Preparatory study on the Review of Regulation 617/2013 (Lot 3)

Computers and Computer Servers

Task 2 report

Markets

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Abbreviations

AC	Alternate Current
AVFS	Adaptive Voltage and Frequency Scaling
B2B	Business to Business
B2C	Business to Consumers
BAT	Best Available Techhnology
BOM	Bill of Materials
CCFL	Cold cathode fluorescent lamp
CPU	Central processing unit
DBEF	Dual Brightness Enhancement Film
DC	Direct Current
dGfx	Discrete Graphic Card
DFS	Dynamic frequency scaling
DIY	Do-it-yourself
DVS	Dynamic voltage scaling
EC	European Commission
EEE	Electrical and electronic equipment
EGA	External graphics adapter
EMEA	Europe, Middle East and Africa
EPA	Environmental Protection Agency (USA)
EPS	External power supply
ESOs	European Standardisation Organisations
EU	European Union
GPU	Graphics processing unit
HDD	Hard disk drives
iGfx	Integrated graphics processing unit
IPS	Internal power supply
JRC	Joint Research Centre
LCD	Liquid crystal display
LED	Light emitting diode
Li-ion	Lithium-ion battery
NiCad	Nickel-Cadmium battery
NiMH	Nickel-metal hydride battery
ODD	Optical disk drive
OS	Operating System
PCB	Printed Circuit Board
PRO	Producer Responsibility Organisation
PSR	Panel self-refresh
PSU	Power Supply Unit
RAM	Random access memory
SME	Small and medium enterprise
SoC	State of charge (of a battery)
SRAM	Static RAM

SSD	Solid state drives
SSHD	Solid state hybrid drive
VR	Virtual Reality
WEEE	Waste Electrical and Electronic Equipment

Introduction to the task reports

This is the introduction to the interim report of the preparatory study on the Review of Regulation 617/2013 (Lot 3) for Computers and Computer Servers. The interim report has been split into five tasks, following the structure of the MEErP methodology. Each task report has been uploaded individually in the project's website. These task reports present the technical basis to define future ecodesign and/or energy labelling requirements based on the existing Regulation (EU) No 617/2013.

The task reports start with the definition of the scope for this review study (i.e. task 1), which assesses the current scope of the existing regulation in light of recent developments with relevant legislation, standardisation and voluntary agreements in the EU and abroad. The assessment results in a refined scope for this review study.

Following it is task 2, which updates the annual sales and stock of the products in scope according to recent and future market trends and estimates future stocks. Furthermore, it provides an update on these trends as well as on consumer expenditure data, which will be used on the assessment of additional life cycle consumer costs if or when setting new requirements.

Next task is task 3, which presents a detailed overview of use patterns of products in scope according to consumer use and technological developments. It also provides an analysis of other aspects that affect the energy consumption during the use of these products, such as component technologies, power supply load efficiency and user interface in particular power management practices. Furthermore, it also touches on aspects that are important for material and resource efficiency such as repair, maintenance and replacement practices, and it gives an overview of what happens to these products at their end of life. Finally, this task also touches on standardised methods to quantify energy consumption in the different power modes, touching on the active mode, and it presents an overview of the energy consumption of products in scope based on manufacturers and ENERGY STAR database information.

Task 4 presents an analysis of current average technologies at product and component level, and it identifies the Best Available Technologies both at product and component level. An overview of the technical specifications as well as their overall energy consumption is provided when data is available. Finally, the chapter concludes with an overview of the product configurations in terms of components and key materials of current average and Best Available Technologies placed on the European market.

Simplified tasks 5 & 6 report presents the base cases, which will be later used to define the current and future impact of the current computer regulation if no action is taken. The report shows the base cases energy consumption at product category level and their life cycle costs. It also provides a high-level overview of the life cycle global warming potential of desktops and notebooks giving an idea of the contribution of each life cycle stage to the overall environmental impact. Finally, it presents some identified design options which will be used to define reviewed ecodesign requirements.

Task 7.1 report presents the policy options for an amended ecodesign regulation on computers and computer servers. The options have been developed based on the work throughout this review study, dialogue with stakeholders and with the European Commission. The report presents an overview of the barriers and opportunities for the

reviewed energy efficiency policy options, and the rationale for the new material efficiency policy options. This report will be the basis to calculate the estimated energy and material savings potentials by implementing these policy options, in comparison to no action (i.e. Business as Usual – BAU).

The task reports follow the MEErP methodology, with some adaptations which suit the study goals

2 Introduction to Task 2

Task 2 follows the MEErP methodology and includes the following:

1. Generic economic data: EU sales and trade data based on production, import and export is assessed based on PRODCOM data analysis, aiming at identifying any similarities with our established stock model and/or filling data gaps.
2. Market and stock data: The establishment of the EU installed base (stock) based on EU annual total sales and growth rates and average product lives.
3. Market trends: The trends have been assessed regarding products, product features, market channels, production structures and market players. This includes the trend towards the increased use of mobile products such as the slates and mobile phones, a progressive move towards services provided as cloud services, key component technological developments (e.g. within the CPU area), network and port interfaces, possible use of SOCs (System On Chip), DC powered products, memory storage and energy storage battery developments.
4. Consumer expenditure base data: Identifying average EU consumer prices, repair and maintenance costs, disposal tariffs and taxes, electricity prices and regional differentiations.

2.1 Generic Economic data

The PRODCOM statistics are the official source for product data on the EU market. It is based on product definitions that are standardised across the EU thus guaranteeing comparability between Member States. It is used and referenced in other EU policy documents regarding trade and economic policy, and therefore often referred to in preparatory studies. Data are reported by Member States to Eurostat.

The PRODCOM statistics have some limitations given the complexities in the market and so are not always as detailed as necessary to support decision making within ecodesign preparatory studies. However, the MEErP methodology recommends to initiate the sales and stock analysis by establishing an overview of the PRODCOM statistics. This overview can be used as comparison with sales and stock data from other sources, e.g. industry and/or market reports.

Within this study, the PRODCOM statistics are used to compare against product data sourced from other data sources and expert assumptions in order to provide a higher degree of confidence in the final product dataset. The product data sourced was used to establish annual sales for product categories in scope, and subsequently for establishing the installed base in the EU (i.e. stock), see section 3.

PRODCOM EU sales and trade (i.e. the EU consumption) is derived by using the following formula based on data from PRODCOM:

EU sales and trade= production + import - export

See Table 1 for the relevant PRODCOM codes and categories for this study. We consider the PRODCOM category "Laptop PCs and palm-top organisers" to correspond to the category "notebook computers" defined in Task 1. The background for this is that there are very few palm-top organisers on the market nowadays because their functionality has been taken over by tablets and smartphones. Furthermore, cell phones are covered

by a separate PRODCOM code (26302200) and it should therefore not be included in the "Laptop PCs and palm-top organisers" category.

It should be noted that PRODCOM does not provide sufficient granularity of data for power supply units (PSUs) and so many of the PSU units may not be for PSUs used exclusively with computers. Separate keyboards may be used as accessory for computers but also for other computer terminals etc. not covered by this study. Therefore, keyboards and power supply units are used in the following only as supplementary data.

Table 1. PRODCOM categories covering products relevant for this study.

PRODCOM code	PRODCOM Nomenclature
26201100	Laptop PCs and palm-top organisers
26201300	Desktop PCs
26201650	Keyboards
27115040	Power supply units for telecommunication apparatus, automatic data-processing machines and units thereof

In addition to the product types above, there are a number of PRODCOM categories related to major and minor components of computers or input and output units. These additional components are not assessed in detail as it would not be possible to identify the proportion of these components that are used in computers within scope of this study against the proportion that were used in other similar electrical and electronic products.

Figure 1, Figure 2 and Figure 3 illustrate the EU-28 production, import and export quantity according to PRODCOM for the "Laptop PCs and palm-top organisers" and "Desktop PCs" as listed in Table 1 i.e. covering the computer category in scope for this study. Figure 3 presents the EU sales and trade data calculated based on the formula abovementioned and using the data shown in Figure 1 and Figure 2. The most recent data retrievable from PRODCOM at the time of writing this report were from 2014.

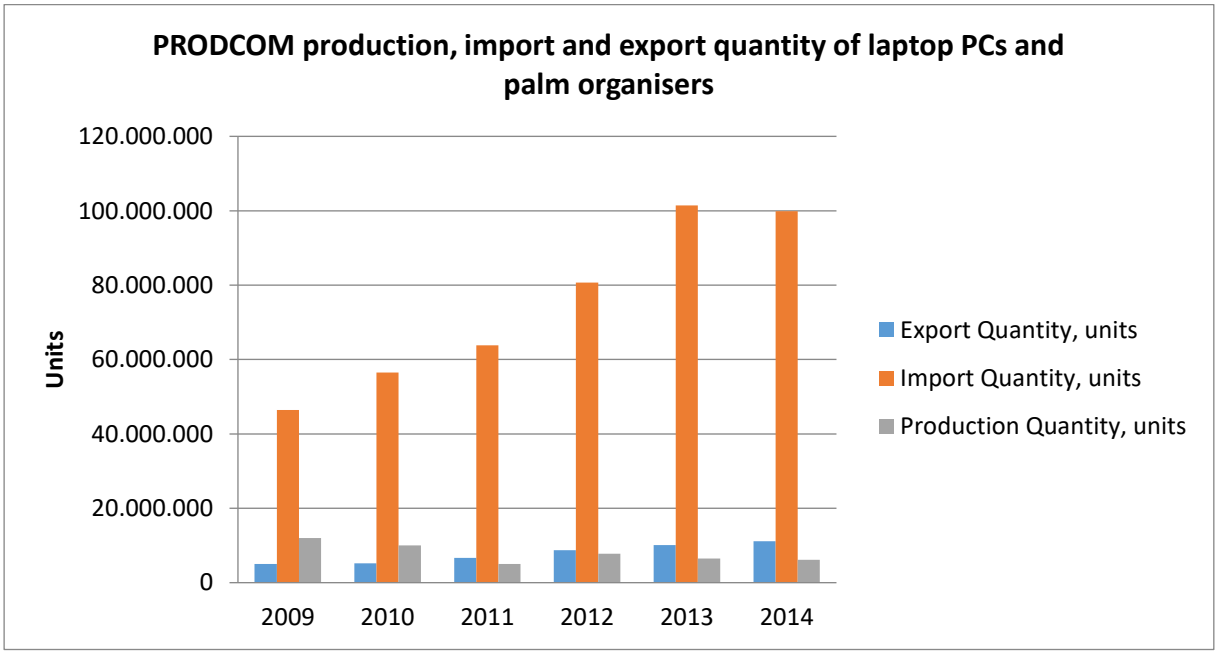

Figure 1. Total production, import and export quantity of laptop PCs and palm organisers (i.e. notebooks) 2009-2014.

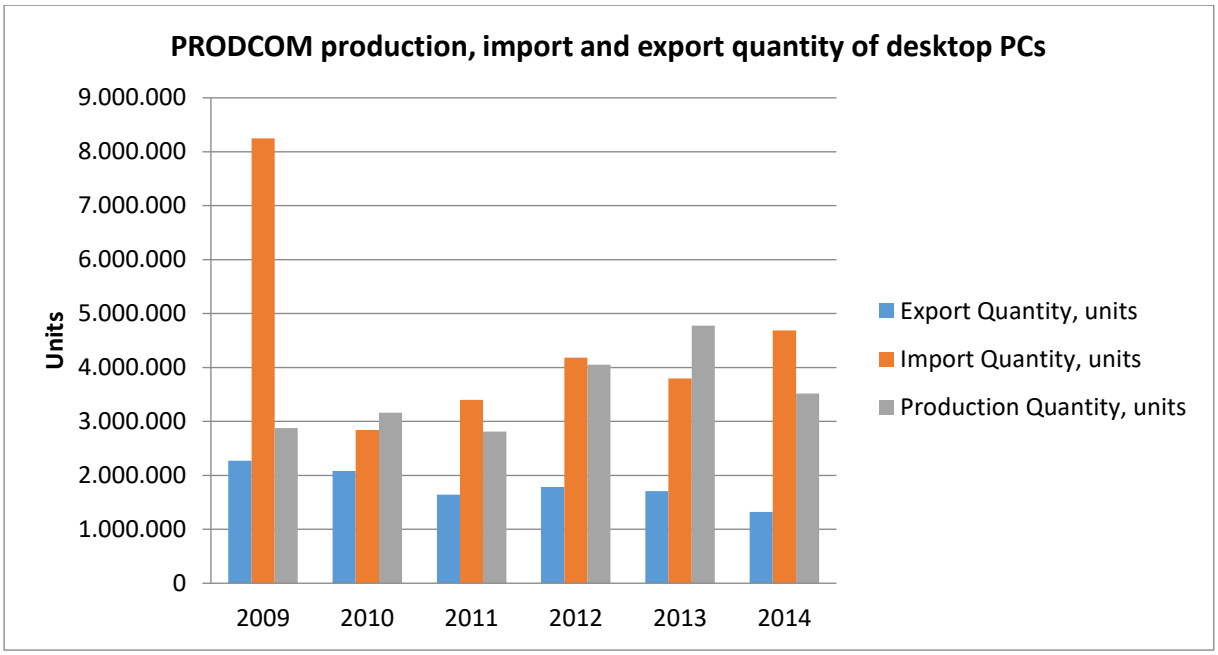

Figure 2. Total production, import and export quantity of desktop PCs 2009-2014.

