An energy-aware survey on ICT device power supplies

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Additional information and materials relating to this Report can be found at:
www.itu.int/itu-t/climatechange.

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Table of contents

Page

1. Executive summary 3

1.1 Introduction 3

1.2 Report structure and main outcomes 3

2. Classification and category definition 5

3. Nameplate data 8

4. Mechanical features 22

4.1 Weight 22

4.2 Volume 26

4.3 Power density 28

4.4 Estimation on use of resources and e-waste 29

5. Electrical features 30

5.1 Efficiency measurements 30

5.1.1 Efficiency measurements – subdivided per-class 31

5.1.2 Efficiency at lower load – impact on some products 40

5.1.3 Power factor vs. load and efficiency 41

5.2 Correlation between safety class and efficiency 44

5.3 Replicability of the efficiency behaviour 45

5.4 Analytical analysis 46

5.5 Output voltage 52

5.6 No-load 59

6. Mass balance and environmental considerations 62

6.1 Global Warming Potential, GWP 62

7. Conclusion 63

8. References 65

9. Appendix A 66

9.1 Test bed 66

10. Appendix B – LIFE CYCLE ASSESSMENT METHODOLOGY APPLIED TO POWER SUPPLIES FOR CUSTOMER PREMISES EQUIPMENT * 67

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1. Executive summary

1.1 Introduction

This report presents the results of a study commissioned by the International Telecommunication Union (ITU) and the Global e-Sustainability Initiative (GeSI). The study analysed over 300 commercially-available External Power Supplies (EPSs) – devices both within and outside the ambit of information and communication technology (ICT) – with a view to providing input to the standardization activity of ITU-T Study Group 5 (Environment and climate change).

Decreasing the life-cycle environmental impact of EPSs is an exceptionally important part of efforts to 'green' the ICT sector, and the results of this study will inform work taking place within ITU-T Study Group 5 on phase two of the very successful ITU Universal Charging Solution – Recommendation ITU-T L.1000: *Universal power adapter and charger solution for mobile terminals and other hand-held ICT devices.*

Considering only the EPSs within the scope of this study, 4 billion new EPSs will be sold in 2012; a figure predicted to increase by 12 per cent annually. If not reasonably energy-efficient, they will consume unnecessarily large quantities of energy; and if not repairable in the case of failure, not (at least partially) recyclable, or not designed to be used with more than one type of device, large volumes of EPSs will find their way to landfill and become part of an escalating e-waste challenge.

Looking at 2014's projected EPS sales, enhancing the energy efficiency of each EPS by as little as 1 Watt would achieve energy savings in the region of 1.8 Tera-Watts per hour (assuming an average usage of 1 hour per day). Additionally, the average weight of an EPS is around 250 grams and, if half of the EPSs sold in 2014 replace those disposed of, EPSs will in that year be responsible for 600,000 tons of e-waste.

1.2 Report structure and main outcomes

The report is composed of two main sections.

1) *In sections 2 and 3, EPSs are classified, analysed and compared on the basis of their electrical (voltage, power, current, efficiency class, etc.) and physical characteristics (e.g., weight, volumes, mains and DC voltage connector type).*

   The results of this analysis give clear indications of a tendency towards "de facto" standards (e.g. output voltages, connector types), and highlight significant opportunities to improve EPSs' eco-efficiency through, for instance, large weight-reduction opportunities associated with the majority of EPSs analysed.

2) *Sections 4 and 5 analyse the energy efficiency of surveyed EPSs.*

   The results strongly indicate that the efficiency of many EPSs is well below the optimum level, both in terms of dynamic behaviour (i.e., when providing electrical current to the attached devices) and in terms of the "no load condition" (i.e., when EPSs are connected to the energy grid, but not providing energy to the attached devices).

The study's findings can be summarized as follows:

a) Optional energy-efficiency regulations are neglected

The Energy Star Program (www.eu-energystar.org/en/index.html), sponsored by the US Government and the European Union (EU), defines energy-efficiency classes and the associated labelling for consumer products. However, only 47 per cent of the analysed EPSs are marked with the Energy Star label and this label is rarely present in the more widespread lower-power adapters; suggesting the presence of efficiency shortfalls in many of the EPSs analysed.

b) Common practices signify the existence of de-facto standards

Voltage, current and power values tend towards common ratings, signifying partial "de facto" standardization. This condition is particularly evident in two specific aspects:

◊ The low-voltage connectors: the five most-used connector types represent 86% of the total
◊ The output voltage: 81% of the devices have an output voltage equal to 5 V, 12 V or 19 V.

c) Potential improvements: Possible benefits of standardization

◊ Improving Usability

- *Different connectors for different output voltages*

Power supplies with very different output voltages often make use of the same type of connector. This situation creates confusion and implies a risk to consumers attempting to use the same EPS to charge products with different input-voltage requirements. The standardization of a set of connectors and output voltages should be considered, as should a standardization of the constraints linking these items.

- *Replaceable cables*

The main cause of failure in all power supplies is a weak point where the low-voltage cable is connected to the power supply. This weak point confirms the need for connectors standardized according to different voltage and current requirements, and it is highly recommended that EPSs provide a detachable, replaceable cable on the low-voltage side of the device.

- *Accuracy of tag information*

Certain adapters were found to produce an output voltage higher than that declared by the supplier and reported on their nameplate. This would understandably lead to difficulties when using the same EPS to charge devices with different requirements.

◊ Design optimization to improve eco-sustainability

- *Reduce EPS size*

Despite having the same electrical characteristics (voltage and power), EPSs produced by different vendors often possess very different physical dimensions (weight and volume). In most EPS categories, a large proportion of EPSs weigh over 20% more than the category's lightest EPS. Weight is directly linked to environmental impact, and manufacturers should be urged to align their products with "best-practice" EPS dimensions.

- *Increase power efficiency*

Measurements taken in the study uncover large power-efficiency variations among items with comparable electrical characteristics; underlining a key opportunity to improve average efficiency. Comparable EPSs display varying power-efficiency levels in "low-load" and "no-load" conditions (i.e., when the supplied device requires 10-30 per cent of the maximum power, or when it is switched-off while the power supply is still connected to the electricity grid). Standards aligning the low-load power efficiencies of EPSs would therefore translate into significant energy savings.

- *Standardized design rules*

The study considers items from two different "safety classes": Class 1 (grounded, 3-pronged mains connector) and Class 2 (2-pronged mains connector). Roughly 65 per cent of the surveyed EPSs belong to Class 2, which is the more stringent of the two classes. Measurements taken in the study indicate that devices belonging to Class 2 are superior to devices in Class 1 with regard to their power efficiency and ratio of weight to supplied power. Class 2 devices also guarantee greater protection from energy grid overvoltages, and a strong case can be made for the adoption of Class 2 as the standardized solution for external power supplies as its 2-prong mains connector would allow compatibility with most country-specific mains receptacles located where ground is not available.

2. Classification and category definition

Due to the large amount of the different types of the both power supplies and the corresponding powered devices, a set of categories with different electrical characteristics has been defined. This subdivision allows a better analysis of the large quantity of data and measurements acquired and, moreover, it allows a better comparison among the different devices. The classification is based on three different main electrical characteristics: output voltage (V), output maximum current (I) and maximum power (W). The first subdivision has been done by using the output voltage, i.e., four separate groups have been identified: under 12V, 12V, between 12V and 18V and over 18V. The two groups 12V and above 18V have been further subdivided: the first one into three categories by using the output maximum current, and the second one into four categories by using the power. The following ten categories are the final results of the classification:

1. **Category A:** Voltage < 12 V, Current: any, Power: any;
2. **Category B:** Voltage = 12V, Current ≤ 1 A, Power: any;
3. **Category C:** Voltage = 12V, 1 A < Current ≤ 2 A, Power: any;
4. **Category D:** Voltage = 12V, 2 A < Current ≤ 3.5 A, Power: any;
5. **Category E:** Voltage = 12V, 3.5 A < Current ≤ 5 A, Power: any;
6. **Category F:** 12V < Voltage < 18V, Current: any, Power: any;
7. **Category G:** Voltage ≥ 18V, Current: any, Power ≤ 45W;
8. **Category H:** Voltage ≥ 18V, Current: any, 45W < Power ≤ 70 W;
9. **Category I:** Voltage ≥ 18V, Current: any, 70W < Power ≤ 95W;
10. **Category J:** Voltage ≥ 18V, Current: any, 95W < Power ≤ 120 W;

As a first attempt, to verify the relative impact of the above-mentioned categories with respect to the equipment offered on the market, a preliminary analysis based on the most recent power supply data list released by the Energy Star Program (ESP) has been realized. The used reference document is named "External Power Supplies AC-DC Product List; December 16, 2010". This document is a sheet which originally lists 3782 models of power supplies including the chargers for mobile devices, and it reports, *inter alia*, the nameplate electrical characteristics, the no-load efficiency, the average active efficiency and the power factor for all the models. This group of devices has been filtered to exclude the mobile chargers and the very low load power external power supplies (EPSs) (not part of this analysis to avoid overlap between L.1000 and L.adapter.phase2)) by limiting the considered elements to those fulfilling both the following parameters:

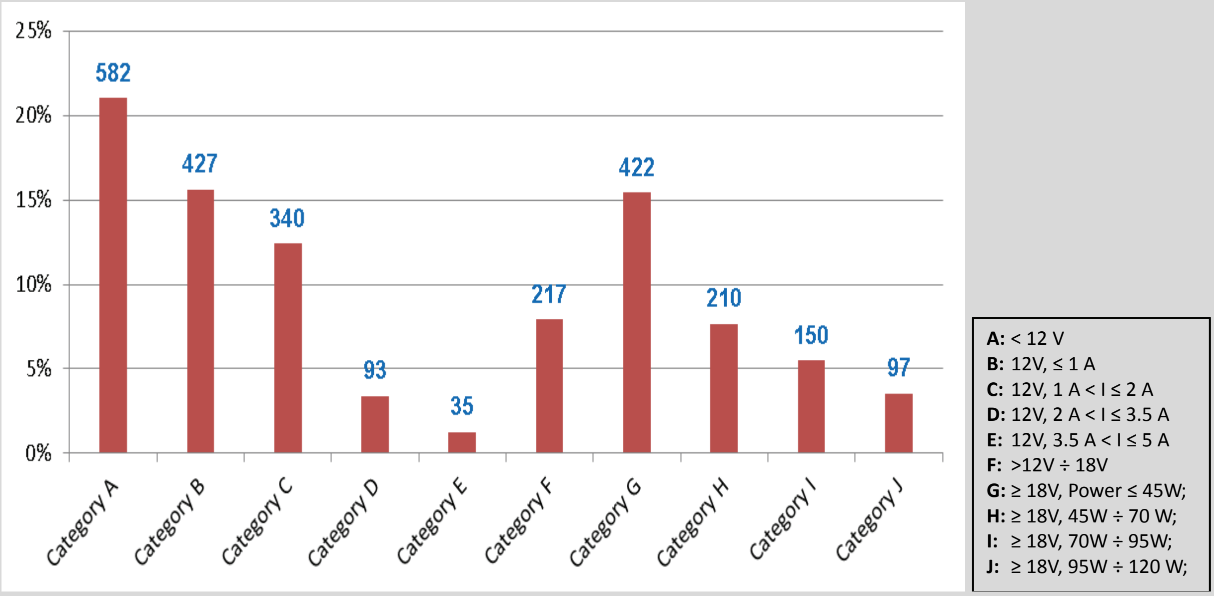
- Output voltage > 6V and maximum power > 4,5W, or
- Output voltage = 5V and maximum output power > 7,5 W

The resulting filtered list has 2743 different models. Figure 1 shows the numerical and percentage impact on the total of all the different categories[1] in this list.

