert opinion is used to formulate the specific grading allocated to individual datasets or outputs, this expert opinion is formed with the following framework.

Grading of data/mapping outputs

Robust – where typically:

- The data is largely representative of the full market and
- The data includes at least a significant element of individual product data and
- The data is from known and reliable sources and
- Test methodologies are known and reliable and
- Any data manipulations are based on solid evidence and should not unduly distort results.

Conclusions from such datasets are as reliable as reasonably possible within the boundaries of the Annex operation.

Indicative – where typically:

- Datasets may not be fully representative of the markets (but do account for a majority, ideally a known and understood majority) and/or
- Any data manipulation used includes some assumptions or unavoidable approximations that could unintentionally reduce accuracy.

Accuracy is, however, judged such that meaningful but qualified conclusions could be drawn.

Illustrative – where typically:

- One or more significant parts of a dataset is known to represent less than a majority of the full market or
- Test methodologies used to derive data are not known or
- Test methodologies used to derive data are known but could lead to significant differences in outcome or
- Data manipulations for the analysis contain an element of speculation or significant assumption or

- Conflicting and equally valid evidence is available.

Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide some insight into the market situation and so is worth reporting, but results must be treated with caution.

Grading of comparison between country outputs (benchmarking)

Robust – where typically:

- The data sources being compared are each largely ‘robust’ and
- No data manipulations for benchmarking were necessary; or if manipulations were used they were based upon solid evidence and should not distort results.

Conclusions from comparisons within and between such datasets are as reliable as reasonably possible within boundaries outlined above.

Indicative – where typically:

- Datasets being compared are themselves only ‘indicative’ and/or
- Any data manipulation used for benchmarking includes some assumptions or unavoidable approximations that could unintentionally reduce accuracy and/or
- For any other reason(s) subsets of the data may not be strictly comparable which leads to some distortion.

However, accuracy is such that meaningful but qualified conclusions could be drawn.

Illustrative – where typically:

- One or more significant parts of the datasets are themselves ‘illustrative’ and/or
- Data manipulations for the benchmarking process contain an element of speculation or significant assumption.

Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide insight into the market situation and so is worth reporting, but results must be treated with caution.

Annex 4 Analysis approach

The generic steps taken for datasets containing performance criteria for individual products were as follows:

1. Ensure dataset contains only notebooks (filter out desktops, thin clients, workstations, integrated desktop PCs and small scale servers).
2. Filter out products with screen sizes less than 7".
3. Normalise idle mode power to 115 V power supply for benchmarking (see section Normalisation of TEC results on page 62).
4. Use the TEC value quoted in the dataset if available.
5. If no TEC quoted (e.g. for datasets before ENERGY STAR Version 5) then use idle, sleep and off power figures to calculate TEC using the following equation:

$$TEC = 0.6 \times P_{off} + 0.1 \times P_{sleep} + 0.3 \times P_{idle}$$

Where:

P_{off} is power measured in off mode (W)
P_{sleep} is power measured in sleep mode (W)
P_{idle} is power measured in idle mode (W).

Note that for the benchmarking analysis, products with a date of test registered in one year are not carried forward to subsequent years to simulate their continued availability on the market. The effect of this is to accentuate the impact on the market average caused by changes in the performance of new products, rather than these changes being slightly ‘diluted’ by legacy products. This was deemed appropriate for this analysis to reveal trends as notebooks develop rapidly and data is only available over a few years.

Where an off mode or sleep mode result for a product was **blank or contained a zero**, this was assumed to be ‘not reported’ and ignored in the analysis. Zero for sleep mode is not possible (implies that the product cannot be woken from sleep without a power switch action). It is possible that some reported zero W for off mode are true and reflect a hard off situation for the product, but these were assumed to be rare and so this would not significantly distort results – whereas taking zeros into account that were simply erroneous entries would distort results.

Normalisation of TEC results

The only normalisation step carried out was to normalise for supply voltage. Product performance declared in the ENERGY STAR database includes options for 100 V, 115 V and 230 V supplies. Some products declare at only one voltage; others declare in 2 or all 3 voltages. Data was most numerous in the 115 V field (predominantly from US products) and so this was chosen as the basis for comparison of all products in benchmarking.