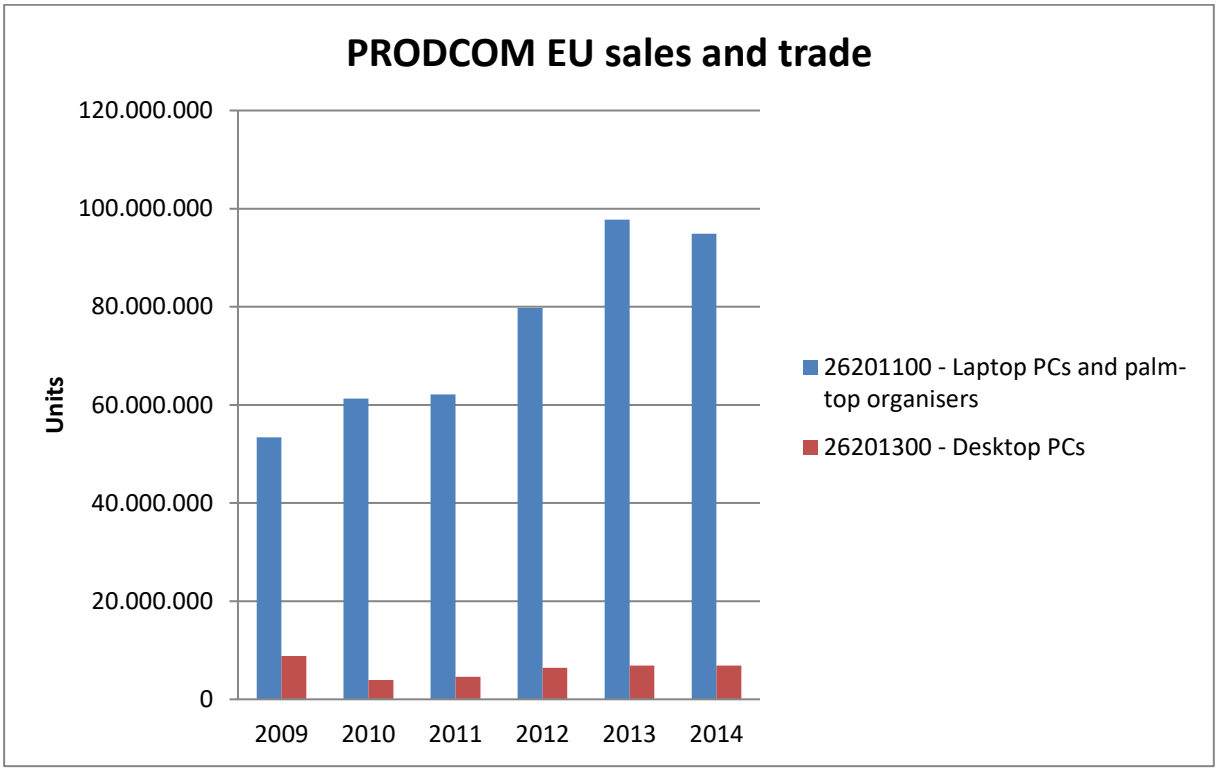

Figure 3. Total EU sales and trade of computers 2009-2014.

In addition to unit data, PRODCOM also contains financial data about the products.

Table 2 presents the production, import and export data in both financial values and quantity for all the product categories included in Table 1.

Table 2. PRODCOM production, import, export and EU sales and trade in quantity and values for 2009-2014.

Product		Laptops	Desktops	Keyboards	PSU	All computers[1]	Total
PRODCOM Code		26201100	26201300	26201650	27115040		
Export Quantity (million units)	2009	5.04	2.27	4.23	14.85	7.31	26.39
	2010	5.22	2.08	4.67	17.13	7.30	29.11
	2011	6.71	1.64	4.90	18.81	8.33	32.05
	2012	8.74	1.78	4.81	34.58	10.52	49.91
	2013	10.14	1.71	4.37	11.81	11.85	28.04
	2014	11.12	1.32	3.75	12.08	12.44	28.27
Export Value (billion EUR)	2009	1.80	0.88	0.11	0.56	2.68	3.35
	2010	1.80	1.00	0.15	0.76	2.77	3.67
	2011	2.38	0.79	0.13	0.79	3.18	4.09
	2012	3.31	0.74	0.13	0.81	4.04	4.99
	2013	3.18	0.65	0.11	0.82	3.84	4.77
	2014	3.27	0.74	0.12	0.83	4.01	4.97
Import Quantity (million units)	2009	46.43	8.25	47.99	247.66	54.68	350.33
	2010	56.49	2.84	50.09	277.23	59.34	386.66
	2011	63.84	3.40	50.36	265.84	67.24	383.43
	2012	80.67	4.18	48.72	188.25	84.85	321.82
	2013	101.42	3.79	46.79	157.91	105.22	309.93
	2014	99.85	4.69	87.09	146.66	104.53	338.28
Import Value (billion EUR)	2009	16.35	0.52	0.34	1.53	16.86	18.73
	2010	21.88	1.07	0.42	1.91	22.95	25.28
	2011	22.14	1.12	0.40	1.88	23.26	25.53
	2012	26.22	1.44	0.43	1.88	27.67	29.98
	2013	26.42	1.25	0.42	1.74	27.66	29.83
	2014	25.89	1.35	0.45	1.87	27.24	29.57
Production Quantity (million units)	2009	12.00	2.88	10.58	1.86	14.88	27.32
	2010	10.00	3.16	21.01	2.42	13.16	36.60
	2011	5.00	2.81	29.52	2.28	7.81	39.61
	2012	7.80	4.05	20.63	2.65	11.85	35.13
	2013	6.49	4.78	19.26	2.39	11.26	32.91
	2014	6.13	3.52	22.33	2.80	9.65	34.78
Production Value, (billion EUR)	2009	5.00	1.54	0.08	0.31	6.54	6.92
	2010	4.00	1.67	0.11	0.45	5.67	6.24
	2011	2.34	1.00	0.14	0.45	3.34	3.93
	2012	2.25	1.20	0.12	0.38	3.45	3.94
	2013	1.78	1.22	0.11	0.33	3.00	3.44
	2014	1.71	1.26	0.12	0.50	2.97	3.59
EU Sales and Trade Quantity (million units)	2009	**53.39**	**8.86**	**54.35**	**234.67**	**62.25**	**351.26**
	2010	**61.27**	**3.92**	**66.43**	**262.52**	**65.19**	**394.15**
	2011	**62.15**	**4.57**	**74.97**	**249.32**	**66.72**	**391.00**
	2012	**79.73**	**6.45**	**64.53**	**156.32**	**86.18**	**307.04**
	2013	**97.76**	**6.87**	**61.69**	**148.49**	**104.64**	**314.81**
	2014	**94.86**	**6.88**	**105.66**	**137.38**	**101.74**	**344.78**

PRODCOM data shows that sales for all computers increase steadily by 2-5% per annum from 2009 to 2011 and it picks up to 21-29% per annum from 2011 to 2013. Total increase of the five years period is 63%. It also shows a 3% decrease in 2014, giving approximately 102 million of sold computer units (compared to about 105 million sold in 2013). Data also shows the switch from desktops to notebooks from a notebook share of total computer sales of 86% to 93-94% the following years, which though seem to be on the high side. This is further described in next section.

When looking at the PRODCOM statistics on laptops shown in Table 2, the numbers show that from 2009 to 2014 the production of laptops in the EU is reduced by approximately

[1] All computers (laptops and desktops).

half, while the total sale of laptops almost doubles. The increase in total sales is the result of doubling in imports over the same period. This suggests that more of the production activities are offshored, and hence the increasing demand for laptop computers is met by increasing imports. The data also shows that the laptop exports also doubled from 2009 to 2014, and though the exports are still much smaller than the imports, they are higher than the production numbers. This can only be explained by supply chains which first import computer products and later export some of these or others to other countries.

Concerning PRODCOM statistics on desktops, it was found that some of the data did not add up. The 2008 and 2009 desktop sales in Europe were extremely high compared to all other years. This discrepancy was found to originate in the import quantities (in units) reported for France, as shown in Figure 4.

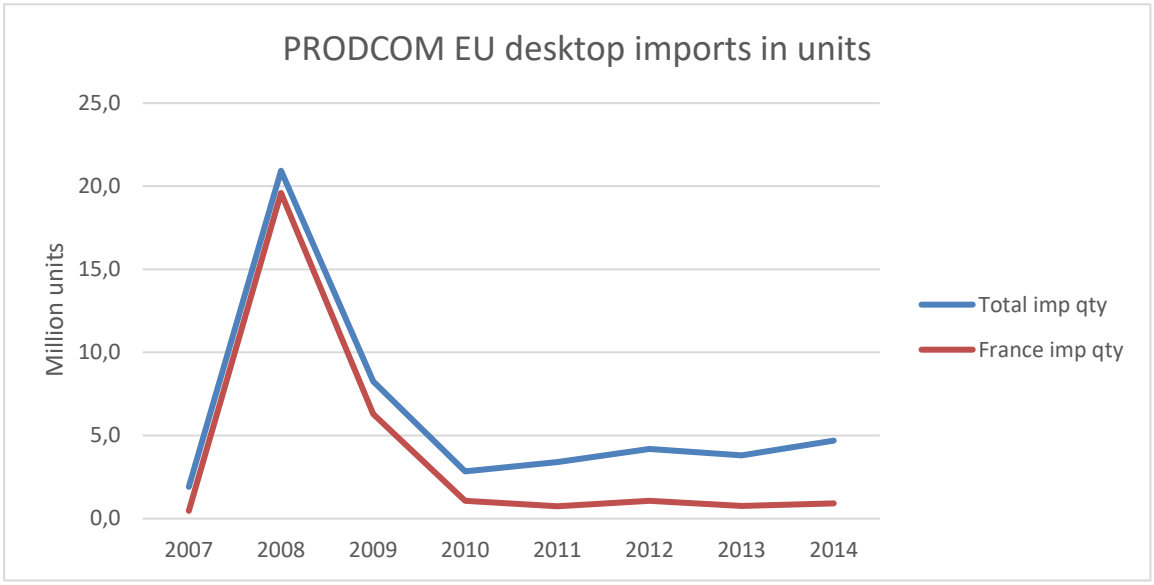

Figure 4. PRODCOM imports of desktop computers for EU-27 and for France.

In the years 2008 and 2009 France's import of desktops account for 94% and 76% of the total EU-27 imports, respectively. For all other years, the share is between 20% and 30%. This, together with the unlikely high numbers, indicate that these numbers are not correct. When comparing with the PRODCOM imports (in EUR) for desktop computers, it becomes even clearer that the import values (in units) are not correct, because the economic imports in 2008 and 2009 were actually lower than the other years. This can be seen in Figure 5.

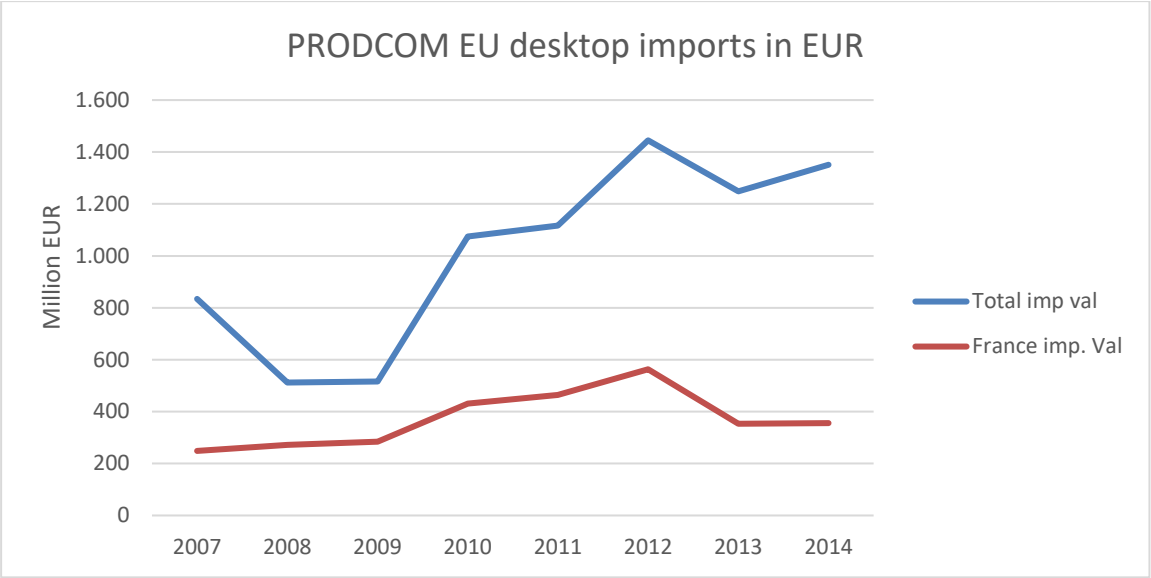

Figure 5. PRODCOM imports of desktop computers for EU-27 and for France.

As seen on Figure 4 and Figure 5 the data within the PRODCOM database contradicts itself for desktop computers, and since the majority of the contradictions come from France, import data for France specifically was sought from other sources[2]. Figure 6 shows import value data for France in the same years as Figure 4 and Figure 5[3]. Using this data source, the imports data do not exceed the values of the following years, and the peak in 2008 is non-existent[4]. Even though the data source showed all computer and information technology imports and not desktop computers exclusively, the general trends are assumed to be comparable to those of desktop computers (see Figure 6)

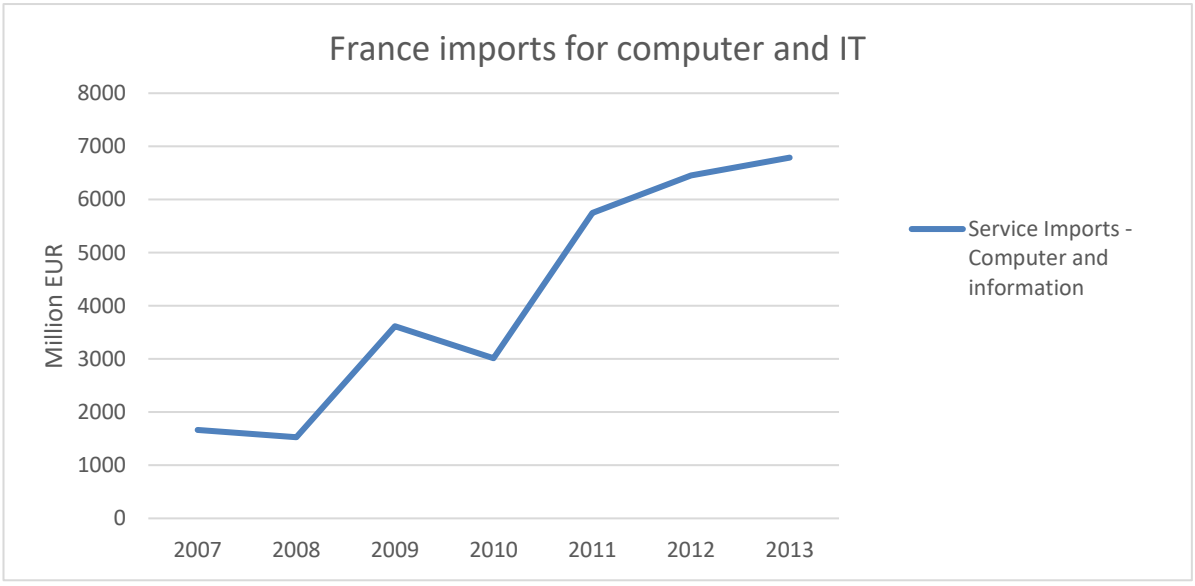

Figure 6. Imports of computer and information technology for France.