[1] Note that, 170 devices of the ESP list do not belong to any defined categories.

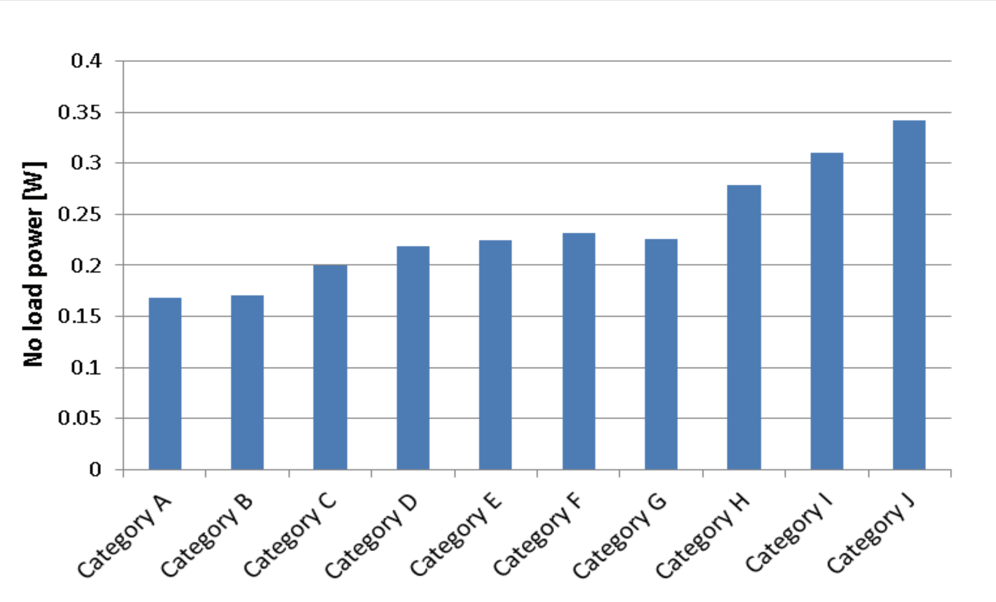
Generally speaking, these data cannot directly represent the numerical impact on the market, because the list has an entry for each model without the corresponding market volume. Public commercial data (e.g., sold units per models) are not available; however, considering the large number of analyzed models, the result has a statistical relevance with respect to the real market, as confirmed by the collected data and our experience.

Figure 1: Numerical and percentage impact of the different defined categories with respect to the filtered ESP device list.



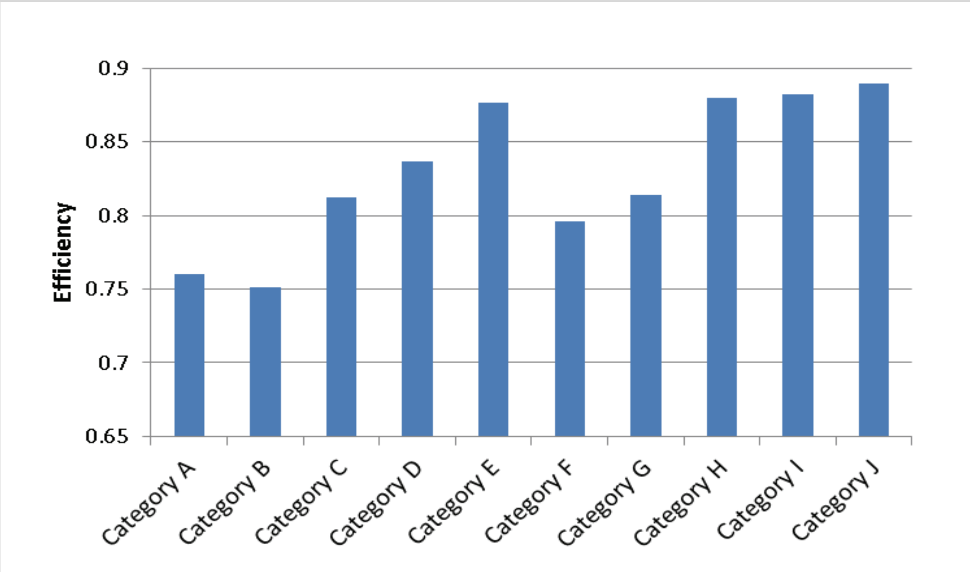
Together with the numerical impact, the average electrical characteristics for each category have also been extracted and reported by means of a graphical representation. The following Figure 2 and Figure 3 report the no-load power consumption and the average efficiency (at 230 V), respectively, averaged on each category and for all the items in the filtered ESP list. These values will be compared in the following sections with those directly measured during this study. Note that these data include all the list of devices and not only the devices with a specific Energy Star rate.

Figure 2: No-load in terms of consumed power (W) versus categories of the items in the filtered ESP device list.



A: < 12 V
B: 12V, ≤ 1 A
C: 12V, 1 A < I ≤ 2 A
D: 12V, 2 A < I ≤ 3.5 A
E: 12V, 3.5 A < I ≤ 5 A
F: >12V ÷ 18V
G: ≥ 18V, Power ≤ 45W;
H: ≥ 18V, 45W ÷ 70 W;
I: ≥ 18V, 70W ÷ 95W;
J: ≥ 18V, 95W ÷ 120 W;

Figure 3: Average efficiency at 230V versus categories of the items in the filtered ESP device list.



A: < 12 V
B: 12V, ≤ 1 A
C: 12V, 1 A < I ≤ 2 A
D: 12V, 2 A < I ≤ 3.5 A
E: 12V, 3.5 A < I ≤ 5 A
F: >12V ÷ 18V
G: ≥ 18V, Power ≤ 45W;
H: ≥ 18V, 45W ÷ 70 W;
I: ≥ 18V, 70W ÷ 95W;
J: ≥ 18V, 95W ÷ 120 W;

3. Nameplate data

This section reports the results of an analysis performed on the set of 307 external power supplies from various brands. This is a quite large number of devices especially considering the great effort needed to analyze each unit. Moreover, this number is definitely larger than the target one we have define at the beginning of the work, it makes the analysis statistically representative and it has been fixed only by the availability of time and the availability of devices to test. The analyzed adapters were selected in order to cover a wide range of output power (from 1W to more than 170W) while representing a different set from the USB range covered by Recommendation ITU-T L.1000. Note that only the fixed output, single voltage adapters have been considered.

Table 1 contains the main nameplate characteristics (selected among a very large number of acquired ones) together with other mechanical features as the weight of the power supply (with and without cables), volume, power density with respect to weight and volume, data about the low voltage connector and information on the presence of a detachable mains cable. Some examples of categories of the main cable connectors are reported in Figure 5. The number of the devices with detachable mains cable (among the ones listed in the following table) is 143 (47%).

A first consideration is related to the Energy Star (ES) marking: only 47% shows the ES label and, moreover, this label is found very seldom in lower power adapter (< 40W).

Remarks – *Lower power adapters constitute the majority of the market with billions of sold devices. If the absence of the ESP label means low quality and efficiency (as confirmed in the following electrical measurement Section), then the result of this analysis suggests the presence of a big problem. Moreover, the Energy star programme was stopped as EPA concluded that the market was already mature and capable to behave autonomously as per the EPS requirements (see www.energystar.gov/ia/partners/prod_development/revisions/downloads/eps_eup_sunset_decision_july2010.pdf?a94e-6fff. It is important to verify if this situation is currently confirmed by the measurements taken).*

In the connector type column, the coaxial ones have been divided into classes (T1, T2, T3, T4, T5… T14) by following the internal and external sizes of the connectors. Some examples of DC power female connectors can be seen in Figure 4.

Remarks – *It can be easily noticed that voltage, current and especially power values seem to tend to common ratings. This fact is conducive to a "de facto" standardization.*

Figure 4: Typical examples of DC power female connectors.

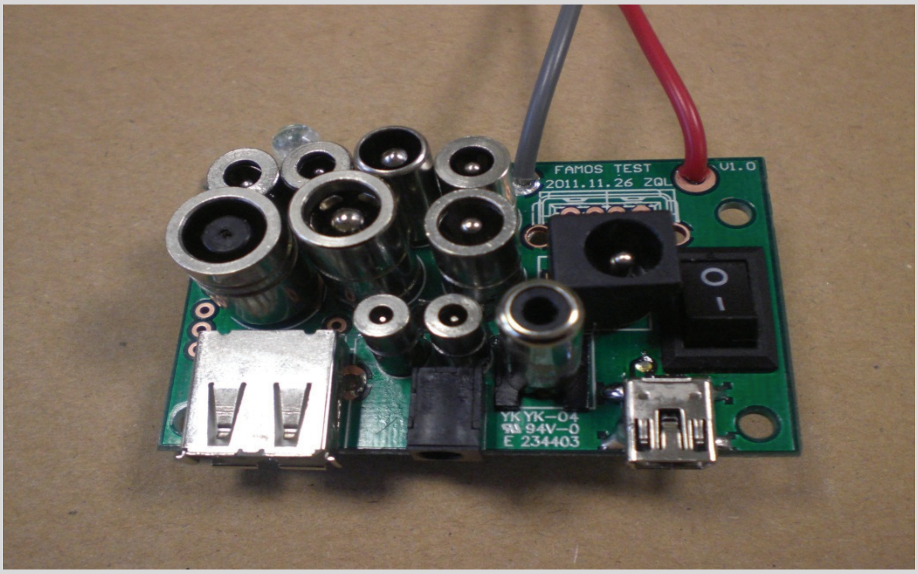


Figure 5: Typical examples of main cable connectors.

The different colors identify the different categories of power supplies defined in the previous section in terms of voltage, current and power; the following list reports the correspondence between the category and the color used in Table 1[2]:

A. Voltage < 12 V, Current: any, Power: any;

B. Voltage = 12V, Current ≤ 1 A, Power: any;

C. Voltage = 12V, 1 A < Current ≤ 2 A, Power: any;

D. Voltage = 12V, 2 A < Current ≤ 3.5 A, Power: any;

E. Voltage = 12V, 3.5 A < Current ≤ 5 A, Power: any;

F. 12 V < Voltage < 18V, Current: any, Power: any;

G. Voltage ≥ 18V, Current: any, Power ≤ 45W;

H. Voltage ≥ 18V, Current: any, 45W < Power ≤ 70 W;

I. Voltage ≥ 18V, Current: any, 70W < Power ≤ 95W;

J. Voltage ≥ 18V, Current: any, 95W < Power ≤ 120 W;

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[2] Note there are 4 devices without any color which do not belong to any defined category

Moreover, Figure 6 summarizes the numerical and percentage impact of the different categories on the total number of the equipment measured.

Figure 6: Numerical and percentage impact of the different defined categories with respect to the total number of measured devices.