The products for which declarations were made in all 3 categories were used to generate average conversion ratios of TEC performance between the 3 voltages as shown in Table 5. For example from Table 5, an average Category A result at 230 V is 4.9% higher than that at 115V (column 2). The lack of consistency across categories could imply that the relationship between power measurements at these different voltages is complex or even spurious but the statistical results have been applied.

Only Swiss data was whole market figures without breakdown into ENERGY STAR categories. In order to normalise Swiss data, an average normalisation factor was calculated assuming a category A, B and C market split the same as for the EU as a whole.

Table 5. Percentage change used to convert TEC values measured at one voltage to a figure approximating what might be achieved at another voltage (based on averages for products with declarations at all 3 voltages).

	Category A			Category B			Category C		
Voltage of TEC data	230/115	230/100	115/100	230/115	230/100	115/100	230/115	230/100	115/100
% change	**4.9%**	**5.6%**	**0.4%**	**3.7%**	**3.7%**	**0.2%**	**0.5%**	**-0.2%**	**-0.6%**
Voltage of TEC data	115/230	100/230	100/115	115/230	100/230	100/115	115/230	100/230	100/115
% change	**-4.6%**	**-5.3%**	**-0.4%**	**-3.6%**	**-3.6%**	**-0.2%**	**-0.5%**	**0.2%**	**0.6%**
Count of data points used to generate the % change	1,714	808	807	865	549	549	43	42	42

Breakdown of data into subsets for analysis

As initially described in section 3.5 Summary of approach for energy performance analysis, data was broken down into the following subsets for various stages of analysis, with the aim of comparing performance of similar products within groups and tracking performance trends over time:

a) Into **ENERGY STAR categories A, B and C**, to enable an answer to the question: *"Are notebook PCs within the categories defined by the main policy (ENERGY STAR) getting more efficient over time?"*
b) By selecting three narrow **bands of similar computing capability** at high, average and low levels, to enable an answer to the question: *"Are notebook PCs getting more efficient over time, for the same capability?"*
c) Into **anonymised brand groups**, to enable an answer to the question: *"Does any difference in performance between brands give insight into scope for improvement?"*

The rationale and method for dividing into these subsets are explained in the following sections.

Attempts to define a narrow band of computing capability representing the most **popular product capability level in that year** failed due to the complexity of market trends for different product types. Even when only category B products were analysed, the resulting trends were equally complex with processor speeds and installed RAM being popular at both high and low ends of the spectra and no clear 'most popular' level. No simple conclusions could be drawn as to the most popular specification for each year and so this line of analysis was stopped.

ENERGY STAR categories A, B, C

The ENERGY STAR categories are defined in Table 7. The relative proportions in the market as indicated by the available data are shown in Figure 2, with the count of products shown in Table 6.

Product experts have indicated that many category C products, being high specification devices, are not able to meet the ENERGY STAR specification and so their low representation in the data does not necessarily reflect an equally low representation in the market. The EU market research report did not mention category C notebook PCs at all, implying that their sales are negligible in Europe but this has not been confirmed.

Table 6. Count of products analysed in each dataset.

	Count of Category A products	Count of Category B products	Count of Category C products
Australia 2009	23	26	3
Australia 2010	21	0	0
USA ENERGY STAR 2009	1,469	860	41
USA ENERGY STAR 2010	1,474	677	38
USA ENERGY STAR 2011	738	780	13
EU ENERGY STAR 2009	1,489	1,087	40
EU ENERGY STAR 2010	1,504	996	52
EU ENERGY STAR 2011	676	759	13

Known limitations and weaknesses in the approach of division by ENERGY STAR category:

- The definitions of the ENERGY STAR categories still allow products to be in the same category but have fairly different energy characteristics. This is why the more narrow performance bands were conceived as described in the next section.

Table 7. Definition of the ENERGY STAR notebook categories.