[2] http://tunisia.opendataforafrica.org/atlas/France/topics/Foreign-Trade/Service-Imports/Computer-and-information
[3] http://tunisia.opendataforafrica.org/atlas/France/topics/Foreign-Trade/Service-Imports/Computer-and-information
[4] http://tunisia.opendataforafrica.org/atlas/France/topics/Foreign-Trade/Service-Imports/Computer-and-information

Comparing the three figures, it seems clear that the deviations in year 2008 and partly 2009 in desktop sales are caused by erroneous numbers in the PRODCOM database on imports to France in these two years. This shows the low reliability of PRODCOM data for desktop computers, indicating that it is necessary to look into other data sources to establish the stock. Due to the other issues with PRODCOM data mentioned at the beginning of this section, it was pursued to establish the stock based on other market sources. See next section.

2.2 Market and Stock data

This section presents estimated market and stock data for each of the product types within scope as defined in task 1.

Industry organisations representing computer manufacturers within the EU were unable to provide sales data for the products that they place on the EU market and prognosis of future sales. We had therefore to derive the sales and stock data using alternative sources of data identified during the course of this task. It was necessary to include estimations for some sales figures, especially past and future sales, in order to fill data gaps. The methods used to estimate sales data are described in the following sections of the report.

2.2.1 Annual total sales

Sales and stock quantity values for the following categories of products within scope were derived for:

- Non-mobile personal computers
    - Desktop computers, including integrated desktop computers as a separate sub-set
    - Workstations
    - Thin clients, including integrated thin clients
- Mobile personal computers
    - Notebook computers, which includes mobile thin clients and mobile workstations
    - Tablet/slate computers
    - Portable all-in-ones
- Small-scale servers
- Peripheral products
    - External graphics adapters (EGA)
    - Docking stations
    - Keyboards and mice
- Computer components
    - Internal power supply units (PSU)
    - External power supply units (EPS)

In the following, we present the result of the sales assessments. The methods used to estimate sales data are detailed in each product-specific section afterwards.

The product type 'Desktop computer' as defined in task 1 includes integrated desktop computers. In order to investigate in further tasks whether their energy consumption differs a lot from other computers, a separate stock sub-set has been created for integrated desktops. The next paragraphs thus show the method to calculate annual

sales as well as their sales and stock figures. This is the same case for 'Thin clients' and its sub-set of integrated thin clients.

Concerning the product categories 'Mobile thin clients' and 'Mobile workstations', their sales are covered under the category 'Notebook computers'. This is because no market data was found concerning these two product categories. Mobile workstations are especially difficult to identify because many notebooks are sold as 'mobile workstations' despite the fact that they would not be classed as true workstation devices as defined in this study. As sales of both of these product types will be relatively low, due to their specialised functionalities, no separate stock models have been developed.

The annual sales in units have been established for this review study, according to the product categorisation shown previously. Table 3 shows the estimated and assumed annual sales in units for each type of product in scope for the period 2009-2030. Description of how the data were derived is described in the next paragraph . Data on peripheral products is shown as these products are known to contribute to the total energy consumption of personal computers but their stock will not be addressed later in this study. The sales are shown only to give the reader an idea of their level of magnitude in the market. They will be further addressed in other tasks of the report when assessing usage patterns and technologies.

Table 3. Estimated sales historically and in future for product types in scope and comparison with historical PRODCOM data 2009-2030.

Million units	2009	2010	2011	2012	2013	2014	2015	2020	2025	2030
Notebook	39.77	48.08	51.38	50.66	47.21	46.79	42.40	41.66	41.55	41.74
Desktop	27.11	24.09	22.08	19.13	15.77	14.84	12.74	12.05	13.47	13.60
Integrated desktop	1.08	0.96	0.88	0.77	0.63	0.59	0.51	0.48	0.54	0.54
Thin client	1.35	1.35	1.35	1.35	1.35	1.43	1.31	1.37	1.37	1.37
Integrated thin client	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.14	0.14	0.14
Tablet/Slate	-	3.56	14.81	28.46	44.74	45.21	40.79	38.38	38.47	38.56
Portable all-in-one	-	0.20	0.21	0.21	0.19	0.19	0.17	0.17	0.17	0.17
Workstation	0.50	0.65	0.74	0.71	0.75	0.80	0.79	0.79	0.82	0.85
External graphics adapters	0.33	0.36	0.36	0.35	0.31	0.30	2.34	2.88	3.61	4.34
Internal power supply units	1.62	1.44	1.32	1.14	0.94	0.89	0.76	0.72	0.81	0.81
External power supply units	n.a.	n.a.	n.a.	n.a.	57.22	57.38	57.55	58.24	58.78	59.14
Small scale servers	0.15	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23
Docking stations	3.70	5.00	5.91	6.38	6.46	6.91	8.50	8.78	9.05	9.33
Total computers	**70.09**	**79.17**	**91.75**	**101.59**	**110.95**	**110.19**	**99.05**	**95.24**	**96.73**	**97.20**
Peripheral products*	90.04	90.88	89.59	82.82	73.05	70.89	62.91	60.46	63.23	63.57
Total all products	**165.8**	**176.8**	**188.9**	**192.3**	**191.7**	**189.2**	**173.6**	**168.1**	**173.4**	**175.2**
PRODCOM data computers	**62.25**	**65.19**	**66.72**	**86.18**	**104.6**	**101.7**	**-**	**-**	**-**	**-**

Deviation from PRODCOM	**13%**	**21%**	**38%**	**18%**	**6%**	**8%**	**-**	**-**	**-**	**-**

*=peripheral products are external graphic adapters (EGA), dockling stations, keyboards and mice and are included in the table to provide an input on the amount of additional products needed to use personal computers since their use also affects their energy consumption

The total sale of computers, found from other sources of market data, is compared against the 2009-2014 PRODCOM data. It is clear that the deviations between the estimated sales figures and the PRODCOM data is quite large for some years but the delta for 2013 and 2014 are quite small at 6% and 8% respectively. This divergence is not unexpected given the uncertainties in the PRODCOM, including those described for desktop sales described above, and the assumptions made for the sales data from other sources derived from this review study. Nevertheless, the comparison serves as a sanity check to show that the total sales are not in orders of magnitude different between the two sets of figures.

The previous ecodesign Impact Assessment on computers estimated that total units sold of computers would be 150 million by 2020, compared to the revised estimated derived in this study at approximately 100 million computers in 2020. Given recent reductions in sales values seen in the computer industry, it is estimated that the revised sales figures are suitable for the purpose. However, it is also important to point out that the computer industry can change direction quickly and unexpectedly, especially after the introduction of new product types. As such, estimates of future sales need to be taken as indicative.

The notebook share of total computer sales grows from 57% in 2009 to 74% in 2014. This is more realistic compared to the notebook share of about 90% based on PRODCOM data; see previous section.

2.2.1.1 Overall EU market

Global sales data published by large market research organisations for product in scope sold was readily available on the internet mainly through Statista (www.statista.com). These global sales values were used as the basis for calculating EU sales for a range of the products in scope.

To calculate EU sales as a proportion of global sales, total computer sales data from an EU ENERGY STAR market survey activity[5] was divided by Worldwide PC Shipment data published by a large market research organisation to give an EU share of global sales at 20%. This value was then used to help derive EU sales, where only global sales figures for individual types of products in scope could be identified (all product types apart from Thin Clients).[6]

For thin clients, it was possible to secure data for the Europe, Middle East and Africa (EMEA). It was assumed, based on IDC reported data that EU sales accounted for 72% of EMEA sales, which was used to calculate thin client sales data.

According to EU ENERGY STAR report for the 3rd and 4th quarters of 2015, which includes whole market data, notebook computers account for slightly less than 2/3 of computer sales in the EU, which is in the same range as indicated above. Sales of desktop computers account for less than 1/3 of the market, leaving approximately 4% of the

[5] Interim Report 3: Q3-Q4 2015: Survey of the Market Penetration of Energy Efficient Office Equipment under the EU ENERGY STAR Programme)
[6] https://www.idc.com/getdoc.jsp?containerId=prUS40909316

market to the integrated computers. The EU ENERGY STAR report does not cover other types of computers that sell in significant volumes such as tablets/slates and workstation computers.

2.2.1.2 Desktop computers

From 1990 to 2000, the growth rate per annum was assumed to be 1.5% for desktop computers as described in the Impact Assessment for Lot 3 computers, servers and displays prepared in 2013[7]. Data from the preparatory study (table 33) was used for the years 2000 to 2008. This fits with other sources from desk research stating that notebook sales exceeded desktop sales for the first time in 2008. Sales for 2009 to 2020 were mainly based on global desktop and notebook data and forecasts from Statista[14].

It was assumed that sales of desktop PCs will grow from 2017 due to increasing demand for Virtual Reality (VR) support[8]. The growth rates starts at 1- 5% p.a. and peaks at 27% p.a. by 2020-2021 before declining to 1-5%. The growth is assumed to stop by 2025 due to market saturation. It is assumed that VR support is divided between a range of products that can provide VR functionality, namely game consoles, smart phones and desktop computers. The shares of VR support amongst the different types of products were based on 2016 data published by Statista with expert assumptions that the increasingly computational performance requirements will increasing require VR functionality to be supported by game consoles and desktop computers (45% each by 2030) rather than smart phones (10% by 2030). See Figure 7 for the estimated development of sales for desktop computers in period 1990-2030.

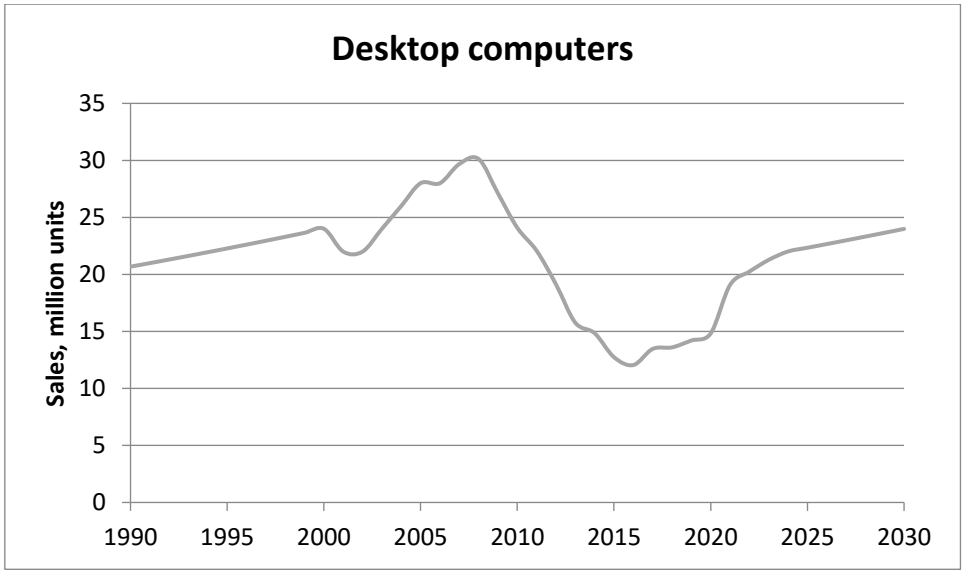

Figure 7. Estimated EU sales of integrated desktop computers 1990-2030.

2.2.1.3 Integrated desktop computers

Little data was available for sales of integrated desktop computers. The EU ENERGY STAR reports[9] show that integrated desktop account for approximately 4% of the total desktop computer market. According to this figure, sales for integrated desktop computers are

[7] Impact Assessment for Lot 3 computers, servers and displays: http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2013/swd_2013_0219_en.pdf
[8] http://www.cnet.com/uk/news/virtual-reality-set-to-take-off-in-2016-researcher-says/
[9] Interim Report 3: Q3-Q4 2015: Survey of the Market Penetration of Energy Efficient Office Equipment under the EU ENERGY STAR Programme)

assumed to be 4% of the sales of desktop computers for the period of 1990-2030. See Figure 8 for estimated EU sales of integrated desktop computers.

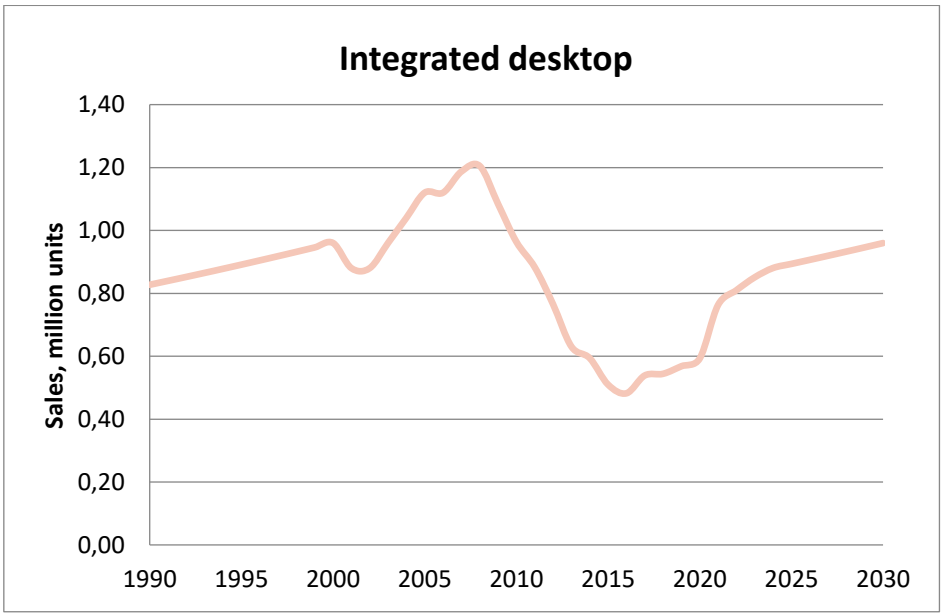

Figure 8. Estimated EU sales of integrated desktop computers 1990 -2030.

2.2.1.4 Workstation

Identifying sales volumes for "workstations" is complicated by the fact that some manufacturers assign the term "workstation" to computers that other manufacturers and most energy efficiency initiatives, such as the Computers Regulation 617/2013, would define as normal or high-end desktop computers. As such, the sales data should be treated with some caution. Sales data for workstation in period 2008 – 2015 is estimated based on the global sales from Statista[10] and assuming 20% EU market share.

Before 2008, the sales are estimated to follow the growth rate found in Impact Assessment of 1.5% per annum, and the 2015 and 2016 sales are predicted to have declined by 1%[11]. Post 2016, growth in Workstation sales is based on average growth seen in previous three years (i.e. 2013-2016). It is assumed growth will be driven by increased business demands for higher computer performance especially to support increasingly data intensive tasks within data science and machine learning. See Figure 9 for the EU estimated sales.