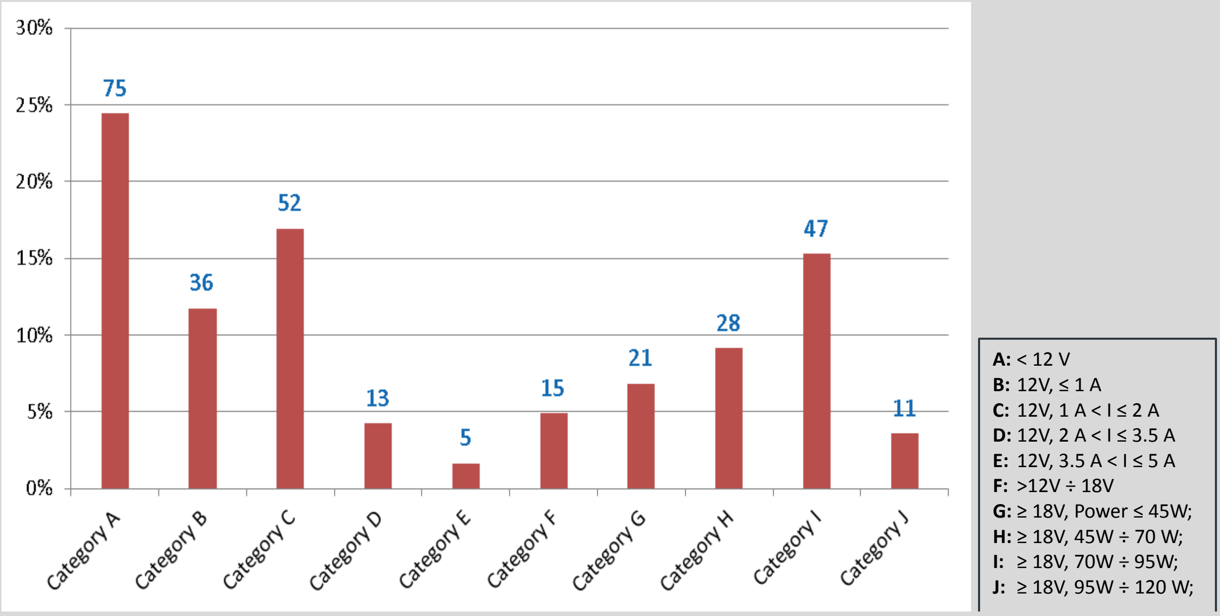


Table 1: Nameplate and measured mechanical features of the analyzed adapters

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
167	1.9	1.4	2.66	2	-	143	-	141	Proprietary	NO	19	19
166	3	1	3	2	-	235	-	268	Proprietary	NO	11	13
138	4	0.15	-	2	V	98	-	82	-	NO	-	-
89	4.5	0.7	3.15	2	-	233	-	243	T4	NO	13	14
57	4.9	0.45	2.205	2	-	68	-	161	Proprietary	NO	14	32
17	5	0.3	1.5	1	-	69	-	145	T3	NO	10	22
137	5	0.5	2.5	2	IV	141	-	286	Proprietary	NO	9	18
8	5	1	5	2	-	110	-	118	T6	NO	42	45
82	5	1	5	2	-	65	-	165	T8	NO	30	77
97	5	1	5	2	IV	68	-	110	USB	NO	45	74
159	5	1	5	2	-	65	-	142	T4	NO	35	77
183	5	1	5	2	IV	83	-	150	Proprietary	NO	33	60
253	5	1	5	2	V	71	-	72	T9	NO	70	70
302	5	1	5	2	V	71	-	72	T9	NO	70	70
46	5	1.4	7	2	-	100	-	151	T8	NO	46	70
31	5	1.5	7.5	2	-	122	-	179	T8	NO	42	61
113	5	1.5	7.5	2	-	128	-	225	T8	NO	33	59
114	5	1.5	7.5	2	-	128	-	225	T8	NO	33	59
157	5	1.5	7.5	2	-	89	-	123	T4	NO	61	84
300	5	1.5	7.5	2	-	119	-	182	T8	NO	41	63
318	5	1.5	7.5	2	-	120	-	104	T8	NO	72	63
243	5	1.5	7.5	2	-	66	-	62	T4	NO	121	114
319	5	1.5	7.5	2	-	120	-	104	T8	NO	72	63
5	5	2	10	2	-	102	-	90	T8	NO	111	98
23	5	2	10	1	-	160	352	176	T8	C13-C14	57	63
58	5	2	10	2	-	96	-	172	T8	NO	58	104
64	5	2	10	2	IV-V	110	-	208	T8	NO	48	91
98	5	2	10	2	-	45	-	114	USB	NO	88	222
108	5	2	10	1	-	159	-	189	T8	C13-C14	53	63
115	5	2	10	2	-	146	-	224	T9	NO	45	68
154	5	2	10	2	-	144	-	239	T9	NO	42	69
177	5	2	10	2	-	144	-	238	T9	NO	42	69
195	5	2	10	1	-	172	-	174	T10	C13-C14	57	58
260	5	2	10	2	V	54	-	88	USB	NO	114	185
261	5	2	10	2	V	54	-	88	USB	NO	114	185

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
359	5	2	10	2	IV	96	-	115	T8	NO	87	104
10	5	2.5	12.5	2	-	156	-	333	T8	NO	38	80
20	5	2.5	12.5	2	-	156	-	333	T8	NO	38	80
191	5	2.5	12.5	2	-	156	-	198	T10	NO	63	80
179	5	3	15	1	-	206	-	195	T8	C13-C14	77	73
94	5.2	0.45	2.34	2	-	79	-	172	Proprietary	NO	14	30
155	5.2	0.45	2.34	2	-	79	-	158	Proprietary	NO	15	30
200	5.5	2.2	12.1	2	-	150	-	94	T10	C7-C8	128	81
28	5.7	3	17.1	2	IV	223	-	189	T8	C7-C8	91	77
80	6	0.2	1.2	2	-	287	-	252	RJ	NO	5	4
6	6	0.3	1.8	2	-	195	-	225	T3	NO	8	9
21	6	0.3	1.8	2	-	196	-	228	T3	NO	8	9
84	6	0.3	1.8	2	-	171	-	180	T3	NO	10	11
172	6	0.3	1.8	2	-	274	-	233	T4	NO	8	7
79	6	0.5	3	2	V	67	-	106	T8	NO	28	45
176	6	2.5	15	2	-	187	-	227	T8	NO	66	80
165	6.5	0.3	1.95	2	V	55	-	83	T10	NO	24	35
2	6.5	0.2-0.4	2.6	2	-	317	-	328	Proprietary	NO	8	8
12	6.5	0.2-0.4	2.6	2	-	317	-	328	RJ	NO	8	8
38	7.5	0.3	2.25	2	V	70	-	114	RJ	NO	20	32
83	7.5	0.8	6	2	-	328	-	296	T3	NO	20	18
164	7.5	0.8	6	2	-	294	-	246	T3	NO	24	20
27	8	1	8	2	-	271	-	235	T8	NO	34	30
160	9	0.2	1.8	2	-	273	-	275	RJ	NO	7	7
163	9	0.3	2.7	2	-	222	-	239	T8	NO	11	12
134	9	0.4	3.6	2	-	162	-	186	Male Coaxial	NO	19	22
19	9	0.5	4.5	2	-	256	-	253	T8	NO	18	18
29	9	0.6	5.4	2	-	96	-	164	T9	NO	33	56
88	9	0.6	5.4	2	-	96	-	156	T9	NO	35	56
26	9	1	9	2	-	556	-	382	T8	NO	24	16
99	9	1	9	2	-	327	-	226	T9	NO	40	28
106	9	1	9	2	-	550	-	386	T8	NO	23	16
122	9	1	9	2	-	440	-	354	T8	NO	25	20
363	9	1	9	2	V	118	-	85	T8	NO	106	76
170	9	1.2	10.8	2	-	523	-	352	T9	NO	31	21
131	9	2	18	2	-	149	-	200	T8	NO	90	121
127	9.5	0.4	3.8	2	-	194	-	195	T9	NO	20	20

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
169	9.5	2.7	25.65	2	-	211	299	172	Proprietary	C7-C8	149	122
205	9.5	3.78	36	2	-	162	267	78	T5	C7-C8	463	222
241	10.5	2.9	30	2	V	141	193	91	Proprietary	C7-C8	328	213
22	12	0.2	2.4	2	-	187	-	215	T5	NO	11	13
25	12	0.3	3.6	2	-	246	-	263	T8	NO	14	15
76	12	0.33	3.96	2	-	58	-	81	T9	NO	49	68
93	12	0.4	4.8	2	-	290	-	272	T9	NO	18	17
174	12	0.4	4.8	2	-	91	-	81	Proprietary	NO	59	53
77	12	0.5	6	2	-	300	-	238	T8	NO	25	20
258	12	0.5	6	2	V	71	-	137	T8	NO	44	85
259	12	0.5	6	2	V	71	-	137	T8	NO	44	85
362	12	0.5	6	2	V	76	-	118	T4	NO	51	79
95	12	0.6	7.2	2	-	313	-	257	RJ	NO	28	23
55	12	0.8	9.6	2	-	96	-	153	T8	NO	63	100
59	12	0.8	9.6	2	-	76	-	191	T8	NO	50	126
324	12	0.8	9.6	2	-	88	-	83	T8	NO	116	109
18	12	0.83	9.96	2	-	167	-	330	T8	NO	30	60
54	12	0.83	9.96	2	-	328	-	256	T8	NO	39	30
4	12	1	12	1	-	167	-	180	T8	C13-C14	67	72
40	12	1	12	2	V	129	-	162	T6	NO	74	93
63	12	1	12	2	-	110	-	177	T8	NO	68	109
68	12	1	12	2	-	127	-	264	T8	NO	45	94
70	12	1	12	2	-	530	-	412	T8	NO	29	23
71	12	1	12	2	-	-	-	391	-	NO	31	-
72	12	1	12	2	-	110	-	177	T8	NO	68	109
107	12	1	12	2	-	285	367	197	Proprietary	C7-C8	61	42
116	12	1	12	1	-	215	236	202	T8	male C13-C14	59	56
117	12	1	12	1	-	210	236	197	T8	male C13-C14	61	57
143	12	1	12	2	-	127	-	264	T8	NO	45	94
146	12	1	12	2	-	127	-	264	T8	NO	45	94
152	12	1	12	2	-	127	-	264	T8	NO	45	94
181	12	1	12	2	V	110	-	151	T6	NO	79	109
208	12	1	12	2	V	110	-	151	T6	NO	79	109
254	12	1	12	2	V	125	-	286	T8	NO	42	96
255	12	1	12	2	V	125	-	286	T8	NO	42	96
256	12	1	12	2	V	119	-	284	T8	NO	42	101
257	12	1	12	2	V	119	-	284	T8	NO	42	101

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
309	12	1	12	2	V	100	-	112	T8	NO	107	120
322	12	1	12	2	-	129	-	123	T8	NO	97	93
65	12	-	12.5	2	-	283	-	320	T9	NO	39	44
44	12	1.2	14.4	2	-	84	-	188	T8	NO	77	171
67	12	1.2	14.4	2	-	559	-	398	T8	NO	36	26
323	12	1.2	14.4	2	-	96	-	86	T8	NO	167	150
16	12	1.25	15	2	-	124	-	207	T8	NO	73	121
45	12	1.25	15	1	V	128	-	122	T9	C13-C14	122	117
60	12	1.25	15	2	V	122	-	233	T8	NO	64	123
73	12	1.25	15	1	V	143	-	169	T8	C13-C14	89	105
74	12	1.25	15	2	V	172	-	203	T9	NO	74	87
110	12	1.25	15	1	-	198	-	146	T9	NO	103	76
197	12	1.25	15	2	-	236	-	287	T8	NO	52	64
198	12	1.25	15	2	-	123	-	202	T8	NO	74	122
61	12	1.4	16.8	2	-	-	-	190	T9	NO	89	-
75	12	1.4	16.8	2	V	104	-	191	T9	NO	88	162
7	12	1.5	18	2	-	133	-	200	T8	NO	90	135
43	12	1.5	18	2	-	145	-	254	T9	NO	71	124
52	12	1.5	18	2	-	-	-	238	-	NO	76	-
56	12	1.5	18	1	-	120	-	126	T8	C13-C14	143	150
69	12	1.5	18	2	-	148	-	212	T8	NO	85	122
85	12	1.5	18	2	-	153	-	316	T3	NO	57	118
103	12	1.5	18	2	V	133	-	200	T8	NO	90	135
105	12	1.5	18	2	V	146	-	277	T8	NO	65	123
111	12	1.5	18	2	-	147	-	211	T8	NO	85	122
119	12	1.5	18	2	-	147	-	211	T8	NO	85	122
120	12	1.5	18	1	-	189	-	172	T8	C13-C14	105	95
126	12	1.5	18	2	-	140	-	241	T9	NO	75	129
149	12	1.5	18	2	-	189	-	170	T8	C13-C14	106	95
150	12	1.5	18	2	-	147	-	211	T8	NO	85	122
151	12	1.5	18	1	-	189	-	169	T8	C13-C14	107	95
202	12	1.5	18	2	-	154	-	247	T8	NO	73	117
242	12	1.5	18	2	V	127	-	109	T2	NO	166	142
201	12	1.6	19.2	2	-	193	-	276	T8	NO	70	99
203	12	1.7	20.4	2	-	166	-	295	T10	NO	69	123
13	12	2	24	2	-	132	-	97	T9	C7-C8	247	182
36	12	2	24	2	V	170	-	230	T12	NO	104	141