Category	Definition	Notebook characterisation
A	All notebook PCs that do not meet the definition of Category B or Category C below will be considered under Category A for ENERGY STAR qualification.	Basic computing capability
B	To qualify under Category B, notebooks must have a discrete graphics processor unit (GPU).	Typical computing capability
C	To qualify under Category C, notebooks must have: • Greater than or equal to 2 physical cores • Greater than or equal to 2 gigabytes (GB) of system memory • A discrete GPU with a frame buffer width greater than 128-bit.	High computing capability

Low, average and high performance bands

This categorisation was intended to isolate relatively narrow bands of similar computing capability, recognising that the ENERGY STAR categories are fairly broad. The overall aim was to provide insight into whether generic efficiency levels are increasing, staying the same or decreasing. This cannot be ascertained by taking the overall typical energy consumption per year for all products because the capability of the products in each year is changing significantly, making comparison difficult. This analysis relies on the assumption that any change in consumption for one performance band that has been isolated reflects the overall trend for products of that type.

A balance has to be struck in this approach on the number of products included in each band of computing capability between embracing sufficient quantity of products to make a meaningful average, whilst having narrow enough bands to be highly comparable in capability within each. The aim was that each data bin (for each dataset in each year in each band) should contain between 50 and 200 products (achieved between 26 and 218, see Table 9). On advice from product experts, the following characteristics were chosen to define the performance bands:

- ENERGY STAR Category (which between categories A and B equates to whether or not the product has a discrete GPU);
- RAM installed (GB);
- Processor speed (GHz);
- Single or dual processor (where possible to distinguish from available data. Products from ENERGY STAR V3 and V4 databases are assumed to be single);
- Number of cores (assumed single core for all ENERGY STAR V3 and V4 products);
- Frame buffer width (where distinguished, assumed all have less than 64 for ENERGY STAR V3 and V4);
- Number of installed hard disks (assumed one for ENERGY STAR V3 and V4).

It was decided **NOT** to use the following aspects to distinguish product capabilities, as being too complex or irrelevant for other reasons:

- Disk speed (desirable to filter on this but is not specified in the available databases);
- Operating system (Mac OSX/Windows/Linux etc);
- Supply voltage (product performance is normalised for this);
- Efficiency of power supply (measured as part of the product performance);
- Processor and graphics processor unit (GPU) brand (Intel/AMD etc; ATI/GeForce/NVIDIA etc);
- Disk size (disk unit energy consumption is highly dependent upon the size of disk and speed, but most notebooks have a 2.5” disk covering most storage capacities).

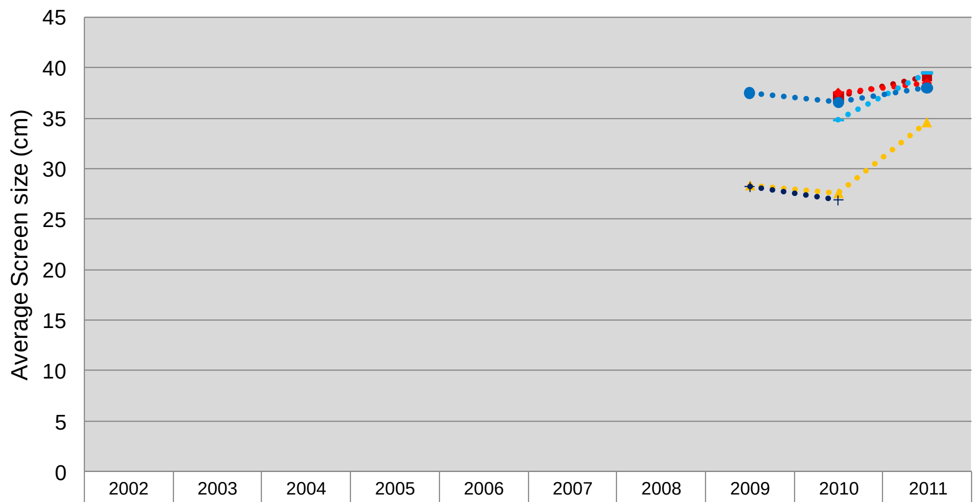
After some iteration of exact parameters based on the count of products achieved in each data bin (as shown in Table 9 and Figure 33), the definitions shown in Table 8 were chosen. The count of products ranges from 22 up to 209, with the high performance band showing the most significant variation. The average performance band is perhaps the most important for deriving conclusions and shows fairly strong counts for 2009 and 2011 – these should provide reasonably robust average performance levels.