[10] http://www.statista.com/statistics/268429/workstation-shipments-worldwide-since-the-3rd-quarter-2008/
[11] http://jonpeddie.com/publications/workstation_report

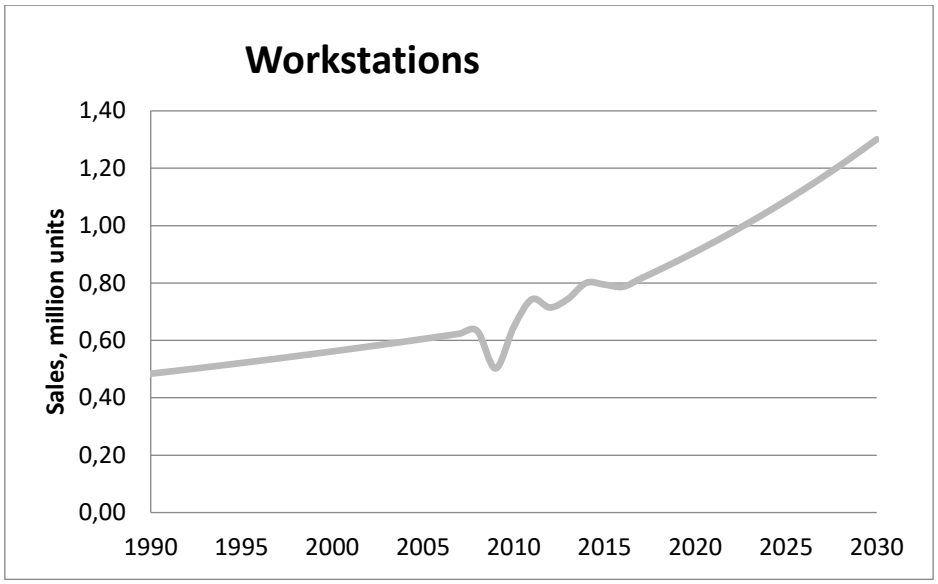

Figure 9. Estimated EU sales of workstations 1990-2030.

2.2.1.5 Thin clients and integrated thin clients

Available sales data before 2013 was limited and therefore sales were assumed to be constant during the period from 2003 to 2013 and equal to the sales in 2013. From 1993 to 2002, the estimated data follows the data estimated by the previous Impact Assessment on computers[13]. Sales data for thin clients during 2013 – 2016 in Europe and the Middle East and Africa (EMEA) have been estimated by IDC[12]. Out of the total EMEA sales, the EU accounts for approximately 72%.

Due to the lack of forecast insights, we had to assume the development. The assumption is that there will be no major growth in sales of for thin clients up until 2030 based on the relatively moderate interest in using thin clients. The sales for thin clients are therefore modelled to follow the population growth rates (i.e. the ratio between sales and population remain constant).

No sales data could be sourced for integrated thin clients. Given the lack of data it was assumed that sales of integrated thin clients are equal to 10% of thin client sales in each year.

See Figure 10 for the estimated EU sales of thin clients and integrated thin clients.

[12] http://www.idc.com/getdoc.jsp?containerId=prCZ25900215

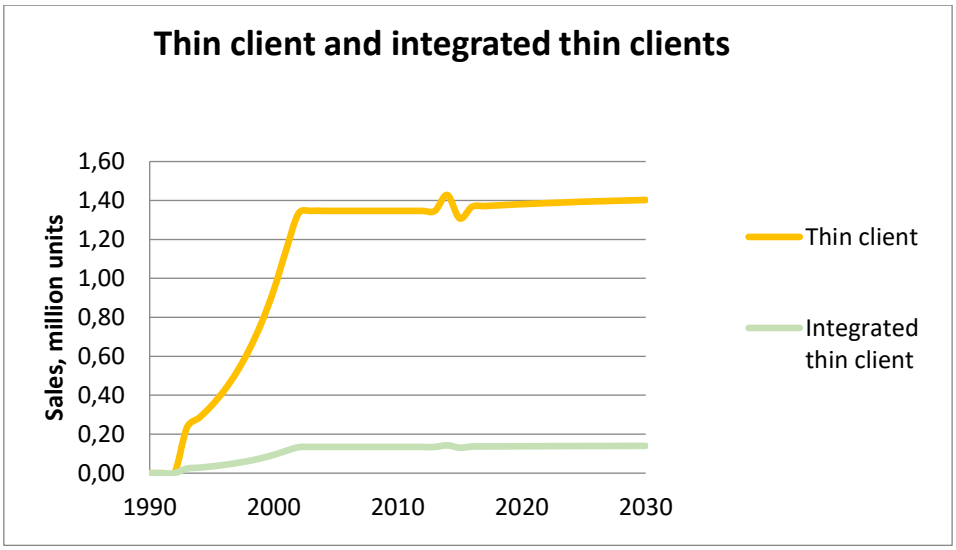

Figure 10. Estimated EU sales of thin clients and integrated thin clients 1990 -2030.

2.2.1.6 Notebook computers

It is assumed that notebook computer sales were insignificant until 1990, and then increased linearly up to 2000. Notebook computer sales in 2000 were estimated to be 6 million within the preparatory study for computers[13] and increased to 31 million by 2008.

The 2009 to 2020 sales are based on global desktop and notebook data and forecasts from Statista[14], where 20% of the sales are assumed to be in the EU. The relative share of notebooks compared to desktop computers was assumed to grow over time with 2008 being the first year where more notebooks were sold than desktops. No predicted data was found for the years 2020 to 2030. It was assumed that there would be some further growth in EU notebook computer sales due to EU population growth and notebook ownership per capita across the EU raising to similar levels as seen in the United Kingdom[15], where notebook ownership levels are high.

The sales for 2-in-1 notebook computers (also known as detachable notebooks and tablet computers in ecodesign nomenclature) are also included in the sales of notebooks. Their sales are estimated to have started in 2008, where the figures from 2008 to 2015 have been estimated based on the market share of different categories in ENERGY STAR database and available sales data for notebook and desktop computers. There is a steady and gradual increase until 2016, where the sales for 2-in-1 are expected to have grown 73% from previous year and that year by year growth would be 15% in 2020, and it can be expected that the same growth rate continues in 2017 – 2020 as the technology matures. No consistent forecast was found for after 2020, so it is assumed that growth follows population growth and increasing ownership per capita.

See Figure 11 for the estimated EU sales of notebooks together with desktop computers for comparison.

[13] Preparatory study for LOT 3 Personal Computers (desktops and laptops) and Computer Monitors, 2007
[14] http://www.statista.com/statistics/272595/global-shipments-forecast-for-tablets-laptops-and-desktop-pcs/
[15] Mintel Report, Digital Trends Spring – UK, March 2016

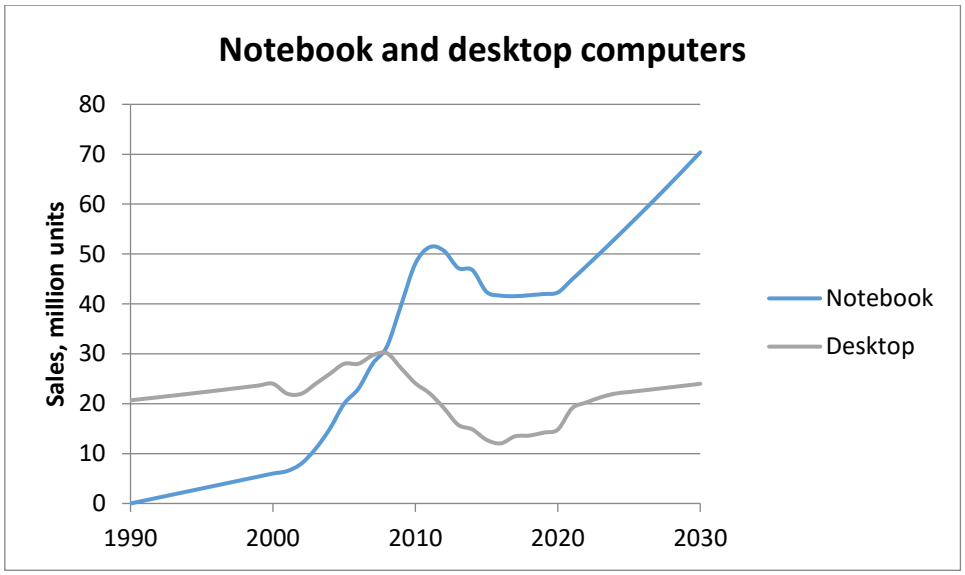

Figure 11. Estimated EU sales of notebook and desktop computers 1990 -2030.

2.2.1.7 Tablet/slate computers

Tablets and slate computers are relatively new to the computer market, with sales assumed to have started in 2010 with the launch of the first Apple iPad. Sales from 2010 to 2014 were based on Statista global sales data[14], and applying the 20% EU share value (as detailed in section 3.1.1). It should be noted that it was not possible to identify the size of products that were covered under the market research company data. Assuming that this Statista category also covers portable all-in-ones (often seen as very large tablet computers) and for the purposes of this project, sales of portable all-in-ones (see next section) have been deducted from the total tablet and slate computer sales and modelled separately as energy use characteristics for some portable all-in-ones are different from other tablet/slate computers. The estimated data fit well with expert knowledge that the sales were highest in 2013-2014. Since there is no consistent forecast after 2016, it is assumed that sales will follow population growth up to 2030. See Figure 12 for the estimated EU sales of tablets and slate computers.

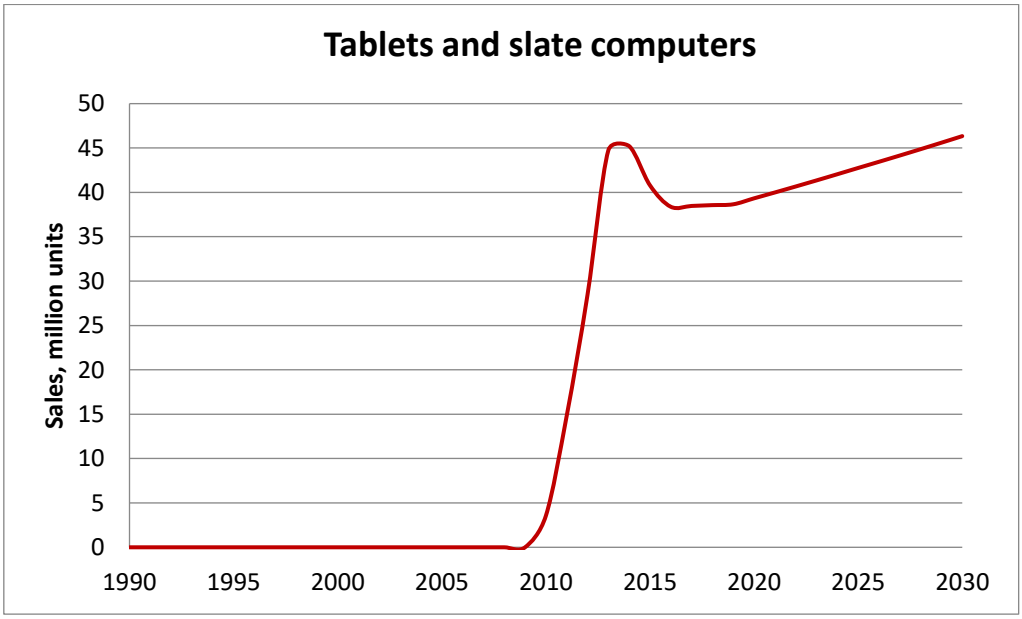

Figure 12. Estimated EU sales of tablet and slate computers 1990 -2030.

2.2.1.8 Portable all-in-ones

No external sales data for portable all-in-ones could be found. As such, the sales of portable all-in-ones are based on the number of products found in the EU ENERGY STAR database which is approx. 0.1% of the entire computer market. For the sold units and sales trend, it was assumed to follow the sales of notebook computers. It is recognised that this approach results in a significant amount of uncertainty.

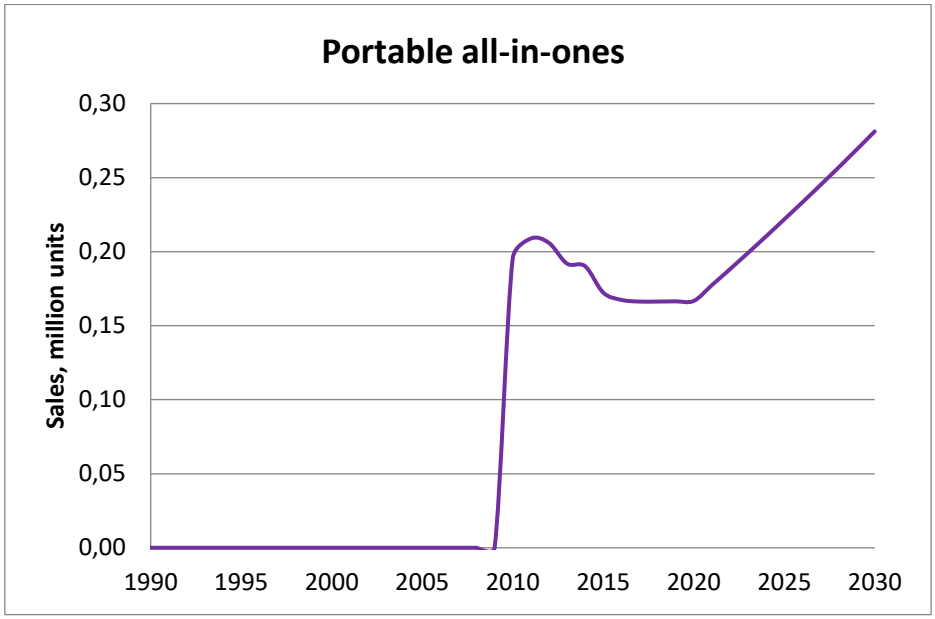

Figure 13. Estimated EU sales of tablet and slate computers 1990-2030.

2.2.1.9 Small-scale servers

As for workstations, identifying sales volumes for "small-scale servers" is complicated by the fact that manufacturers use a variety of product names, in addition to "small-scale servers", when referring to computers that provide storage and network services. The product terms such as "micro-servers" or "home servers" are also used. These products may be small-scale-servers but could also be more technologically advanced servers that provide processing functionalities. As such, the sales data should be treated with some caution.

Once identified what the relevant sales for small-scale servers were, it was realized that the market for small-scale servers is relatively small. Sales estimation for 1999 to 2020 is taken from Impact Assessment, which based their calculation on global sales data from 2007. Before 1999, the sales are assumed to follow the growth rate of 1.5% p.a. used in Impact Assessment. There is reason to believe that the small-scale servers market will not grow significantly after 2020 because there is a trend of moving individually owned servers to cloud applications, so growth in sales is assumed to follow population growth only. See Figure 14 for EU estimated sales.