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
39	12	2	24	2	V	142	-	181	T6	NO	132	169
47	12	2	24	2	V	220	308	144	T9	C7-C8	166	109
102	12	2	24	2	-	185	-	323	T8	NO	74	130
104	12	2	24	2	-	150	-	252	T5	NO	95	160
112	12	2	24	1	-	156	-	254	T8	NO	94	154
129	12	2	24	2	-	131	-	240	T8	NO	100	183
145	12	2	24	1	-	207	-	167	T10	C13-C14	144	116
156	12	2	24	2	-	119	-	207	T8	NO	116	202
171	12	2	24	2	IV	158	-	220	T8	NO	109	152
173	12	2	24	2	V	145	-	287	T9	NO	84	166
180	12	2	24	2	V	141	-	182	T6	NO	132	170
184	12	2	24	2	V	189	-	333	T4	NO	72	127
189	12	2	24	2	IV	160	-	286	T8	NO	84	150
199	12	2	24	2	V	142	-	305	T9	NO	79	169
207	12	2	24	2	V	145	-	287	T9	NO	84	166
251	12	2	24	2	V	155	-	276	T8	NO	87	155
252	12	2	24	2	V	155	-	276	T8	NO	87	155
321	12	2	24	2	-	179	-	131	T8	NO	183	134
317	12	2.1	25.2	2	-	157	-	156	T8	NO	162	161
41	12	2.5	30	2	-	248	-	205	T9	C7-C8	147	121
42	12	2.5	30	2	IV	163	240	134	T8	C7-C8	225	184
48	12	2.5	30	2	IV	223	-	390	T9	NO	77	135
187	12	2.5	30	2	IV	200	298	166	T3	C7-C8	181	150
148	12	3	36	2	-	290	377	222	T8	C7-C8	162	124
178	12	3	36	2	-	214	-	133	T9	C7-C8	270	168
185	12	3	36	2	V	158	212	79	T5	C7-C8	454	228
206	12	3	36	2	-	162	267	78	T5	C7-C8	463	222
357	12	3	36	2	IV	151	200	76	T5	C7-C8	476	238
15	12	3.3	39.6	1	-	312	-	266	T8	C13-C14	149	127
121	12	3.3	39.6	1	-	309	-	257	T8	C13-C14	154	128
147	12	3.3	39.6	1	-	309	-	257	T8	C13-C14	154	128
141	12	3.7	44.4	2	-	338	440	372	Proprietary	NO	119	131
142	12	3.7	44.4	2	-	338	440	372	Proprietary	NO	119	131
24	12	3.75	45	1	-	309	-	291	T9	C13-C14	155	146
87	12	4.2	50	1	-	325	-	330	T8	NO	152	154
123	12	4.16	50	1	-	253	-	219	T9	C13-C14	229	198
140	12	14.2	170.4	2	-	840	979	1246	Proprietary	C17-C18	137	203

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
153	13	0.625	8.1	2	-	543	-	445	T6	NO	18	15
96	15	-	5.4	2	V	62	-	78	Proprietary	NO	69	87
301	15	0.5	7.5	2	-	83	-	88	T8	NO	86	90
11	15	0.8	12	2	-	132	-	126	T8	NO	95	91
37	15	0.8	12	2	V	100	-	153	T8	NO	79	120
62	15	0.8	12	2	-	138	-	227	T8	NO	53	87
9	15	1	15	2	-	453	-	387	T8	NO	39	33
49	15	2	18	2	IV	124	-	219	T8	NO	82	145
51	15	1.2	18	2	-	149	-	277	T8	NO	65	121
78	15	1.2	18	2	-	149	-	277	T8	NO	65	121
53	15	2	30	2	-	195	292	168	T8	C7-C8	179	154
109	15	2	30	2	-	195	-	168	T8	C7-C8	179	154
358	15	5	75	2	V	339	404	312	T12	C7-C8	240	221
3	16	3.36	53.76	2	-	254	-	157	T13	C7-C8	342	212
158	16	4.5	72	1	-	310	-	214	T9	C5-C6	337	232
168	18.5	2.7	50	1	-	258	461	138	T5	C5-C6	361	194
315	18.5	2.7	50	1	-	200	308	105	T5	C5-C6	477	250
188	18.5	3.5	64.75	1	IV	233	388	139	T14	C5-C6	466	278
250	18.5	3.5	64.75	1	IV	238	-	144	T6	C5-C6	451	272
306	18.5	3.5	65	1	IV	234	-	143	T5	C5-C6	455	278
308	18.5	3.5	65	1	V	253	401	145	T14	C5-C6	449	257
244	18.5	4.9	90	1	-	258	-	232	T5	C5-C6	388	349
245	18.5	4.9	90	1	-	267	-	242	T14	C5-C6	372	337
247	18.5	4.9	90	1	-	259	-	246	T5	C5-C6	366	347
192	18.5	4.9	90.65	1	-	320	463	231	T5	C5-C6	393	283
118	18.5	6.5	120	1	-	639	-	396	T9	C5-C6	303	188
124	18.5	6.5	120	1	-	659	812	399	T9	C5-C6	301	182
209	18.5	6.5	120	1	V	609	763	354	T14	C5-C6	339	197
210	18.5	6.5	120	1	V	609	763	354	T14	C5-C6	339	197
211	18.5	6.5	120	1	V	630	786	357	T14	C5-C6	336	190
217	18.5	6.5	120	1	V	630	782	351	T14	C5-C6	342	190
218	18.5	6.5	120	1	V	609	763	354	T14	C5-C6	339	197
360	18.5	6.5	120	1	V	612	745	361	T14	C5-C6	333	196
361	18.5	6.5	120	1	NA	651	761	412	T9	C5-C6	291	184
246	18.5	-	-	1	-	261	-	244	T5	C5-C6	-	-
35	19	1	19	2	V	105	2	82	-	C7-C8	232	181
33	19	1.5	28.5	-	OK	-	-	-	-	C5-C6	-	-

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
186	19	1.58	30	1	V	145	300	84	T5	C5-C6	355	207
238	19	1.58	30	2	V	152	-	84	T1	NO	355	197
240	19	1.58	30	1	V	170	360	104	T10	C5-C6	288	176
316	19	1.58	30	1	V	129	265	84	T5	C5-C6	357	233
346	19	1.58	30	1	V	142	274	84	T5	C5-C6	357	211
347	19	1.58	30	1	V	142	274	84	T5	C5-C6	357	211
348	19	1.58	30	1	V	171	306	100	T5	C5-C6	302	175
349	19	1.58	30	1	V	171	306	100	T5	C5-C6	302	175
350	19	1.58	30	1	V	171	306	100	T5	C5-C6	302	175
351	19	1.58	30	1	V	171	306	100	T5	C5-C6	302	175
352	19	1.58	30	1	V	151	282	100	T5	C5-C6	302	199
353	19	1.58	30	1	IV	163	293	110	T7	C5-C6	272	184
86	19	2.15	40	2	V	209	-	277	T7	NO	144	191
233	19	2.15	40	2	V	209	-	120	T8	NO	332	191
237	19	2.15	40	2	V	193	-	123	T8	NO	326	207
313	19	2.1	40	2	V	152	206	86	T1	C7-C8	467	263
314	19	2.1	40	2	V	152	206	86	T1	C7-C8	467	263
194	19	3.16	60	1	-	291	-	203	T7	C5-C6	295	206
132	19	3.42	65	1	V	238	390	141	T9	C5-C6	462	273
232	19	3.42	65	1	V	243	398	156	T8	C5-C6	417	267
234	19	3.42	65	1	V	220	376	124	T8	C5-C6	526	295
303	19	3.42	65	1	V	246	400	152	T7	C5-C6	428	264
311	19	3.42	65	1	IV	234	342	145	T9	C5-C6	447	278
320	19	3.42	65	1	V	209	364	147	T9	C5-C6	443	311
325	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
326	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
327	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
328	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
329	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
330	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
331	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
332	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
333	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
334	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
335	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
354	19	3.42	65	1	V	213	364	147	T9	C5-C6	443	305
356	19	3.42	65	1	V	247	377	148	T9	C5-C6	440	263