In order to characterise the types of notebooks included in the 3 categories, Figure 31 shows the average screen size (from limited available data) for each performance band and Figure 32 the installed RAM, showing how RAM increases with the higher performance bands.

Table 8. Parameters used to define each performance band (low, average, high).

Parameter	Low performance band	Average performance band	High performance band
ENERGY STAR category	No discrete GPU	Category B (= has discrete GPU)	(Any)
RAM installed	2 to 4 GB	4 GB	4 to 8 GB
Processor speed (GHz)	1.4 to 2.1 GHz	2.1 to 2.4 GHz	2.4 to 2.9 GHz
Single or dual processor	Single	Single	Single or dual
Number of cores	Single or dual	Single or dual	At least dual
Frame buffer width	N/A	64 bit	128 bit
Number of installed hard disks	(Any)	1	(Any)

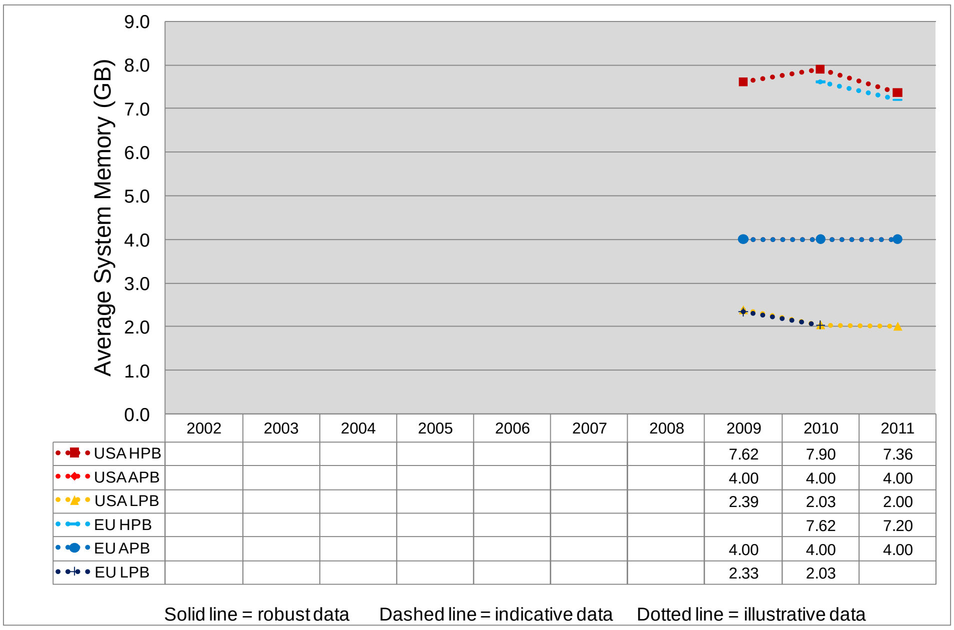
Figure 31. Average screen size (cm) for the 3 performance bands for USA and EU ENERGY STAR.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA HPB									37	39
USA APB									37	38
USA LPB								28	28	35
EU HPB									35	39
EU APB								37	37	38
EU LPB								28	27	

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

Figure 32. Average system memory (RAM) for the 3 performance bands for EU and USA ENERGY STAR.