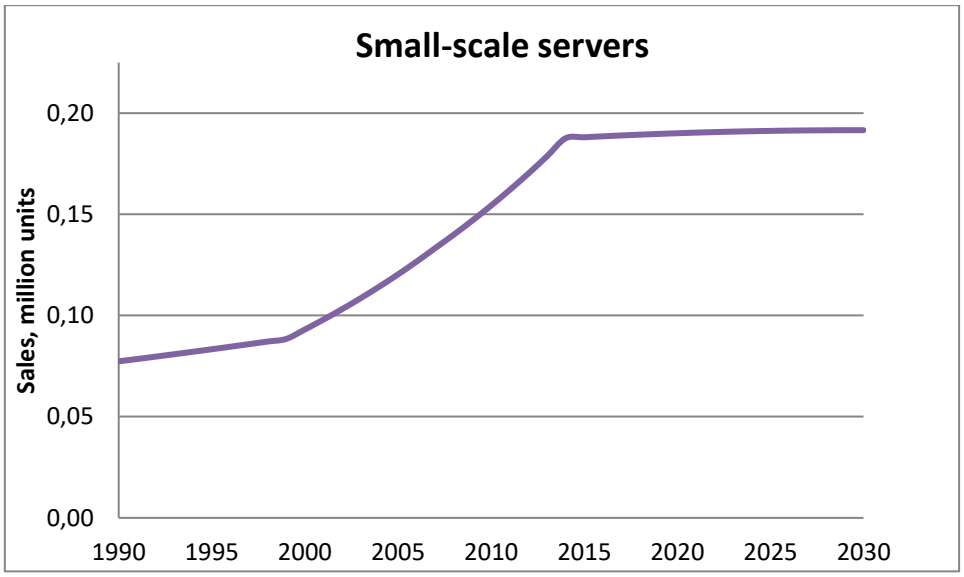

Figure 14. Estimated EU sales of small-scale servers 1990-2030.

2.2.1.10 External graphics adapters

Sales for external graphics adapters (EGA) are estimated to be small before 2008 due to a lack of standards supporting use of these products. In 2008, AMD launched its XGH external graphics standard, therefore sales from 2008 were expected to increase. The increase is based on assumed ratio of notebook and desktop computers using external graphics adapters. The share of notebook computers sold with "the possibility" of using a separate EGA is assumed to be low (5%) in 2015 but increasing to 25% in 2030 as improved connections (e.g. Thunderbolt 3) encourage more use of powerful external graphics cards. The number of EGAs used with desktop computers is estimated to be lower at 2% in 2015 and 10% in 2030, since discrete GPUs can be more readily included within desktop computers hence diminishing the need for a separate EGA. See Figure 15 for estimated EU sales.

2.2.1.11 Docking station

The EU market sales for docking stations between 2015 and 2020 are estimated based on published sources, which state that global sales reached 43 million units in 2015 and is expected to reach over 50 million by 2020[16]. Again, it was assumed that 20% of the market is assumed to be within EU. Sales between 2015 and 2020 have been interpolated. Sales before 2015 are estimated. From 2021 onwards, the sales growth rate is based on growth rate in notebooks and the same ratio of docking stations per notebook. See Figure 15 for estimated EU sales.

2.2.1.12 Peripheral products (keyboards and mice)

It is recognised that there are many other peripheral products used with personal computers, but keyboards and mice are the most typically peripherals that are bundled with personal computers as they are placed on the market. Whilst the amount of energy used by these products during operation would be minimal, given the large sales volumes there may be wider environmental considerations relating to resource use. For modelling purposes, a keyboard and a mouse was assigned to each desktop, integrated desktop

[16] http://www.businesswire.com/news/home/20160122005015/en/Global-Docking-Station-Market-Worth-USD-7.3

and workstation. Furthermore, it was assumed that a third of notebooks would be used with a mouse and external keyboard. See Figure 15 for estimated EU sales.

2.2.1.13 External Power Supplies (EPS)

External power supply units (EPS) sales are based on background data from the EPS review study from 2012[17]. This study included all types of EPS including those for mobile phones, set top boxes, amongst other products where EPS are used for. Only two categories were relevant for this study: 'Portable PC/Laptop (90W)' and 'Tablets (10 W)', which represent the EPS figures in this study. The population growth[18] is used to estimate the growth rate in EPS sales from 2009 to 2030. For the stock calculations, a lifetime of 5 years was assumed for the PC/laptop EPSs, and 3 years for the Tablet EPSs. Since there is no data for EPS sales prior to 2009, Figure 15 shows the sales as zero from 1990 to 2009.

2.2.1.14 Internal Power Supply Units

Estimated Internal PSU sales (i.e. where PSUs are sold as separate products and not those placed on the market within a computer) are based on an estimated share of desktop computers that are self-built. The term "self-built" is used to refer to individuals that build computers from a collection of components for personal use rather than manufacturers that also assemble computers from components to later sell on the market. Research indicated that most self-built desktop computers are higher end gaming machines and that they account for approximately 6% of desktop computer sales. This 6% value was based on the published [19] percentage of high end desktops that are DIY multiplied by the estimated share of high-end desktops on the EU market (based on IDC data)[20]. See Figure 15 for estimated EU sales.

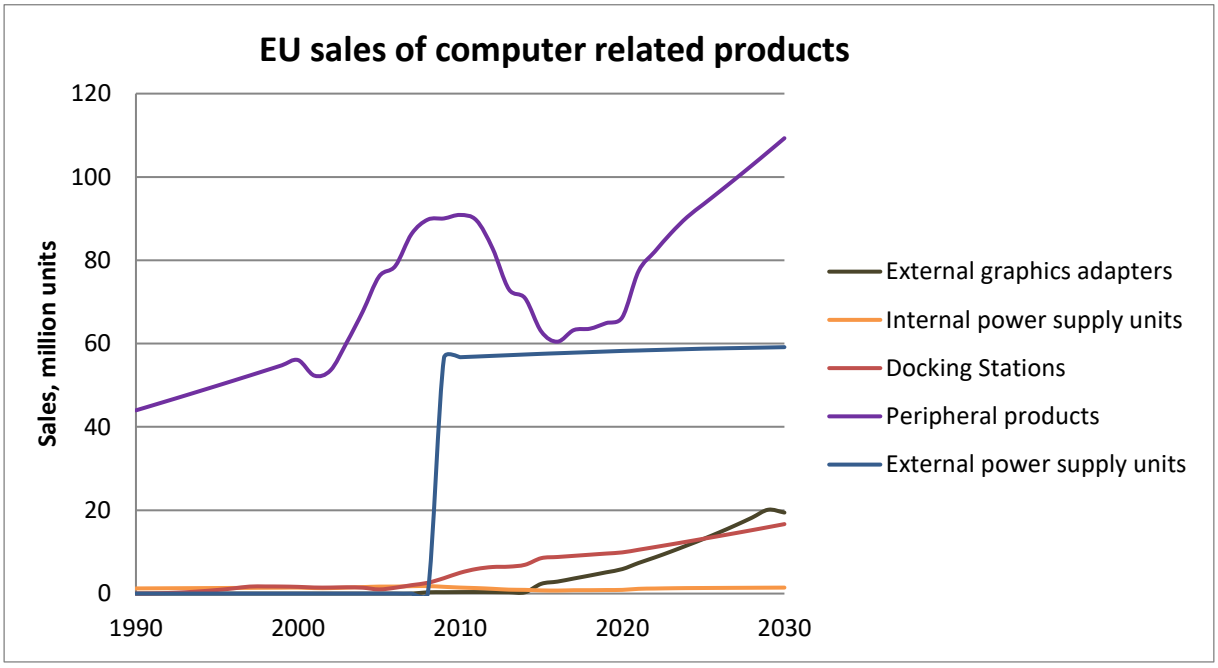

Figure 15. Estimated EU sales of computer related products 1990-2030.

[17] https://www.ebpg.bam.de/de/ebpg_medien/ener7/007_studyd_13-03.pdf
[18] http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00114
[19] https://www.jonpeddie.com/download/media/slides/Enthusiast_PC_Gaming_HW_Report_2H14_TOC.pdf
[20] Interim Report 3: Q3-Q4 2015: Survey of the Market Penetration of Energy Efficient Office Equipment under the EU ENERGY STAR Programme)

2.2.2 Installed base ("stock")

Stock of the selected categories of computers and related products have been calculated using annual sales presented in section 2.2.1 and applying a normal distribution, assuming the typical lifetime as the mean and the standard deviation of 1. The annual sales and the normal distribution based on the lifetime were used to establish the installed base (i.e. the stock).

Table 4 presents the typical lifetime assumed for the different categories, which was based on findings from the preparatory study, the impact assessment, expert assumptions and industry inputs to studies of external power supplies[21], which also included data on computer products.

Table 4. Typical lifetime used for stock model for computers and related products.

Category	Typical life time, years
Notebook	5
Desktop	6
Integrated desktop	6
Thin client	5
Integrated thin client	5
Tablet/Slate	3
Portable all-in-one	5
Workstation	7
External graphics adapters	5
Internal power supply units	6
Small scale servers	6
Docking stations	5
Peripheral products	6

Figure 18 shows the development of sales and stock from 1990 to 2030. In some years the stock declines due to changes in the market, e.g. when the level of functionality available in products is more than adequate to run the applications that most people use. However, it increases again thereafter, as the demand for new and more computational intensive functionalities from the end-users increase.

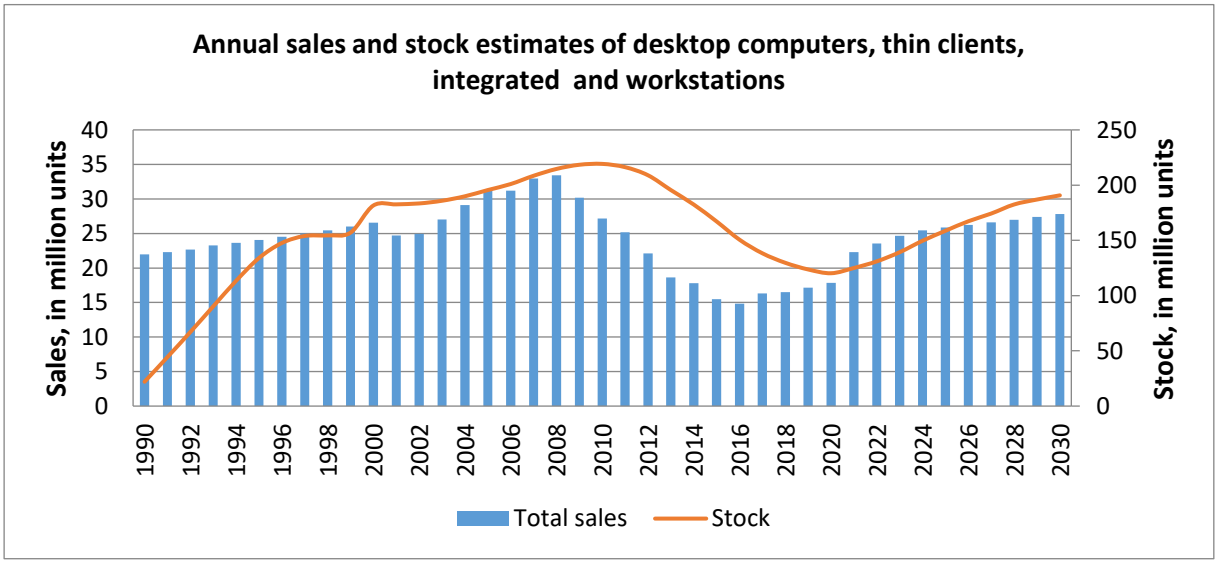

Figure 16. Annual total sales and stock estimation of all stationary computers including desktop computers, integrated desktop, thin client, integrated thin clients and workstations.

[21] Impact assessment for external power supplies, 2015.

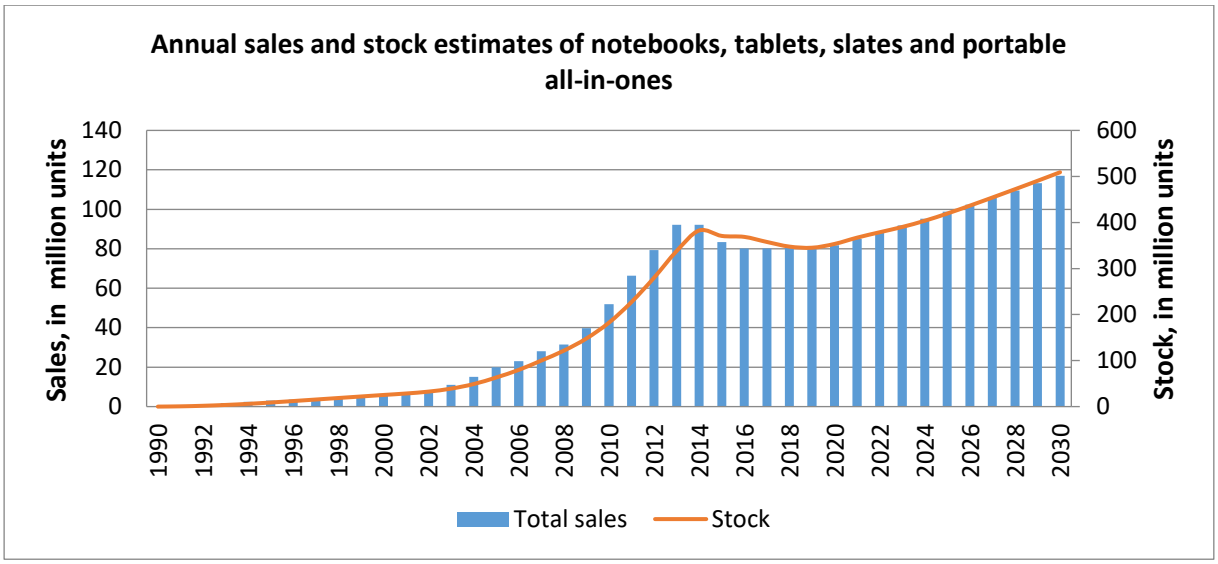

Figure 17. Annual total sales and stock estimation of all portable computers including notebook, tablets, slates and portable all-in-ones.