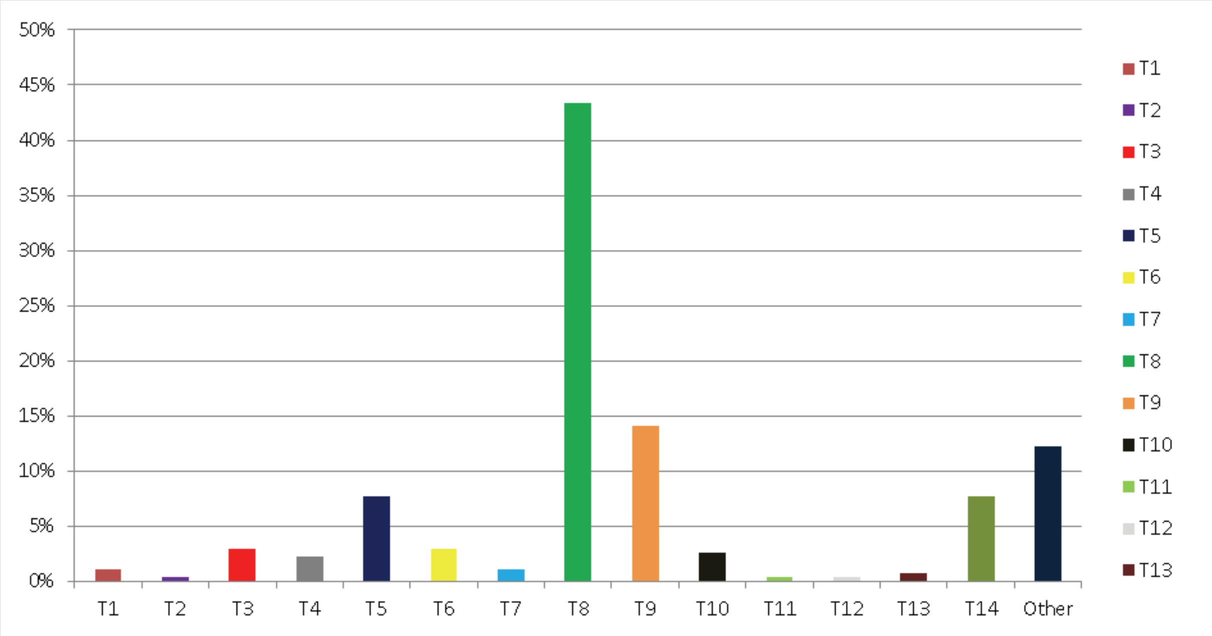
N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
125	19	4.74	90	1	-	354	-	235	T11	C5-C6	384	254
175	19	4.74	90	1	-	358	509	190	T5	C5-C6	473	251
182	19	4.74	90	1	V	327	469	192	T5	C5-C6	469	275
190	19	4.74	90	1	-	261	401	241	T14	C5-C6	373	345
193	19	4.74	90	1	IV	347	484	186	T5	C5-C6	484	259
204	19	4.74	90	1	V	352	535	187	T14	C5-C6	480	256
212	19	4.7	90	1	V	355	510	188	T14	C5-C6	478	254
213	19	4.74	90	1	V	360	460	196	T14	C5-C6	460	250
214	19	4.74	90	1	V	351	510	194	T14	C5-C6	463	256
215	19	4.7	90	1	V	353	410	357	T14	C5-C6	252	255
216	19	4.74	90	1	V	343	436	194	T14	C5-C6	463	262
219	19	4.7	90	1	V	360	515	188	T14	C5-C6	478	250
220	19	4.7	90	1	V	355	510	188	T14	C5-C6	478	254
221	19	4.74	90	1	V	341	503	194	T14	C5-C6	463	264
222	19	4.74	90	1	V	364	500	243	T8	C5-C6	370	247
223	19	4.74	90	1	V	364	500	243	T8	C5-C6	370	247
224	19	4.74	90	1	V	386	545	229	T8	C5-C6	394	233
225	19	4.74	90	1	V	390	545	229	T8	C5-C6	394	231
226	19	4.74	90	1	V	345	495	195	T8	C5-C6	461	261
227	19	4.74	90	1	V	342	472	194	T8	C5-C6	463	263
228	19	4.74	90	1	V	342	472	194	T8	C5-C6	463	263
229	19	4.74	90	1	V	364	500	243	T8	C5-C6	370	247
230	19	4.74	90	1	V	345	496	195	T8	C5-C6	461	261
231	19	4.74	90	1	V	364	517	243	T8	C5-C6	370	247
236	19	4.74	90	1	V	365	519	243	T8	C5-C6	370	247
239	19	4.74	90	1	V	363	500	247	T8	C5-C6	365	248
248	19	4.7	90	1	-	348	-	188	T5	C5-C6	479	259
249	19	4.7	90	1	-	349	-	186	T5	C5-C6	485	258
304	19	4.74	90	2	V	300	365	228	T14	C7-C8	395	300
305	19	4.74	90	1	-	341	-	185	T5	C5-C6	488	264
307	19	4.74	90	1	-	261	440	243	T14	C5-C6	371	345
312	19	4.74	90	1	IV	342	520	193	T14	C5-C6	466	263
235	19	6.32	120	1	V	590	728	351	T8	C5-C6	342	203
128	20	1	20	2	IV	143	-	293	T8	NO	68	140
100	20	2.5	50	1	IV	354	541	252	Proprietary	C5-C6	198	141
310	20	3.25	65	2	V	230	287	126	T13	C7-C8	516	283
336	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244

N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm³)	Connector's type	Detachable main cable (connector)	mW/cm³	mW/g
337	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
338	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
339	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
340	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
341	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
342	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
343	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
344	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
345	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
355	20	4.5	90	2	IV	369	449	269	T9	C7-C8	335	244
81	24	6	120	1	-	557	700	427	T5	C13-C14	281	215
135	32	0.7	22.4	2	IV	209	295	196	Proprietary	C7-C8	114	107
1	-	-	-	2	-	115	-	179	T8	NO	-	-

For each model, the rated voltage, current and power on the DC side are reported, together with the safety and Energy Star class and other features such as the weight of the power supply (with and without cables), volume, information about the low voltage connector, the manufacturing country and information on the presence of a detachable main cable or a main connector integrated with the power supply itself. About 90% of the adapters analyzed were made in China.

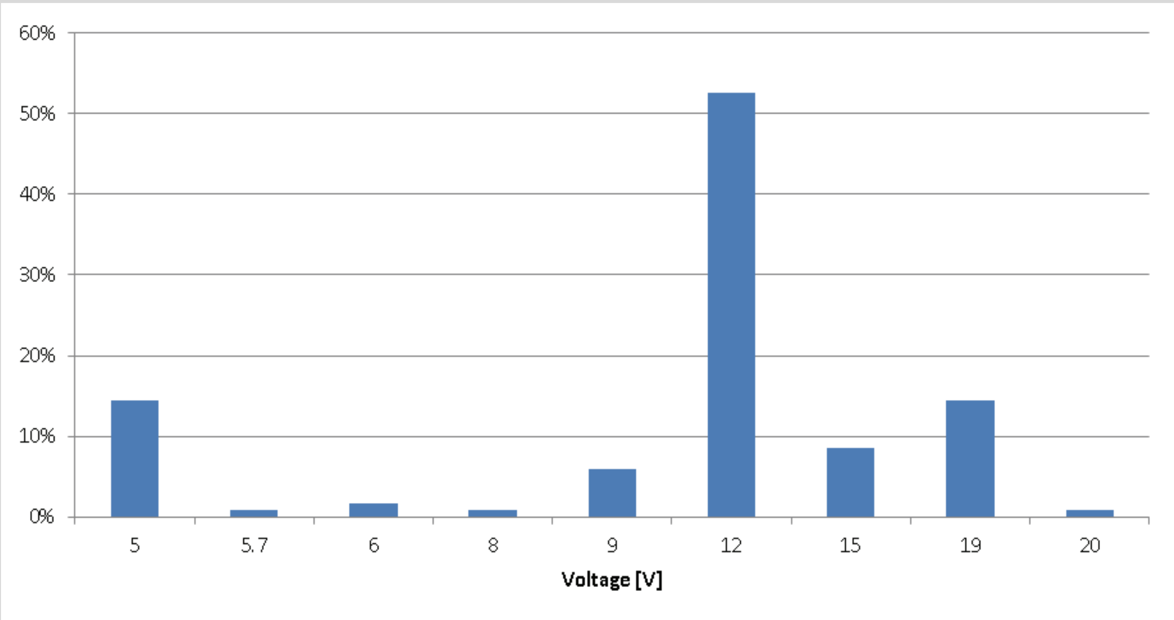
Figure 7 demonstrates the percentage of the connectors belonging to each different category. It can be noticed that the majority of the connectors are barrel type. The five most used connectors represent 86% of the total. We recall that all the connectors except those in the category “other” are barrel ones and the classification have been made by using the internal and external size measurements. The “other” category is a mix of many different connectors such as USB, RJ and proprietary.

Figure 7: Used connector percentage versus connector types.



Taking the T8 category (the largest one) as an example, Figure 8 clearly highlights that the same type of connector is used for power supplies with a different output voltage, from 5V to 20V.

Figure 8: Percentage of connectors belonging to category T8 versus the nameplate output voltage of their power supplies.

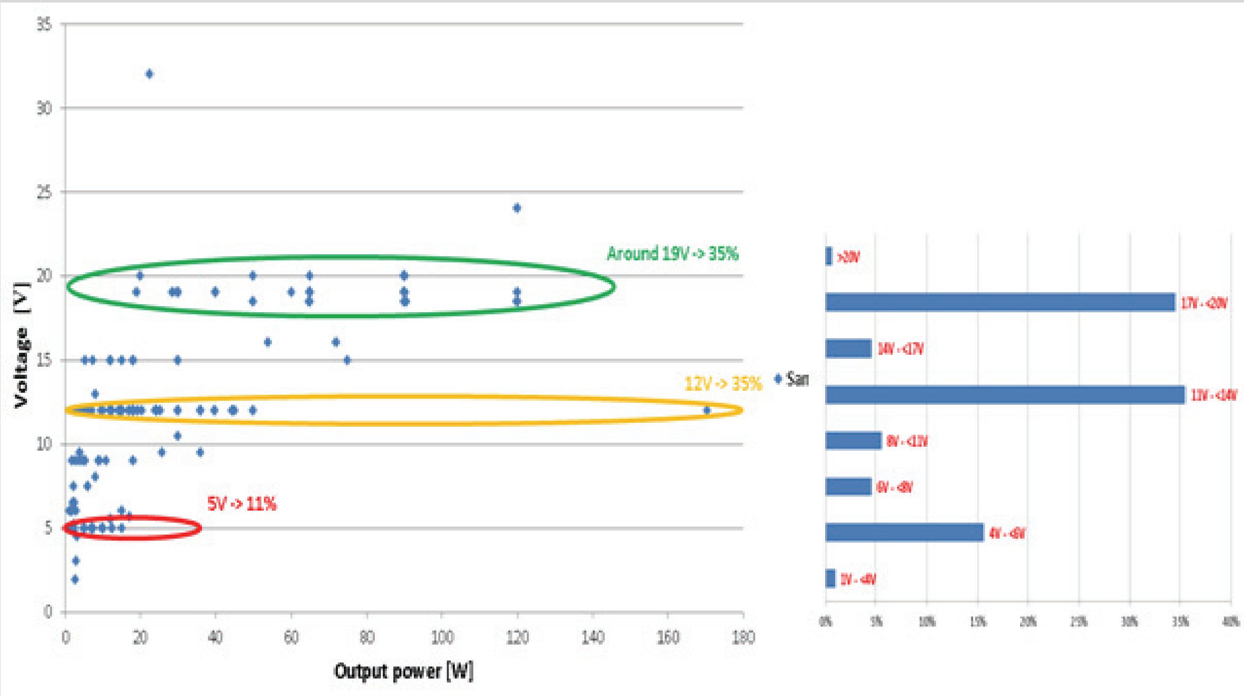


Remarks –*Adapters with a very different output voltage often have the same connector type as Figure 8 clearly underlines. This can create confusion among users and could generate problems in case they would use one of them to power different products.*

- *If a power supply is used to power a device that requires higher voltage values, this could not work properly or even not work at all.*
- *If an adapter is used to power a device that requires lower voltage values, this could damage the device and create dangerous conditions for the user.*
  - *Should be evaluated weather it would be better to standardize the use of existing connectors defined by HGI and ETSI, or to define new connectors (one for each category) such us the ones under study in other standardization activities.*

Figure 9 shows the nameplate output voltage against the rated output power of each adapter. The graph also underlines the large number of power supplies with voltage equal to 5V, 12V and around 19V.

Figure 9: Nameplate output voltage of the adapters against their declared power.