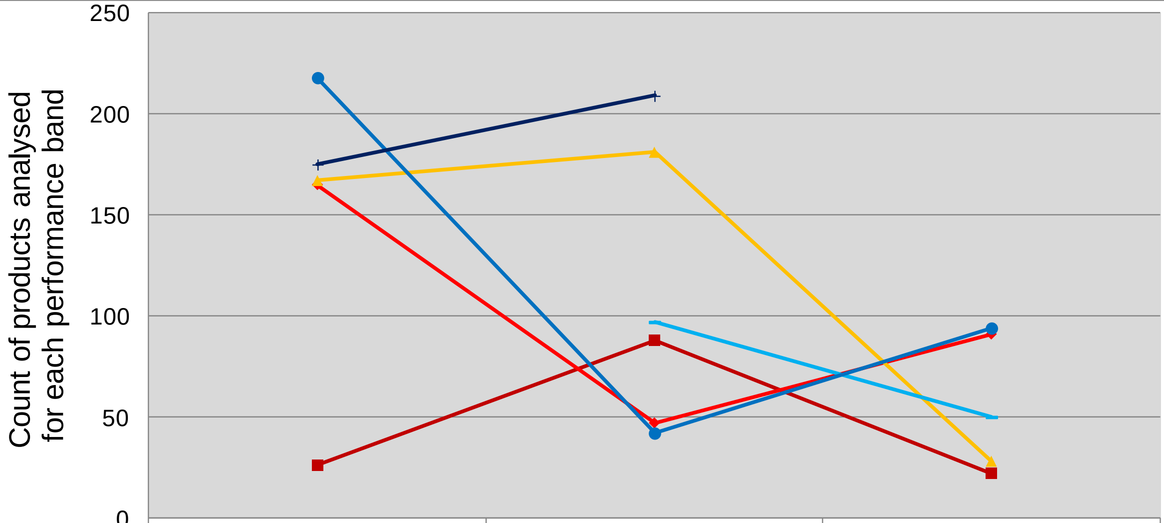


	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
USA HPB								7.62	7.90	7.36
USA APB								4.00	4.00	4.00
USA LPB								2.39	2.03	2.00
EU HPB									7.62	7.20
EU APB								4.00	4.00	4.00
EU LPB								2.33	2.03	

Table 9. Count of products included in each data bin for high, average and low performance bands (PB), based on the subset definitions shown in Table 8.

		2009	2010	2011
USA	High PB	26	88	22
	Average PB	165	47	91
	Low PB	167	181	28
EU	High PB	0	97	50
	Average PB	218	42	94
	Low PB	175	209	0

Figure 33. Plot of count of notebooks included in each performance band for EU and USA (to show how these vary between years and between sets).



	2009	2010	2011
USA HPB	26	88	22
USA APB	165	47	91
USA LPB	167	181	28
EU HPB		97	50
EU APB	218	42	94
EU LPB	175	209	

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

These bands were analysed for average TEC and also to reveal the scope for improvement buy looking at best/average/worst TEC, and how this changes over time

Known limitations and weaknesses in this approach for low, average and high performane bands:

- The count of products in each data bin varies, which means that representation is not consistent and trends may not be robust
- Tracing a static specification level means possibly tracking products whose popularity is waning over time.

Analysis by brand

The objective of this analysis was **not** to identify which particular brand is better or worse than another. Instead it was to see if average energy performance of different brands can give any insight into the scope for improvement, perhaps through showing whether some brands appear to prioritise energy efficiency to a greater extent across their product range than others. Also, the analysis sought to gain some insight into whether the ENERGY STAR policy is driving performance improvement equally across all suppliers – only the EU and US ENERGY STAR databases were used as sources for this analysis.

It is recognised that some brands focus on a certain stratum of the market and so in order to ensure inclusion of products that are reasonably comparable, this analysis was carried out using only products in ENERGY STAR category B.

In order to focus on a manageable number of brands (the US ENERGY STAR database included 79 different brands) it was decided to focus on 7 top brands by indicative market share[34] which account for around 70% of mobile PC[35] shipments globally. Note that this does **not** imply that the *data analysed* accounts for 70% of global mobile PC shipments, as many products from those suppliers may not appear in the ENERGY STAR database and many may be out of scope for this analysis.

Table 10 shows the count of products included in each brand data bin by year, with this data shown graphically in Figure 34. Steps were taken to eliminate data that could be highly mis-leading:

- Representation of brand B (yellow line on Figure 34) was too low to merit inclusion and it was omitted from the analysis.
- Data bins containing fewer than 10 products were omitted from the analysis.