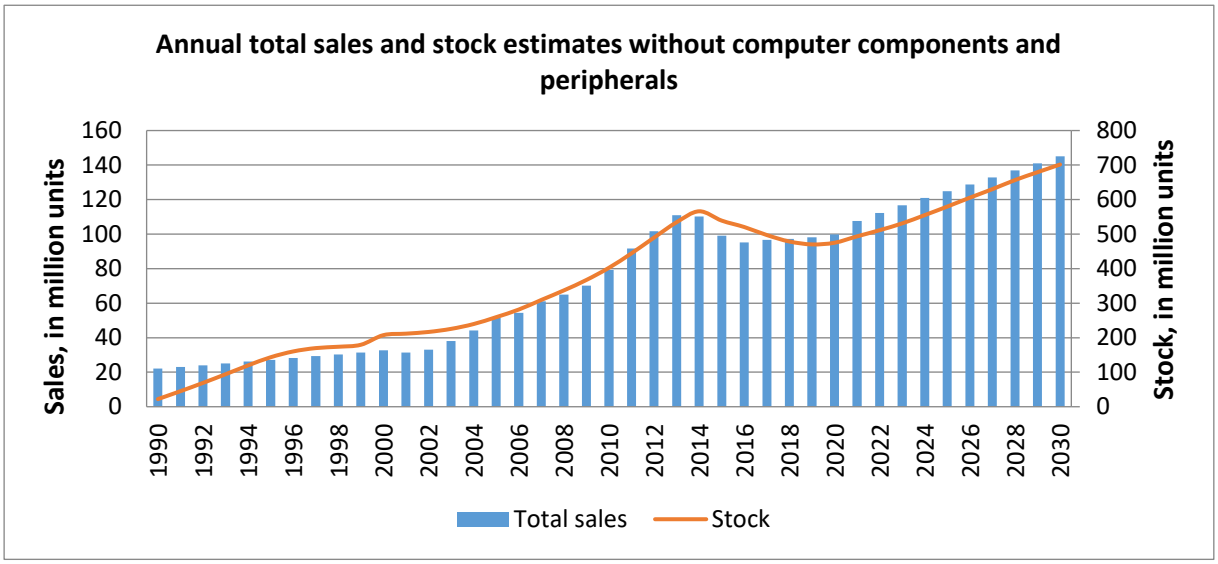

Figure 18. Annual total sales and stock estimation including all computers without related products.

The total stock for computers and computer related products is estimated to be 852 million in 2015 and is expected to increase to 1.2 billion in 2030. From these products, the total computer stock (i.e. only computer products) is estimated to be 535 million in 2015 and this will increase slightly to 671 million by 2030 due to increasing sales volumes of most types of computer. Sales of notebook and desktop computers have stalled slightly in recent years due to a wide range of issues including weak economy and the fact that personal computers are able to accomplish most tasks currently required of them. However, as the economy improves and new higher performance demanding applications come to market (e.g. virtual reality and ultra high definition (UHD) content), sales of these products are expected to increase again.

Table 5. Estimated stock for computers and related products 2010-2030.

Million units	2010	2015	2020	2025	2030
Notebook	178.63	230.52	216.56	272.09	349.02
Desktop	199.41	148.70	102.23	137.96	167.62
Integrated desktop	7.17	4.93	3.56	5.06	5.99
Thin client	7.41	7.45	7.54	7.63	7.69
Integrated thin client	0.74	0.74	0.75	0.76	0.77
Tablet/Slate	3.56	139.28	135.86	146.25	158.65
Portable all-in-one	0.20	1.03	0.92	1.08	1.39
Workstation	4.51	5.28	6.18	7.26	8.69
Total computers	**402.50**	**539.05**	**475.04**	**579.79**	**701.66**
External graphics adapters	*0.99*	*3.84*	*22.48*	*53.25*	*94.82*
Internal power supply units	*10.72*	*7.38*	*5.32*	*7.57*	*8.95*
Small scale servers	*0.88*	*1.12*	*1.43*	*1.69*	*1.84*
Docking Stations	*15.20*	*36.22*	*50.54*	*63.85*	*82.48*
Peripheral products	*542.49*	*514.91*	*418.99*	*527.70*	*651.39*
Total all	***971.90***	***1101.39***	***972.37***	***1232.15***	***1539.30***

2.3 Market Trends

2.3.1 General market trends

The personal computer market is extremely diverse both in terms of the types of products placed on the EU market and in terms of the different organisations involved within the industry. The industry has a reputation for extremely quick product innovation with new types of products frequently being launched to market. Continual evolution in terms of the levels and types of functionalities that are supported through established computer form factors, such as notebook and desktop computers, is also a hallmark of the industry. In addition, there is also both continual divergence (i.e. specialised functions) and convergence (i.e. common functions) between the functionalities provided by personal computers and related electronic products such as smart phones, game consoles and other digital media playback devices.

Personal computers provide a broad range of functionalities for users, who in turn leads to a diverse range of personal computer types on the market. The relationship between innovation in functionalities and innovation in product design is multi-faceted with product design sometimes encouraging new types, or levels, of functionality whilst new functionalities can also drive technological change within products.

It is not just new computer hardware that forces change within the computer industry. New or updated software, such as operating systems (e.g. Microsoft Windows, Linux, Mac OS, Android, Chrome OS), can also have a significant impact on the shape of the personal computer market. For example, adding the ability for operating systems to support touch screen technology can stimulate demand for touch screen products in the marketplace. In addition, where new operating systems and software package updates are not supported by older technology it results in product obsolescence and a consequent growth in sales of new products. Conversely, new and more optimised versions of established operating systems would negatively impact on sales of new products as the useful life of existing products would be extended – if the operating systems can use the hardware resources more efficiently.

The enhanced levels of innovation present in the personal computer industry have resulted in some key market trends emerging over the last several years. More details are presented in the following section.

2.3.1.1 Growth of Mobile

Since 2008 notebook computers have outsold the more traditional desktop computer thanks to improved levels of computational performance, reduced purchase costs and better battery life combined with the convenience of portability/mobility or even security (e.g. no UPS necessary and possibility of hiding the computer). The trend towards mobile computing products accelerated in 2010 with the advent of the tablet computer, (academically known as the slate computer). Popularity of tablet computers increased significantly from 2010 to 2014 but has since reduced as other types of computing product offering similar, or better, levels of functionality become more popular. For example, smart phones now offer much of the same level of functionality found in tablet computers though the user interfaces (keyboards and screens) are less usable for many purposes. Other types of mobile product such as the 2-in-1 notebook, which offers the convenience of a tablet when an attached keyboard is removed, but the computational performance of a notebook computer when the keyboard containing enhanced components is attached.

2.3.1.2 Smaller Form Factors

In general, due to improvements in technology, personal computers can be made smaller whilst at the same time levels of functionality can be increased. There is a trend towards mini-desktops and laptops, stripped of floppy disks since a while, are now also stripped of DVD units. With the advent of USB-C even external connectors, such as USB-A or audio jacks and SD readers will be phased out. Light and thin tablets/slates have now performances comparable or superior to low-end laptops.

Another example is small stick computers that can be attached directly to a television HDMI socket, which can provide a broad range of high definition media functionalities that could only previously be supported by devices many times the size and with a much higher power demand.

Whilst not all types of personal computers will shrink in size, there is a general trend towards smaller devices.

2.3.1.3 Virtual Reality and Gaming

Technological advances in virtual reality and gaming are likely to stimulate increasing demand for higher specification computers, and especially high-end discrete graphics cards. Virtual reality as it stands in 2016 is still in its infancy but already requires very high specification desktop computers to operate effectively. As the levels of sophistication in virtual reality and gaming increase so will the need for ever greater computational performance.

2.3.1.4 Data Science and Advanced Machine Learning

Businesses are aware that a better understanding of their markets and customers through the analysis of digital data can improve business performance and lead to higher profits. The need to analyse the ever increasing amounts of digital data (also called "big data") available to businesses is resulting in the growth of advanced analytical activities that require higher performance computers.

2.3.1.5 The Internet and the Internet of Things

The Internet has helped to drive the uptake of computers within all sectors of society, as users seek access to enhanced ways of working, connecting or improvements in entertainment services. New ways of using the Internet to improve connectivity between

a diverse range of devices, often called the "Internet of Things", whilst not directly supported by personal computers as we know them, will likely encourage new uses for personal computers and alike devices and changes in the types of personal computers available on the market.

2.3.2 Market channels and production structure

The personal computer product market in the EU consists of both large multinational organisations and a large number of smaller organisations. IDC data suggests that during the years 2014 to 2015 five main manufacturers were responsible for over 70% of the 169 million personal computers placed on the market within Europe, the Middle East, and Africa (EMEA) region (no EU specific data are available, therefore EMEA data are referenced). The remaining 30% of the market still accounted for over 49 million personal computers within the EMEA region. Analysis conducted for this project suggests that the EU-28 accounts for approximately 70% of personal computer sales within the EMEA region and it is assumed that the share of sales per manufacturer would be similar at the EU level as at the EMEA level.

The top three manufacturers in terms of personal computer sales, as well as many other large manufacturers, are represented by the European industry association DigitalEurope[22]. ASUS and Acer (among the top five manufacturers) are not currently represented by DigitalEurope. See Table 6 for the top five vendors in the EU.

Table 6. IDC Top five Vendors for Europe, the Middle East, and Africa (EMEA) Personal Computer Shipments.[23]

Vendor	2014 Shipments million units	2015 Shipments million units	2014 Share	2015 Share
HP	20.65	17.91	22.2%	23.5%
Lenovo	17.03	15.22	18.3%	19.9%
Dell	9.20	8.14	9.9%	10.7%
ASUS	8.16	7.15	8.8%	9.4%
Acer Group	9.91	6.81	10.6%	8.9%
Others	28.19	21.11	30.3%	27.7%
Total	**93.14**	**76.35**	**100.0%**	**100.0%**

Production of personal computers is highly fragmented across the globe, with many different types of organisations involved including component designers, key component manufacturers, component assemblers to global brands selling pre-assembled products. Organisations may belong to one or more, sometimes all, of these different groups.

Organisations – which design key computer components – are primarily based in the USA, EU and South East Asia but are also increasingly found in Latin American countries. Key computer components, such as CPUs, are manufactured in throughout the world including the USA, South East Asia and within the EU[24, 25]. High volume product assemblers are primarily based in countries with lower labour costs, such as China, but computer assembly is also conducted in many other regions. Personal computer vendors are based in almost all countries throughout the world but the largest are headquartered in the USA and South East Asia.

[22] http://www.digitaleurope.org/
[23] https://www.idc.com/getdoc.jsp?containerId=prEMEA40979216
[24] http://www.intel.ie/content/www/ie/en/company-overview/intel-leixlip.html
[25] http://globalfoundries.com/about/manufacturing

2.3.3 Trends in product design and features

Given the large variety of products within the personal computer industry, and the even greater variety of functionalities provided by these products, means that there are numerous new and evolving trends in product design and features. The main drivers for change in the personal computer product design and features include, amongst many others; vendors' financial profit, consumer and business desires for the "next big thing" in computing, additional functionality, product cost, quality and in more recent years' design for energy and resource efficiency, both because of pressure from regulators and attention by consumers and – in the case of mobile computers – because of increased autonomy (or reduced battery cost or size).

There are some key trends in product design and features that will have a large impact on this ecodesign projects. Some of those are described in the following.

2.3.3.1 Convergence and specialisation

There are many products on the market that – for all intents and purposes – are personal computers in that they contain computational components and provide computational functions. Whilst these different product types remain distinct, many functionalities and the hardware itself are converging: smartphones, game consoles, set-top-boxes, and media players. Indeed, the level of convergence can be so large that for some new types of products it is becoming increasingly difficult to identify which of the established categories of computers they fit into.

An integrated desktop with a big display may be considered different from a smart television with a small display because of the lack of internal hard-wired tuners. However, the use of these two product types can be very similar if we consider that a smart TV can support typical computer applications, such as Youtube or a web browser, and be operated via a keyboard and mouse, have its operating system updated and have to boot at startup. Gaming computers have blurred boundaries with game consoles in that they provide game play as their primary function but also support productivity software applications (e.g. word processing etc.) and are designed to be used either via a television or a computer monitor. Given the large cross over in functionalities it is therefore difficult to identify if these new types of gaming computers are desktop gaming computers or game consoles. This is an important consideration since energy associated with gaming computer devices is considerable. It has been noted that gaming computers account for 2.5% of global computer stock but account for 20% of total energy use, and that this energy use will more than double by the year 2020 if current sales and efficiencies remain constant[26].

Smartphones are also beginning to converge even further with other types of mobile personal computers such as notebook computers. For example, one major manufacturer has released a smartphone that can slot into a docking station that has an attached keyboard, larger battery and integrated display. The smartphone provides all of the computational hardware and the docking station provides all the other functionalities found in a notebook computer.

Whilst it is clear that there is a large amount of convergence in the personal computer industry, there is also a large amount of product specialisation. Furthermore, in many cases products share many of the same functionalities as other types of computers, and

[26] Mills et al, 2016, "Taming the energy use of gaming computers", available from http://evanmills.lbl.gov/pubs/pdf/Taming-the-Energy-Use-of-Gaming-Computers.pdf

so are largely converged, but may offer one or two specialised functionalities, or provide a shared functionality at a higher level of performance, which makes them unique.

For example, high definition media playback and internet surfing are supported through both stick computers and desktop computers and so are converged in these respects. Desktop computers, though, can provide a large number of functionalities unlike the stick computer. Conversely, the stick computer is specialised in providing media playback at very low power demand levels that could not be met by a typical desktop computer. These functionality differences between different types of computer are one of the primary causes of computer proliferation within EU businesses and homes. This uniqueness in functional units within different types of computers also makes it difficult to compare across all products on a like for like basis when attempting to identify environmental impacts and suitable requirements.

In this study, only computers that are likely to have significant environmental impacts will be covered. That is, products such as stick computers neither use a significant amount of energy in use nor have large material impacts and so will not be covered under the project scope.

2.3.3.2 Computing performance

As previously alluded to in the preceding section, many functionalities provided by computers drive demand for higher specification products. Over the last couple of decades, the continual need for better computational performance from personal computers has resulted in high sales volumes and short lifespans of existing products in stock. In more recent years, the level of computational performance needed for general home and office computing has remained largely static, with relatively old products being fully capable of supporting these functionalities. This has contributed to the reduced sales volumes of established types of personal computers, such as notebook computers, and resulted in the computer industry trying to stimulate sales through the introduction of new types of computers, such as tablets and the need to develop new functionalities that reinstate the drive for continual performance improvements.

2.3.3.3 Environmental impacts

Whilst computational performance remains an important driver in the personal computer industry, other drivers such as the need to reduce environmental issues associated with the products have increased in importance. Indeed, in recent years the personal computer industry has made significant improvements in reducing the environmental impacts from the energy use associated with the products that they place on the EU market.

For example, the average levels of energy efficiency found in new personal computers on the market is significantly better than found in products on the market just a few years ago. It is also clear that industry have taken some steps to reduce other environmental impacts associated with their products, such as reducing hazardous material content. However, recent research also shows that there is still significant scope for additional energy savings within the personal computer market[27].

Conversely, the trend of designing and manufacturing smaller computer products results in manufacturers gluing instead of screwing components to the cabinet and not letting the users replace or upgrade the battery, data storage, RAM modules, graphic cards and

[27] http://www.superefficient.org/Tools/Developing-Improving-Energy-Efficiency-Computers

integrated keyboards. This decreases the rate of recovery of components containing rare earth materials, precious metals, which would otherwise be recyclable. It also results in decreased product lifetime and reparability issues because the user cannot replace components and it is usually not cost-effective to have a technician do the job.