Remarks –Figure 9 *clearly highlights a particular concentration of power supplies around the values of 5V, 12V and around 19V. This fact supports the idea of the creation of standardization classes for the power adapters.*

4. Mechanical features

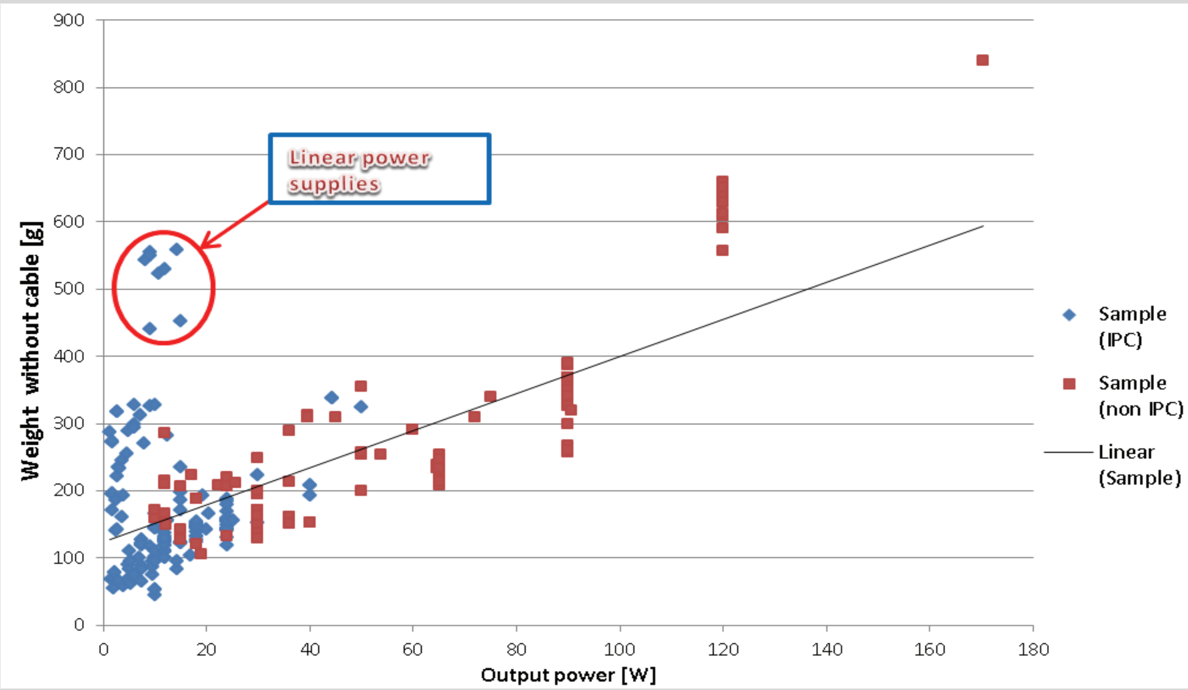
4.1 Weight

Figure 10 and Figure 13 report the measured weight without and with the mains cables of the adapters, respectively. Note that, in cases where power supplies with a standard detachable power cord had not been provided, the total weight (with both the high and low voltage cables) could not have been measured. In these cases, the weights with the cables have been estimated adding the average mains cable weight values obtained by the available measurements. As further information, the average length of adapters' low voltage cables is about 197 cm with a maximum of 300 cm and a minimum of 93 cm. In Figure 13, the estimated ones have been highlighted by using the red color.

In Figure 10, Figure 11 and Figure 13, a red circle identifies the "linear" power supplies that are characterized by a larger weight with respect to the switching ones which are currently mostly used. This subset of adapters has been excluded from the following analysis.

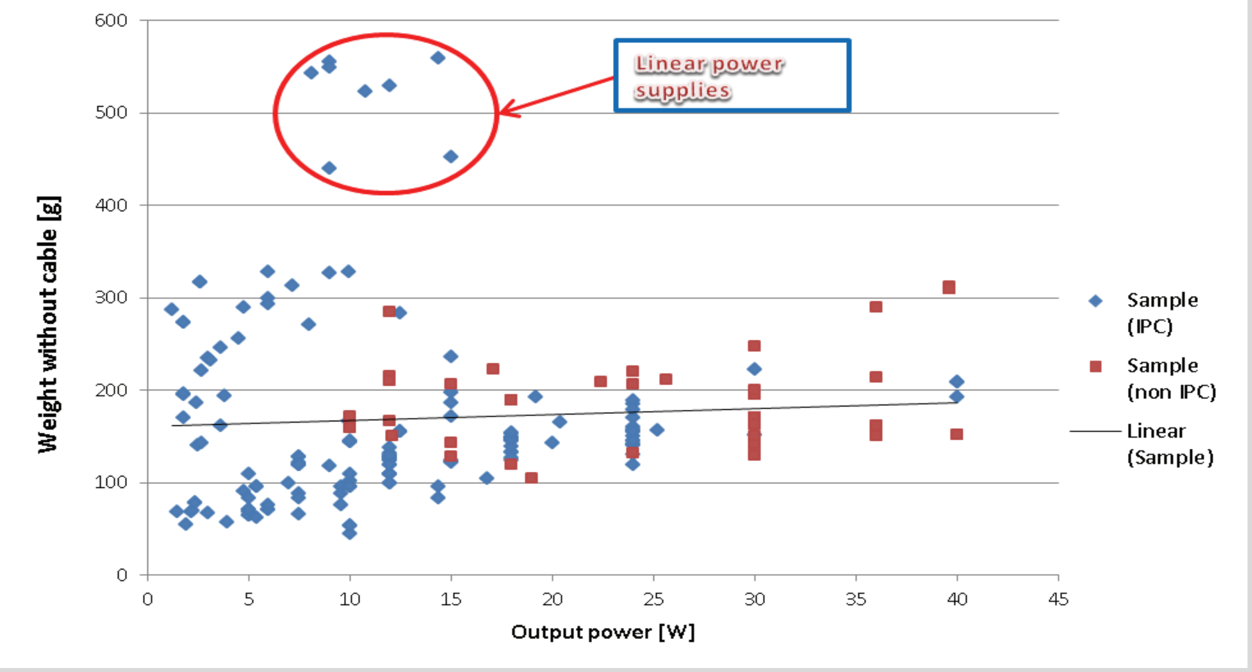
Weight is expected to be the parameter more correlated to the environmental impact of the power supplies (in particular in the case in Figure 10 which reports the weights of the adapters without their mains cord). For this reason, another analysis has been made to emphasize the improvements that can be achieved if we consider as reference the best results. Figure 14 shows the weights of all the adapters, without their mains cables, versus the different categories (defined in Section 2). Maximum, minimum and average weight, for each category, has been added to easily evaluate the distance between the lighter and the heavier device in each class. As it is better revealed in Figure 15, for the majority of the categories, the percentage of the power supplies heavier than 1.2 times the lighter one, is definitely large.

Figure 10: Weights of the adapters without their mains cord against their declared power



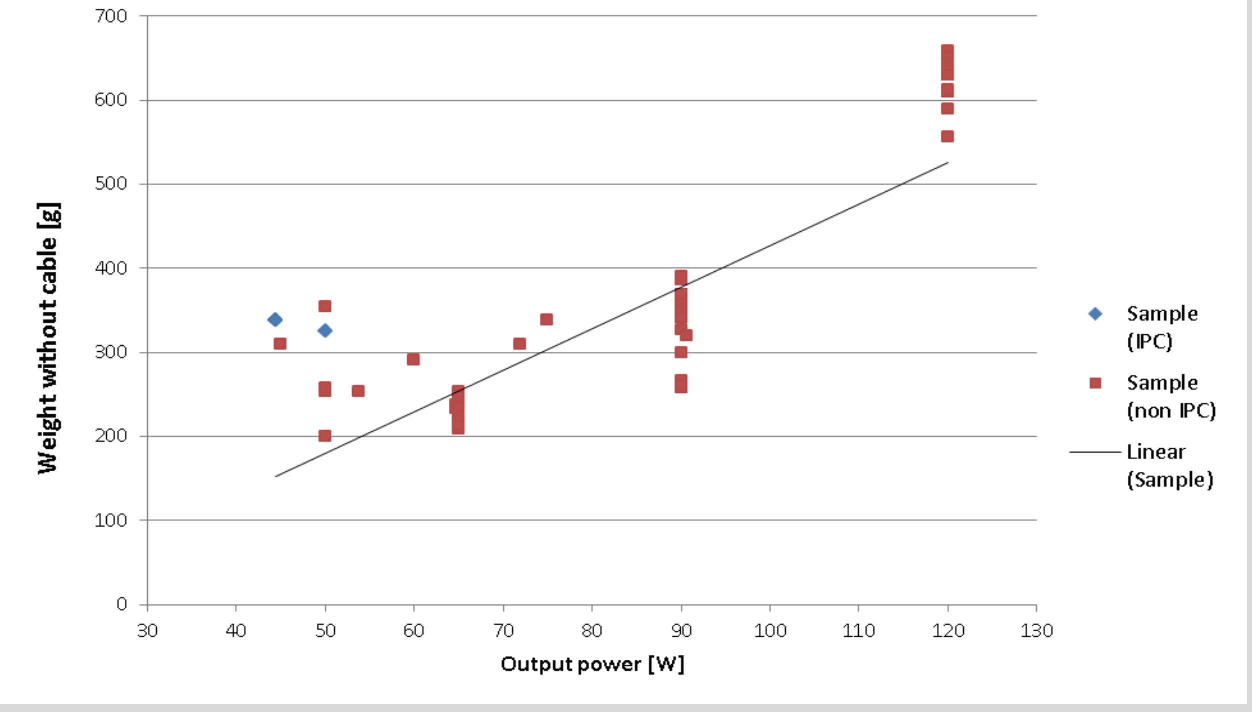
The power supplies with a detachable mains cable (not Integrated Power Connection) were highlighted in red. A linear trend line has been included in the graph.

Figure 11: Weights of the adapters without their mains cord against their declared power, limited to the lower power category (≤ 40W).



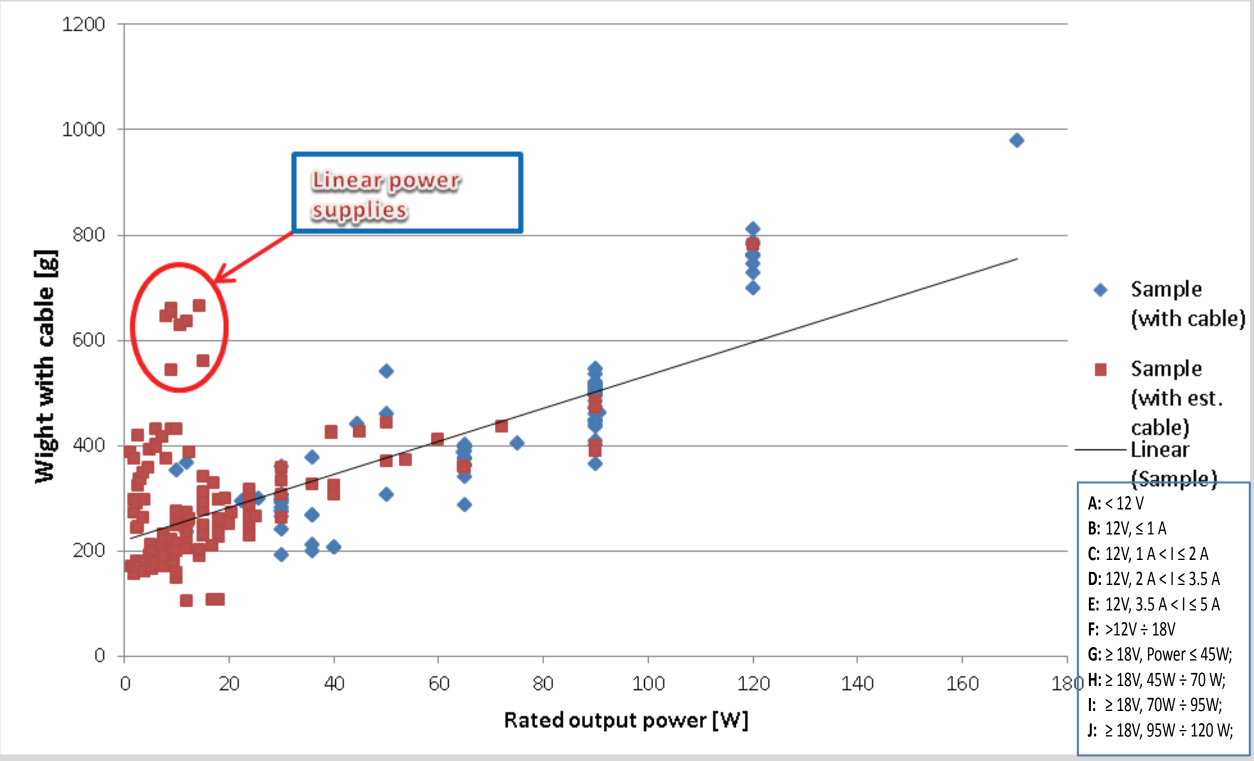
The power supplies with a detachable cable (not Integrated Power Connection) were highlighted in red. A linear trend line has been included in the graph.