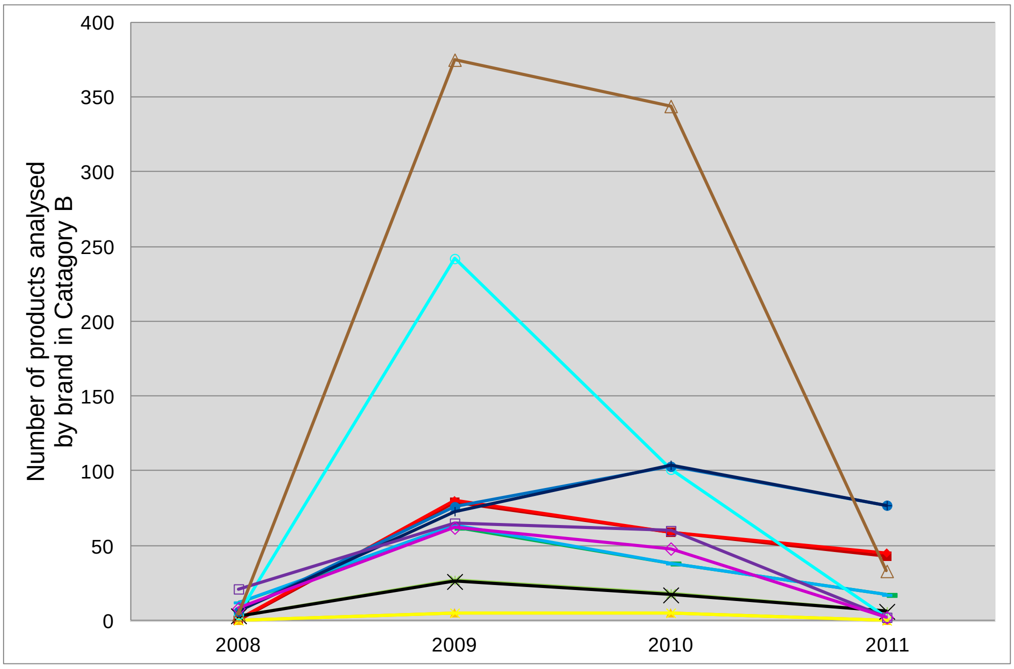
Representation of brands is similarly spread in EU compared to US for all but brand G. Brand G in the USA is slightly less dominant than in EU, resulting in a more even spread in the USA and so the US data was selected in preference to analyse brands and simplify the picture (compared to plotting both EU and USA). Even amongst the USA remainder, there is a wide variation in count of products per bin – ranging from an average of 13 to 87 products. This could exacerbate differences in average consumption.

[34] The top 5 of which were indicated in a DisplaySearch news article of August 2011. The top 5 chosen account for 64% of global mobile computing shipments by unit count as at Q2 2011; two more major brands were added to this list that were the next most numerous in the ENERGY STAR databases.
[35] 'Mobile PC' is the terminology used by the market data supplier (DisplaySearch) and means all portable computers including notebooks, tablets, smart phones etc.

Table 10. Count of Category B products included in each brand data bin, ENERGY STAR data only. Brand B and all data bins with fewer than 10 products were omitted from the analysis.

Region	Brand	2008	2009	2010	2011	Average count by brand all years
Europe	A	0	80	59	43	45.5
	B	0	5	5	0	2.5
	C	3	27	18	6	13.5
	D	12	62	38	17	32.3
	E	6	76	108	77	66.8
	F	21	65	60	2	37.0
	G	4	375	345	33	189.3
	Average EU	**6.6**	**98.6**	**90.4**	**25.4**	**55.3**
USA	A	1	80	59	45	46.3
	B	0	5	5	0	2.5
	C	3	26	17	6	13.0
	D	12	64	38	17	32.8
	E	6	73	104	77	65.0
	F	8	62	48	2	30.0
	G	4	242	101	2	87.3
	Average US	**4.9**	**78.9**	**53.1**	**21.3**	**39.5**

Figure 34. Count of products analysed in each brand set, ENERGY STAR category B only. Each coloured line represents a different brand.



Known limitations and weaknesses in the division of products by brand:

- Brands analysed represent around 70% of global mobile computing market but not necessarily 70% of notebook PCs.
- The analysis only considers the ENERGY STAR category B component of each brand's notebook portfolio and so may not be representative of the whole brand performance. Including all products would mean comparing different mixes of types of products and so could be misleading; having reasonable comparability of products analysed is chosen in preference.
- Brands have different representation in each year and different counts of products analysed and so comparability is not robust.
- Other factors may be changing over time within each brand product mix. For example, some brands have raised the average system memory (gigabytes of RAM) of the product in the family that is registered for ENERGY STAR which would increase energy consumption.