2.3.3.4 Technological Features

Changes in the types of computers available on the EU market occur quickly, but technological development of components used within personal computers occurs even more rapidly. This section of the report briefly investigates some of the component level technological features that are likely to have a strong influence on the analysis conducted as part of this study.

Central Processing Units (CPUs)

There have been considerable achievements by industry in terms of increasing the energy efficiency of CPUs. Many of these improvements have been achieved through die shrinkage (i.e. shrinking the size of transistors in the CPU) which reduces the power demand of transistors during switching. Industry have also taken steps to reduce current leakage within CPUs through improvements in insulating materials. Industry has also made greater use of dynamic voltage and frequency scaling within newer CPUs which can optimise power demand under given tasks. Adaptive Voltage and Frequency Scaling (AVFS), a relatively new technology, is also being used in CPUs to manage voltage with real-time monitoring of CPU conditions. CPU manufacturers have also continued to use older energy savings technologies such as clock gating, which works by disabling portions of the circuitry that are not needed during CPU operation. Integrating the voltage regulator onto the CPU die, rather than on a motherboard voltage regulator, has been shown to provide further savings in idle mode power demand. As well as new hardware features that reduce power demand, enhanced power management functions have also been included in newer CPUs, which allow CPUs to power down into much lower power modes quickly so as not to impact user experience.

Other power management technologies

Power management functionality is a well-established technology in personal computers. However, some users disable the functionality due to either real or perceived impacts on the usability of products. Newer power management technologies available in some higher end products allow main components (e.g. CPU, GPU etc.) to power down when not in use without the user knowing. Improvements in power management could therefore result in significantly more energy savings if users are not inclined to disable the functionality.

Optimising power management settings within a computers firmware has also showed to offer significant energy savings. Indeed, a recently published report showed that simply changing the power management settings in a computer's firmware could reduce idle mode power demand by 50%[28].

Graphics solutions

All personal computers contain either an integrated graphics processing unit (iGfx), a discrete graphics solution (dGfx) or both. In general, dGfxs provide much higher levels of graphics processing capabilities than iGfxs but also require more power. However, recent

[28] Aggios, 2015, "Desktop Computer Optimization Analysis and Demonstration Project - Final Report V1.0, May 31st 2015", available from http://docketpublic.energy.ca.gov/PublicDocuments/14-AAER-02/TN204795_20150531T234825_Vojin_Zivojnovic_Comments_Desktop_Computer_Optimization_Analysi.pdf

advancements in iGfxs have resulted in them providing levels of performance comparable to some middle range dGfx's but with significantly lower power demand.

In addition to performance improvements in iGfxs, technologies exist in the mobile computing platforms to allow switching between iGfxs and dGfxs. This switching technology allows the iGfx to be used when on battery power or when only when low graphics performance is required but then allows for the use of the dGfx when more graphics processing is required. As such, the higher power demanding dGfx is only used when the extra performance is required.

Manufacturers of dGfxs have also employed many of the power saving features described earlier for CPUs and in doing so have made significant improvements in the idle mode power demand of even very high specification graphics cards. However, there is still a strong correlation between increasing dGfx performance and power demand during active use, which is of concern given the likely impact of VR and gaming on performance demands into the future.

Power Supply Units

Computer PSUs can be separated into two main types: Internal PSUs and External Power Supply (EPS) units. Some types of personal computer, especially notebook computers but also increasingly desktop computers, use External Power Supply (EPS) units instead of Internal PSUs which themselves are predominantly used in desktop form factor personal computers.

The efficiency of a PSU is a measure of how efficiently Alternate Current (AC) is transformed into Direct Current (DC) used by the computer circuitry. The overall energy efficiency of a computer is therefore highly dependent on the efficiency of the PSU/EPS itself. There is still a wide range of efficiencies within PSUs available on the EU market, but highly efficient PSU's, especially DC-DC based products, are available on the market. EPS tend to be, but are not always, more efficient than internal PSUs. The varying efficiency levels of PSUs available on the EU market are discussed in detail within the Task 4 report.

Integrated Displays

In general, the displays integrated in some types of personal computers such as notebooks and integrated desktop computers have become increasingly efficient in recent years. Some displays have achieved increased efficiency through the inclusion of improved components such as highly efficient LEDs and Dual Brightness Enhancement Film (DBEF). Integrated display panels are typically manufactured by a limited number of panel manufacturers around the world that provide the same panels for use in other display products such as detached computer displays and televisions. The connected electronics may be different from one end-product manufacturer to another.

Panel self-refresh

Panel self-refresh (PSR) technology offers the opportunity for high power demanding components within a computer to enter low power modes when no refresh of an attached display is required. The technology relies on the inclusion of a small amount of RAM in a display, which stores the last screen image. Panel self-refresh (PSR) technology was initially designed for use in notebook computers where it serves to help increase battery life. However, it could also be included in other displays to help reduce power demand in other types of computer.

Storage

Most personal computers require a device on which data can be permanently stored. Hard disk drives (HDD) or solid state drives (SSD) are the main forms of permanent storage used in computers. The energy use of these drives varies considerably between the two types, with SSDs generally being more efficient because of them having quick resume times from lower power modes to active states and as a result of them not needing mechanical energy to spin platters. Indeed, the increasing uptake of SSDs in place of HDDs has resulted in significant energy savings. In addition, new types of SSD coming to market have significantly lower power demands than traditional SSDs, which could result in further savings. However, energy efficiency levels also vary considerably within the same type of storage device with some SSDs and HDDs being significantly more energy efficient than others. SSDs provide quicker access times to data and faster computer start-up than HDDs. These performance advantages could help to extend a product's lifetime as the length of time a user feels satisfied with performance is increased.

Memory

All computers rely on volatile random access memory (RAM) to function. Whilst RAM modules do not, in general, have very high power demand levels, overall energy use can be noticeable when multiple RAM modules are installed in a product. A new type of RAM called DDR4, is likely to offer significant energy savings in low power modes due to the inclusion of an enhanced power management functionality called "deep power down" which allows a RAM module to go into a sleep mode that requires no refresh of the memory. Conversely, additional RAM is frequently permitting an extension of the computer lifetime because the reduced "paging" activity to manage virtual memory improves the overall computer performance.

Enhanced connectivity

Most personal computers include external connections that allow other external products to be connected to the computer in order to increase functionality. The amount of data and power that can be passed through these connection dictates the usefulness of a connection. New types of computer connections have recently launched to market that allow significantly more data and power to be passed through a single connected cable. These increases in available data and power throughput open up new possibilities in terms of the types of devices that can be connected to a personal computer and the functionalities that these devices can provide.

For example, the recently released Thunderbolt 3 connection (delivered via the new USB type C connection) allows for up to 100 W of power throughput and 40 GB/s of data. This opens up the possibility of powering external displays from a notebook computer and provide video signal and even audio with a single cable/connection. The connection also opens up the possibility for using high specification desktop dGfx's, via an External Graphics Adapter (EGA) to provide graphics functionality to a notebook computer without needing to compromise battery life. Increasing usage of EGAs could result in significantly more energy use.

Docking Stations

Where the use of docking stations to support additional connectivity in notebook computers was once popular – especially in corporate environments – their usage has diminished in the past 6 or 7 years although new types of docking stations are coming to market, which transform tablets or phablets into notebooks (or rather 2-in-1). New

powered types of docking stations are also available, which can significantly increase the functionality of personal computers. These docking stations can have PSUs rated at up to 300 W and so could add a considerable energy burden.

2.4 Consumer expenditure base data

2.4.1 Average EU consumer prices

Table 7 and Table 9 present the product price data collected via online research, where average prices were established by expert interpolation of the low-end and high-end products. Low-end, high-end and average product prices are presented. Table 7 contains products which can be divided into sub-categories and Table 9 the remainder. Explanation of sub-categories are given below Table 8.

The intention of collecting prices at sub-category level is to show differences in prices and their correlation with performance and graphic capabilities. As observed, the price difference is quite large, both across the different graphic capabilities but also in terms of performance. The trend shows that as more capabilities as higher the price, which in some cases can be more than twenty times more expensive. This highlights the uncertainties it will bring by aggregating products categories with a wide range of performances, since this variation is also shown in the prices. Furthermore, the variation on price level (i.e. from low-end to high-end) is not as big as the variation between graphic capabilities and performance (i.e. between sub-categories).

For some of the product categories, the product sub-category does not apply, since the graphic capabilities and performance at those levels are not found for these products in the EU market. In those cases, the sub-category was found not relevant. For other product categories, it was not possible to find price information for some specific sub-categories. This is in particular for portable all-in-ones, thin clients and slate computers. If this sub-categorisation is still found relevant in the analyses of further tasks, more resources will be placed to find the missing data points to be able to identify the design option with the Least Life Cycle Costing, which is the basis for recommending policy measures.

Table 7. Computer product prices by product category, price level and performance (EUR/unit). See explanation of sub-categories below.

Product type and price level		Product price per sub-category (EUR/unit)					
		0	I1	I2	I3	D1	D2
Desktop computer	Low-end	191	569	674	335	554	806
	High-end	303	849	1000	1023	702	8580
	Average	**262**	**745**	**879**	**768**	**647**	**5701**
Integrated desktop computer	Low-end	319	405	485	588	540	909
	High-end	469	596	754	1885	1510	4763
	Average	**414**	**525**	**655**	**1404**	**1150**	**3336**
Notebook computer (incl. tablet computer)	Low-end	n.r.	225	344	477	489	1339
	High-end	n.r.	834	2771	3018	4381	5507
	Average	**n.r.**	**609**	**1872**	**2051**	**2939**	**3963**
Slate computer	Low-end	n.a.	125	258	n.a.	*n.r.*	*n.r.*
	High-end	n.a.	1362	2812	n.a.	*n.r.*	*n.r.*
	Average	**n.a.**	**904**	**1866**	**n.a.**	***n.r.***	***n.r.***
Portable all-in-one	Low-end	n.a.	1040	n.a.	455	n.a.	n.a.
	High-end	n.a.	3530	n.a.	1577	n.a.	n.a.
	Average	**n.a.**	**2608**	**n.a.**	**1164**	**n.a.**	**n.a.**
Mobile thin client	Low-end	n.a.	775	957	n.a.	*n.r.*	*n.r.*
	High-end	n.a.	867	1070	n.a.	*n.r.*	*n.r.*
	Average	**n.a.**	**833**	**1028**	**n.a.**	***n.r.***	***n.r.***

Product type and price level		Thin Client	Integrated Thin Client	Ultra-thin Client
Desktop thin client computer	Low-end	200	510	76
	High-end	1262	430	126
	Average	**869**	**460**	**108**

n.r. = not relevant - The sub-category does not apply to that type of computers since the performance at that level is not found on the EU market.
n.a. = not available - The data was not found available.

The ENERGY STAR specification 6.1 was used for defining subcategories of computers (except for workstations, small-scale servers and desktop thin clients, where sub-categorisation is not available) according to the performance and graphics capability. See Table 8 below. Desktop thin clients are sub-categories according to the product design types, which are also related to performance and graphic capabilities (i.e. thin client, integrated thin client and ultra-thin client).

Table 8. Subcategory definition according to performance and graphic capability as defined in ENERGY STAR specification 6.1.

Sub-category	Graphics capability	Desktop or integrated desktop	Notebook and other portable computers
0	Any graphics dGfx≤G7	P≤3	P≤2
I1	Integrated or switchable graphics[29]	3<P≤6	3<P≤5.2
I2		6<P≤7	5.2<P≤8
I3		P>7	P>8
D1	Discrete graphics dGfx≤G7	3<P≤9	2<P≤9
D2		P>9	P>9

Note: P is the performance score, which is defined as P = [# of CPU cores] × [CPU clock speed (GHz)], where # of cores represents the number of physical CPU cores and CPU clock speed represents the Max TDP[30] core frequency.

Table 9 shows the unit prices for personal computer products without sub-categories, peripheral products and components that are sold as separate units. The difference of prices between price levels is sometimes great, in particular for most of peripheral products and computer components. Due to the fact that no harmonised performance sub-categories exist yet for these products, average product prices will be used to perform the further Life Cycle Cost analysis in later tasks of this review study. However, the price differences between low and high end may be related to performance, which can be used to identify BAT and improved design options. This will be investigated in further tasks.

[29] Integrated or switchable graphics are either (i) a type of graphics solution included in personal computers where graphics components are found either within the CPU die or on a separate component but without their own dedicated memory (i.e. integrated graphics), or, (ii) a functionality included in personal computers that always switching between the use of integrated graphics and discrete graphics depending on the level of graphic performance required (i.e. switchable graphics).

[30] Max TDP is the maximum amount of heat generated by the CPU that the cooling system in a computer is required to dissipate in typical operation. It is defined in watts (W) and declared by the CPU manufacturer.

Table 9. Computer, peripheral and component products prices by product type and price level (EUR/unit).

Product group	Product type and price level		Product price (EUR/unit)
Personal computer product	Workstation computer	Low-end	912
		High-end	7337
		Average	**4957**
	Mobile workstation computer	Low-end	897
		High-end	2987
		Average	**2213**
Computer server	Small scale server	Low-end	312
		High-end	2234
		Average	**1522**
Peripheral products	External graphic adapter	Low-end	31
		High-end	298
		Average	**199**
	Mice	Low-end	4
		High-end	451
		Average	**285**
	Keyboards	Low-end	9
		High-end	208
		Average	**134**
	Docking stations for notebooks	Low-end	54
		High-end	235
		Average	**168**
Computer components sold as separate units	Internal power supply	Low-end	17
		High-end	391
		Average	**252**
	External power supply	Low-end	23
		High-end	100
		Average	**71**
	CPU	Low-end	26
		High-end	2877
		Average	**976**
	Discrete graphics card dGfx	Low-end	29
		High-end	7205
		Average	**2273**
	Internal storage	Low-end	47
		High-end	615
		Average	**404**

2.4.2 Electricity prices

Electricity prices are presented in the MEErP methodology. Recent updated average household and industry prices were found for 2014 including average annual price increase based on EUROSTAT[31], and are presented in Table 10.

[31] Source: Eurostat, assessed December 2015

Table 10. Household and industry electricity costs.