Figure 12: Weights of the adapters without their mains cord against their declared power, limited to the "higher" power category (>40W).



The power supplies with a detachable cable (not Integrated Power Connection) were highlighted in red. A linear trend line has been included in the graph.

Figure 13: Weights of the adapters with their mains and low voltage cable against their declared power. A linear trend line has been included in the graph.



Remarks – Figure 10 *through* Figure 13 *show a high dispersion on weights of adapters having the same ratings. In particular for the lower power equipment (<40 to 50 W),* Figure 11 *shows substantial independence between weight and power, while the higher power equipment (laptop power supplies reported in* Figure 12*) look more aligned among themselves and they show a sort of linear dependence between power and weight.*

As weight can be directly linked to the environmental impact, it would be advisable to urge manufacturers to take care of this issue and optimize their products aligning to what others already achieved.

Figure 14: Weights of the adapters without their mains cord, divided by following the defined categories. For each category, maximum, minimum and average weights have been highlighted.

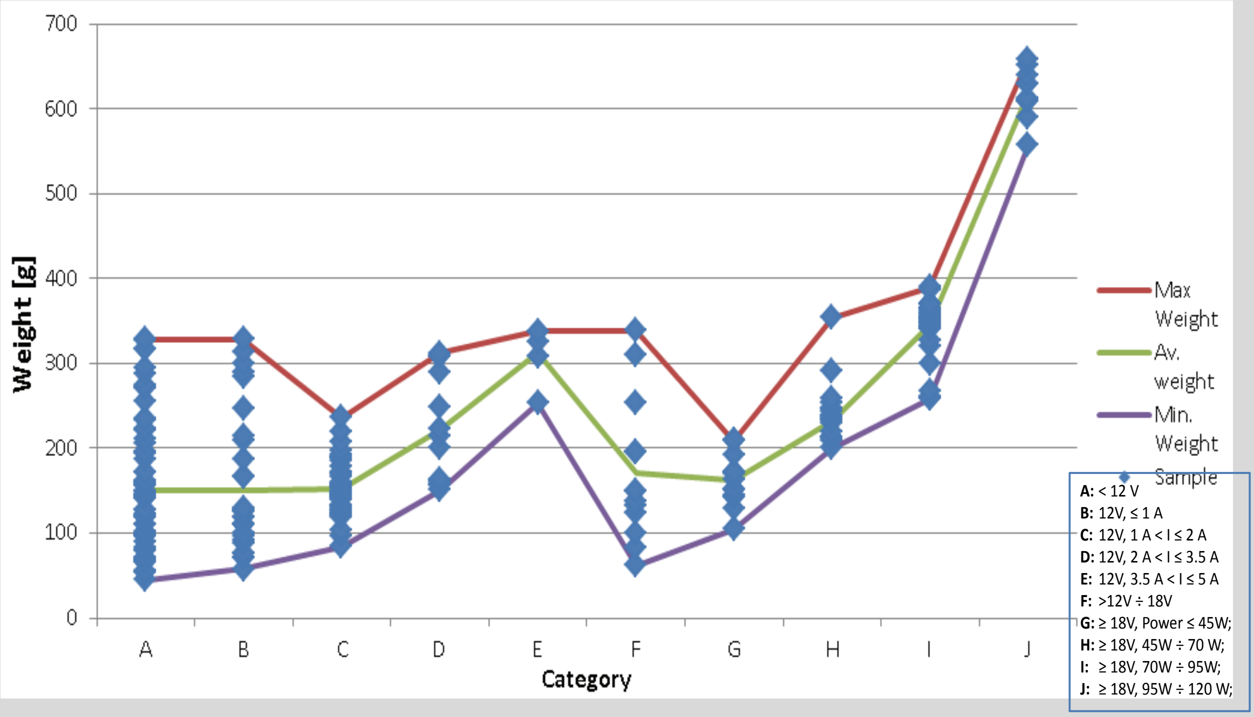
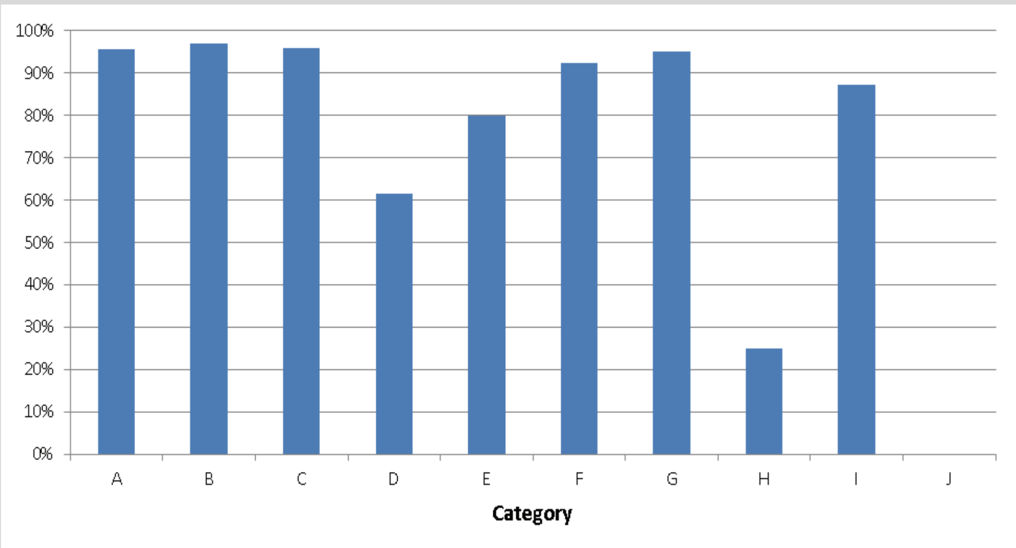


Figure 15: Percentage of power supplies that weigh more than the best in class plus the 20% of its weight, for each category.



The above analysis (Figure 11 and Figure 14) shows that the mean weight of equipment rated up to 40W is substantially stable and independent from the actual rated power and is rather higher than that of the lightest EPSs in those classes. Above 40W (Figure 12 and Figure 14), there is an evident linear relationship between rated power and weight while the spread is reduced.

Remarks –Figure 14 *and* Figure 15 *clearly show the huge difference between the best and the worst adapter, in terms of weight, for each category. For most of the categories, the percentage of power supplies that weigh more than the best plus the 20% is really large. This demonstrates that a lot can still be done to minimize the environmental impact of the power supplies.*

4.2 Volume

Similar to the previous graphs, Figure 16, Figure 17 and Figure 18 show the volumes measured for the set of analyzed devices according to their rated output power: Figure 16 for the total number of devices, Figure 17 for the "lower" power ones (≤40W), and Figure 18 for the "higher" power supplies.

The obtained results outline how the collected volume is almost not correlated with the adapter power for the lower power devices (the trend line is almost flat and there is a wide dispersion of the values) and that the correlation is very limited also for the higher power ones. Note that, in some cases, the measured devices with output power between 50 and 100 W appear to have smaller form-factors than the ones rated at 1-20 W.

Figure 16: Volumes of the adapters against their declared power. A linear trend line has been included in the graph.

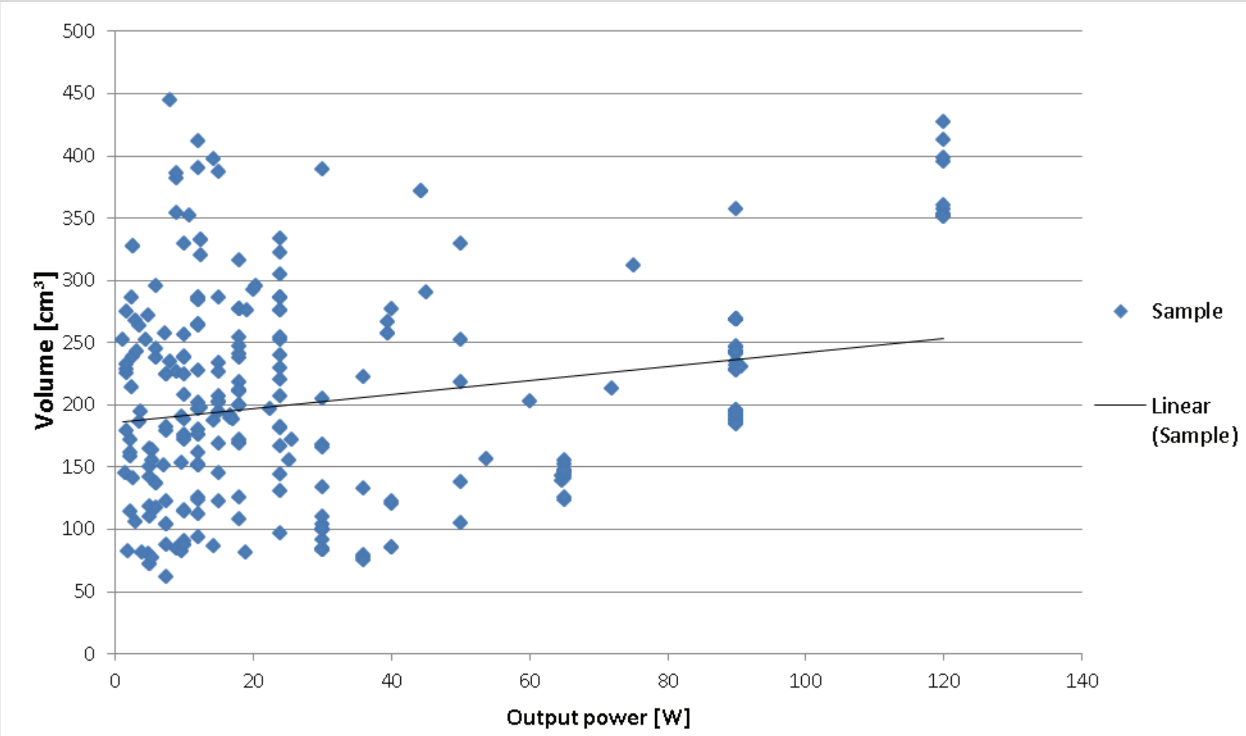


Figure 17: Volumes of the adapters against their declared power, limited to the lower power category (≤ 40 W). A linear trend line has been included in the graph.