EU country	Household electricity price, €/kWh	Annual household price increase, %/a	Industry electricity price, €/kWh	Annual industry price increase, %/a
Belgium	0.2097	-3%	0.0916	0%
Bulgaria	0.0832	-10%	0.0736	-8%
Czech Republic	0.1283	-16%	0.0819	-19%
Denmark	0.3042	1%	0.0934	4%
Germany	0.2981	2%	0.0844	-2%
Estonia	0.1307	-3%	0.0794	-6%
Ireland	0.2407	5%	0.1303	-2%
Greece	0.1767	13%	0.1090	5%
Spain	0.2165	-3%	0.1185	2%
France	0.1585	4%	0.0743	-5%
Croatia	0.1312	-4%	0.0903	-4%
Italy	0.2446	7%	0.1080	-4%
Cyprus	0.2291	-17%	0.1672	-16%
Latvia	0.1365	-1%	0.0903	-5%
Lithuania	0.1330	-3%	0.0958	0%
Luxembourg	0.1738	4%	0.0949	1%
Hungary	0.1202	-14%	0.0836	-8%
Malta	0.1474	-11%	0.1770	-1%
Netherlands	0.1821	-5%	0.0771	-2%
Austria	0.2021	-3%	0.0827	-5%
Poland	0.1421	-4%	0.0777	-12%
Portugal	0.2175	5%	0.1029	1%
Romania	0.1290	-2%	0.0753	-17%
Slovenia	0.1630	1%	0.0754	-10%
Slovakia	0.1507	-11%	0.1107	-11%
Finland	0.1563	-1%	0.0664	-2%
Sweden	0.1967	-6%	0.0702	-12%
United Kingdom	0.1918	10%	0.1246	11%
EU (28 countries)	**0.2038**	**2%**	**0.0917**	**-2%**

2.4.2.1 Interest, inflation and discount rates

The generic interest and inflation rates in the EU-28 are presented in Table 11. The European Commission recommends a discount rate of 4%[32].

Table 11. Generic interest and inflation rates in the EU-28[33].

	Domestic	Non-domestic
Interest rate (%)	7.7	6.5
Inflation rate (%)	2.1	
Discount rate (%)	4	

2.4.3 Repair and maintenance costs

Several costs are identified for the repair and maintenance of the products in scope:

- Service agreement (maintenance)
- Upgrading
- Repair

2.4.3.1 Service agreement

Preparatory study Lot 3[34] indicates that in most cases it is through service agreements that maintenance and repair costs or part hereof are paid by businesses. In some cases,

[32] http://ec.europa.eu/smart-regulation/guidelines/tool_54_en.htm
[33] VHK(2011), MEErP 2011 METHODOLOGY PART 1.
[34] Lot 3 Personal Computers (desktops and laptops) and Computers Monitprs. Final Report (Task 1-8). IVF Industrial research and Development Corporation. 2007.

the agreements do not include replacement of parts, e.g. broken display or used-up batteries, which in turn could be covered by an additional insurance. The same kind of service agreement may also be available for private users, if they choose the service, however the costs would differ for private users. Therefore, it is important to differentiate between Business to Business (B2B) and Business to Consumers (B2C) end-users.

According to Lot 3, service agreements with businesses are often included in the purchase price. Similar to when private consumers buy a computer, businesses are also prompted to buy extra insurance, guarantee, etc., and there is therefore opportunity to buy a service agreement for an additional charge during purchase. According to preparatory study, this kind of service agreement for a computer set that cost approx. 1000 €, the agreement costs about 67 € per year for B2B and up to about 120 € per year for private consumers[34].

An example of an extended service agreement for private end-users[35] found from desktop research online presents a cost between 67 € and 1,696 € for 3 years (ca. 23 € and 565 € per year respectively) depending on the response time, the coverage of repair activities and the location of the services to be provided. . For companies, service agreements can cost between approx. 22 €[36] and 130 € for 3 years[37] (ca. 7€ and 43 € per year respectively), depending as well on the response time, the coverage of repair activities and location of the services to be provided. Service agreements often cover a trained technician or necessary parts to be dispatched to the customer's site (if this option is chosen) within a certain response time (cost varies depending on the how quickly they should respond) to identify problems, repair or install new parts and other reparation activities.

2.4.3.2 Upgrading

Lot 3 preparatory study for computers and displays estimated that by 2007, only 2% of the end-users would upgrade to fulfil a better computer performance, and this would be mostly done by private users as it does not pay off for business. However, this may have changed from 2007 since now non-mobile and mobile personal computers come in smaller non-modular designs making upgrading more difficult and costly. In the contrary, purchase prices are lower making purchase at the same level or cheaper than upgrading.

A computer upgrade usually means hardware upgrades while keeping the majority of the components in the existing notebook and desktop computer (focusing on those components that are becoming slow and less powerful in light of the technological development). Desk research shows that an upgrade can cost about 225 € or less[38]. An upgrade could be switching to a solid-state drive, adding more or speedier memory (higher than 2-4 GB), replacing integrated graphics card with a discrete graphics card or with a stand-alone graphics card to improve frame rates and resolutions and upgrading CPU to chip with higher GHz.

Computer upgrades as such are mostly done by gaming or computer enthusiasts who are most likely to have the competences to assemble their own desktop computer, hereafter called "DIY" (do-it-yourself) computers. The enthusiast gamer DIY shows a much larger market than previously estimated. Based on a report on worldwide PC gaming hardware

[35] http://www.uk.insight.com/apps/productpresentation/index.php?product_id=0003249650
[36] https://www.pcworldbusiness.co.uk/catalogue/item/P121554P?from=category&heat=title
[37] http://configure.euro.dell.com/dellstore/config.aspx?oc=n005o3240aio&model_id=optiplex-3240-aio&c=dk&l=da&s=bsd&cs=dkbsdt1
[38] http://www.pcworld.com/article/2019575/10-killer-pc-upgrades-for-less-than-250.html

market[39], it is estimated that 6% of the desktops are DIY computers and therefore much more likely to undergo an upgrade.

2.4.3.3 Repair

According to preparatory study Lot 3 for computers and displays, those end-users who do not have a service agreement do repair their computers when they break. However, this may be true for the time when the preparatory study was published (2007), since the prices of computers have been dropping greatly, in particular for daily-use computers whose performance is not as high. Many private end-users choose to replace the computer with a new one, especially if breakdown occurs after the original basic warranty is out (usually 1-3 years). The repair costs identified by Lot 3 for repairing computers, monitors, software upgrade or reinstallation during the computer's lifetime are presented in Table 12. Software upgrade costs are only shown for comparison, but they are not part of the scope of this review.

Table 12. Repair costs identified in preparatory study Lot 3 during the computer's lifetime.

Type	Repair cost, EUR/service
Computers	50 -150 € (usually 75 € for ordinary service)
Monitors	120 €
Software	75 €
Total repair and maintenance costs	270 €
Total repair and maintenance costs (without software upgrade)	195 €

According to a study performed a major warranty provider for mobile personal computers (i.e. iPads and notebook computers) and other electronics[40]:

- 1 in 3 laptops fail over a period of 3 years.
- 31% of laptop owners reported a failure in the first 3 years, 20.4% of these came from hardware malfunctions.
- Netbooks[41] (defined as mobile personal computers with a purchase price equal to or less than ca. 360 €) are projected to have 20% higher failure rate from hardware malfunctions than more expensive laptop computers.

These figures show that there is a high rate of failure in some of the mobile personal computers, which tend to occur to low-end products.

A common repair may be the replacement of batteries for mobile personal computers. One of the most common problems is that the battery is damaged due to various reasons, so that it can no longer last the original amount of time. According to desktop research, a typical notebook battery costs 65 €- 130 €, however, the price can vary from 26 € to 260 € depending on notebook type and retailer.

For most notebook computers, the battery can be replaced by the users easily, and if battery is the only malfunctioning component, it is very likely that the battery will be replaced at least once within its lifetime. However, for ultra-thin notebooks, slates, tablets or portable all-in-one computers, the battery is enclosed within the casing and it

[39] http://jonpeddie.com/publications/pc_gaming_hardware_market_report
[40] https://www.squaretrade.com/htm/pdf/SquareTrade_laptop_reliability_1109.pdf
[41] Netbooks are small, lightweighted, legacy-free, and inexpensive computers introduced in 2007, which compete in the same market segment as table computers and some thin clients (i.e. Chromebooks). They are rarely seen on the market nowadays.

requires a trained technician to replace the battery. The cost of battery replacement would consist of the cost of battery itself and the fee for the technician.

For these notebook computers, the current regulation has set an information requirement on that this statement "*the battery /ies in this product cannot be easily replaced by users themselves*" be included in the technical documentation, free-access website and on the external packaging of the computer. In these cases, the cost of battery replacement will be in the high end.

2.4.4 Installations costs

Unless it is DIY notebook or desktop computers, installation costs are likely to be irrelevant. There are SMEs offering very customised computers, where the end-user can design a computer most suitable for their purpose by choosing the CPU, graphics card, hard disk and casing and other components. The end-users can then either assemble the components themselves or pay a fee to the SMEs to assemble everything and ensure it is running.

For B2B channels, the installation costs may cover setting up the computers so it is ready to use and this could be a part of the service agreement, depending on the terms of agreement. For B2C, it will be assumed no cost, with the exception of the DIY market and in the particular case it is the SMEs who do the assembly and installation.

2.4.5 Disposal costs

According to article 12 of the Directive on Waste Electrical and Electronic Equipment (WEEE), it is up to Member States to ensure that producers provide, at least, the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE from private households, providing that the WEEE has been deposited at collection facilities set up by Member States which allow end-users to dispose of the waste free of charge[42]. This Directive states that Member States may encourage producers to finance also the costs of collection from private households, i.e. by introducing a take back system.

Concerning the disposal of WEEE by others than private households, Article 13 of the same Directive states that all the costs, from collection to disposal/recovery, may be absorbed by the producers. The Directive states also that Member States may make end-users partly or totally responsible for these costs and gives the liberty to producers and end-users to agree on other financial methods.

A study made by BIO Deloitte in collaboration with other organisations[43] showed that, by the time of the study, great discrepancies still existed among Member States on the average fees paid by producers per piece of WEEE. Figure 19 shows these discrepancies for some of the products covered under the Directive, by normalizing to the highest paid fees in order to make a comparison. In spite these fees do not apply to computers, monitors and TVs can be used as an indication of the variation for personal computers with integrated displays. The authors of the study argued that establishing the share of the cost to manufacturers in proportion to that to Member States was very difficult for WEEE products, as this data was almost impossible to obtain. However, the results for

[42] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) – recast.
[43] Development of guidance on extended producer responsibility (EPR). Report for the European Commission – DG Environment. (2014). BIO Intelligence Service; in collaboration with Arcadis,Ecologic, Institute for European Environmental Policy(IEEP), Umweltbundesamt (UBA).

the comparison shown in Figure 19 resulted from a survey to countries belonging to the WEEE Forum[44] .

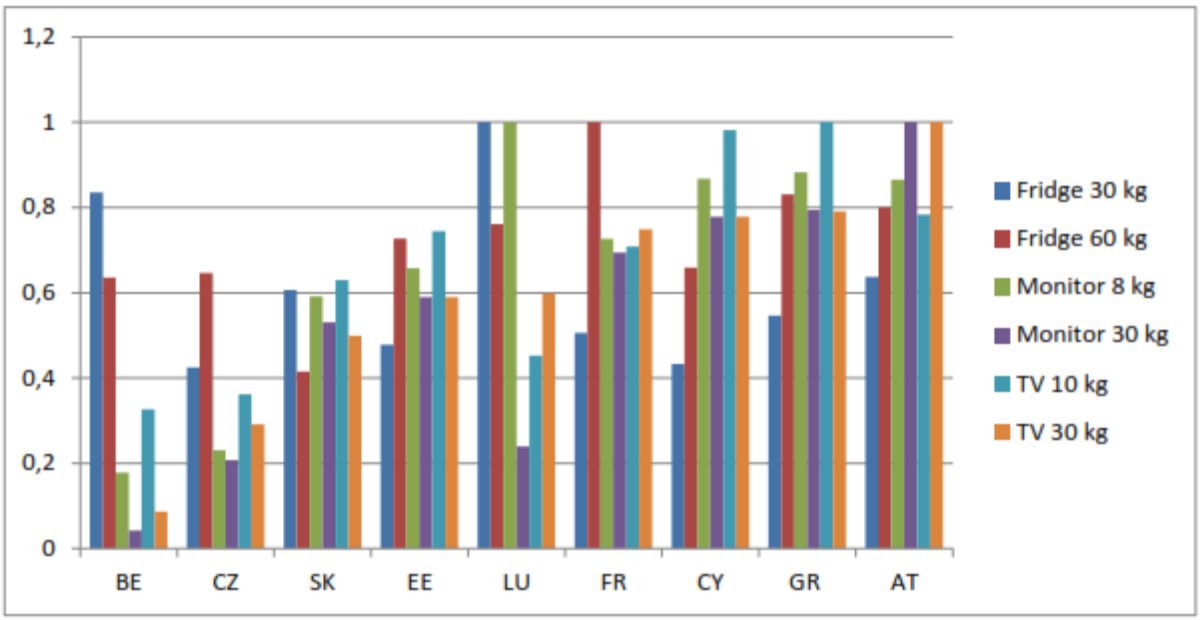

Figure 19. Normalised average fees paid by producers per piece of WEEE[45].

Furthermore, according to a study done by the Danish Environmental Protection Agency (i.e. Danish EPA)[46], the recycling costs of desktop computers and game consoles in the UK vary from £0-9/ton, those of notebooks vary from £9-250/ton and those of servers vary from £9-150/ton. The variation depends mainly on whether there is a Producer Responsibility Organisation (PRO), who manages the waste, or whether it is the municipality. In some cases, such as the case of notebook computers, this variation also depends on whether the display is free of mercury backlight.

According to expert judgment and based on an ongoing WEEE project in Denmark[47], an estimated interval for the costs of disposing/recovering/recycling WEEE could be 0-27 EUR/product.

It is the intention of the study team to establish contact with some of the authors of these studies and members of these organisations for the end-of-life assessment in the next tasks of this review study. This is to obtain more information about the share of fees paid by Member States and whether these are partially or totally absorbed by end-users in the form of taxes. Furthermore, it will be investigated whether the fees paid by the producers are included in the purchase price of the computer products.

[44] http://www.weee-forum.org/
[45] The fees have been normalised and presented as compared to the highest fees. Development of guidance on extended producer responsibility (EPR). Report for the European Commission – DG Environment. (2014). BIO Intelligence Service; in collaboration with Arcadis,Ecologic, Institute for European Environmental Policy(IEEP), Umweltbundesamt (UBA).
[46] Environmentally friendly design of electronic products. Project number 1449 (2012). Danish Environmental Protection Agency.
[47] Voluntary Agreement on the environmentally friendly design of products and recycling of electronic products. Project description available at (in Danish): http://mst.dk/service/nyheder/nyhedsarkiv/2013/okt/frivillig-aftale-om-elektronik/