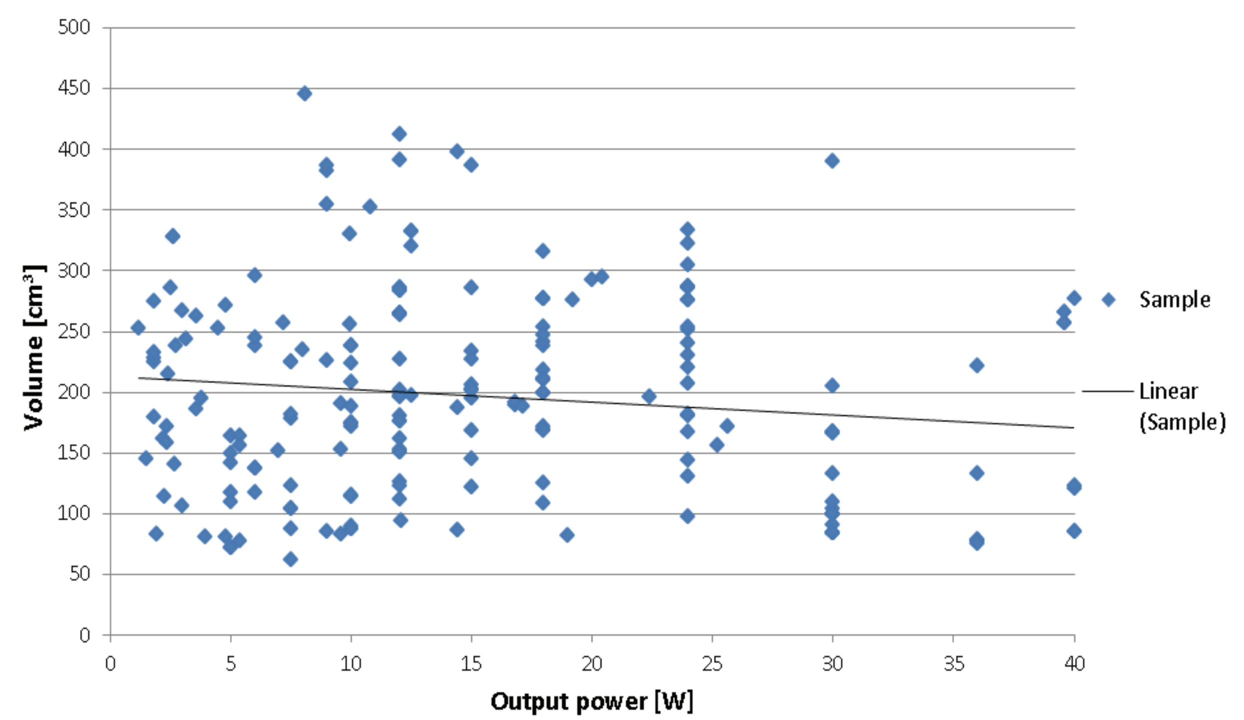
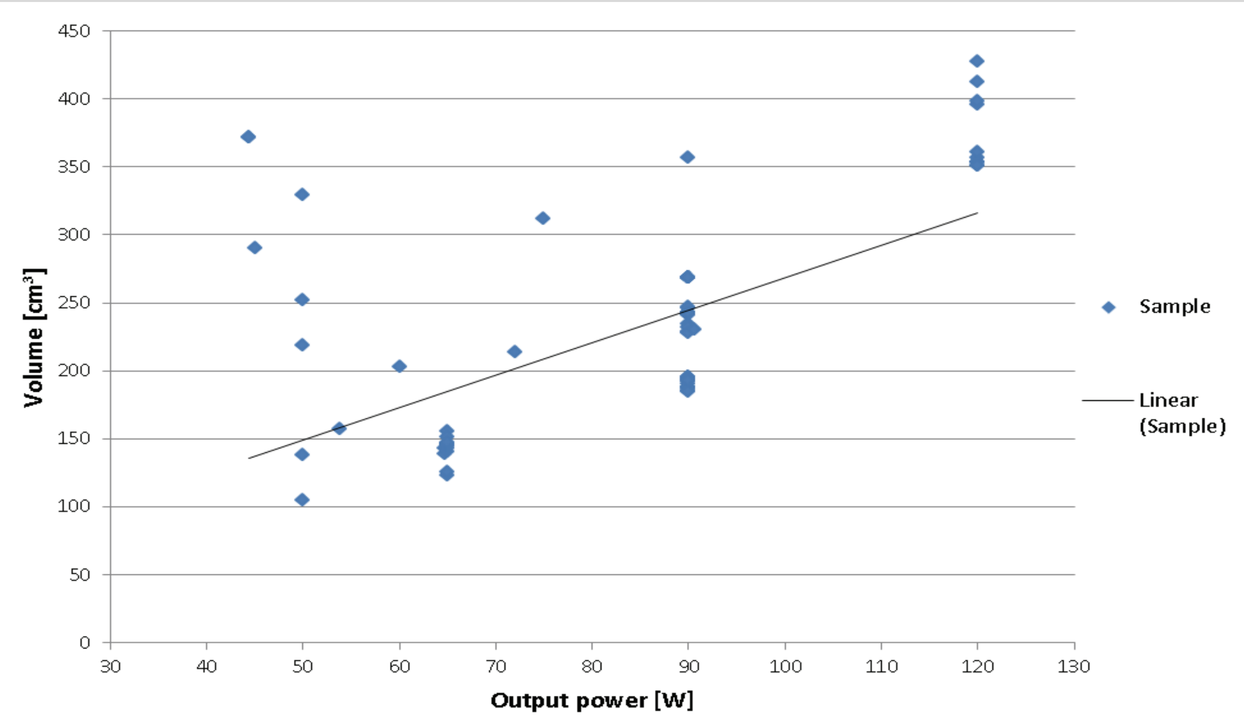


Figure 1: Volumes measured from the adapters without their cord against their declared power, limited to the "higher" power category (>40 W). A linear trend line has been included in the graph.



4.3 *Power density*

Figure 19 and Figure 20 report the power density (with respect to volume and weight, respectively) versus the output power. Though there is a wide dispersion of the values, some correlation can be found showing increase of mass and volume density with power increase.

Figure 19: Power density with respect to the weight (without cable), versus output power.

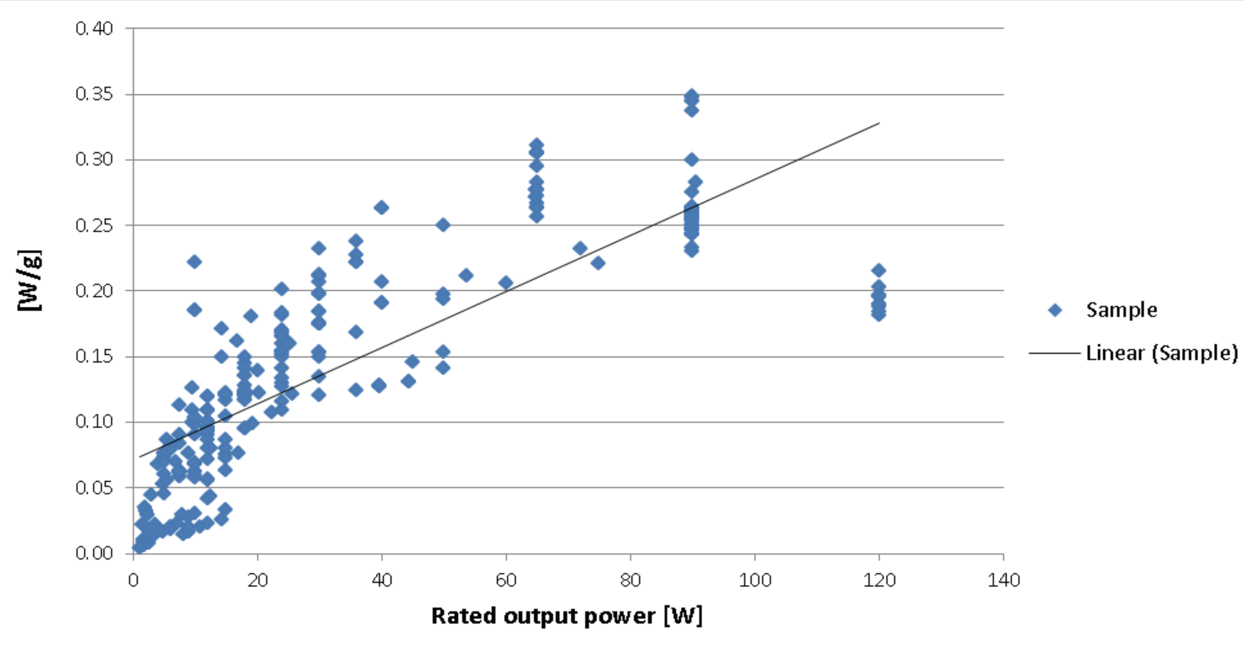
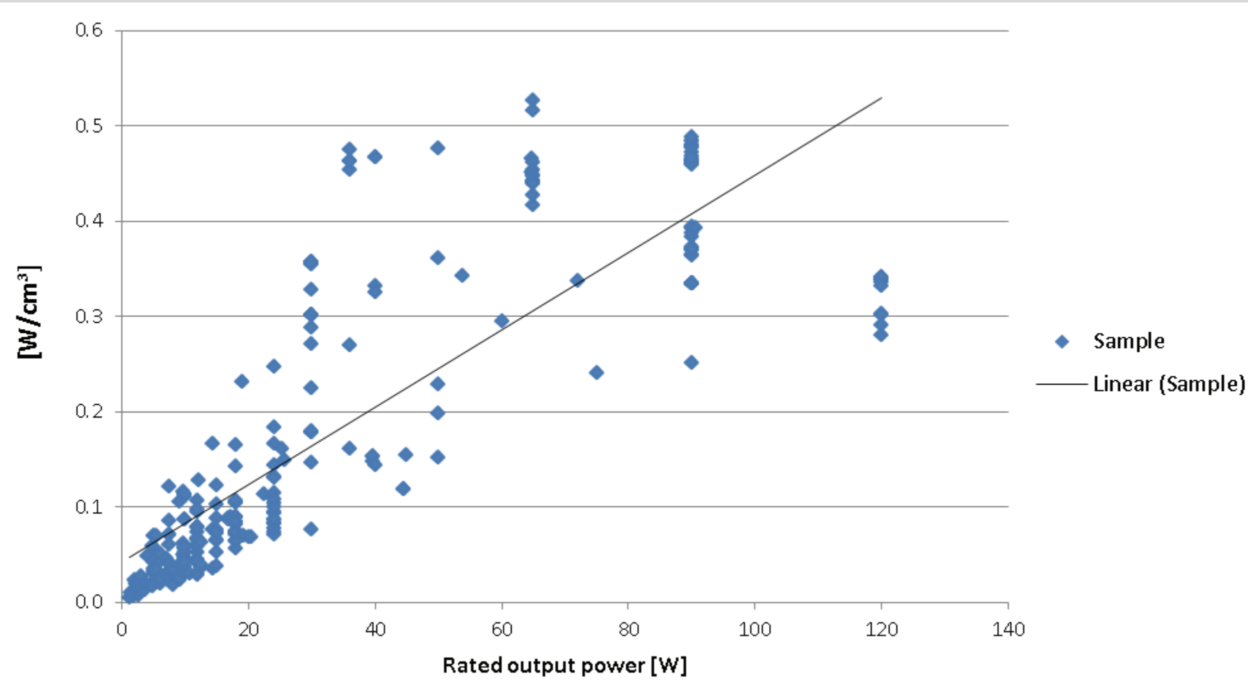


Figure 20: Power density with respect to the volume, versus output power.



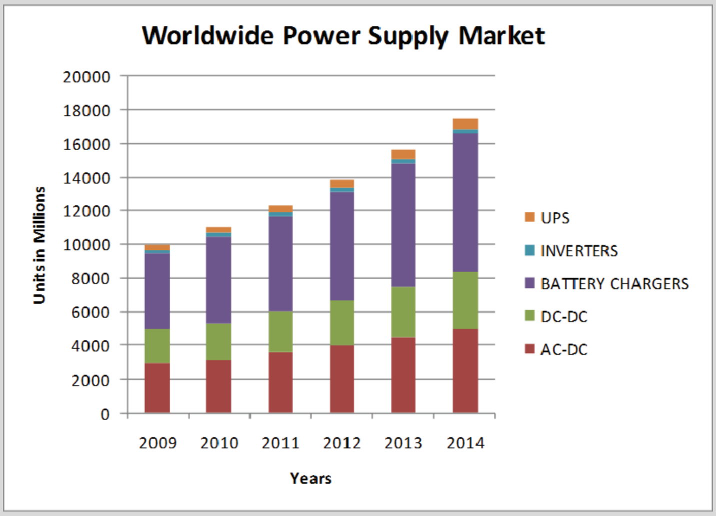
4.4 Estimation on use of resources and e-waste

Each year, billions of external power supplies are introduced into the market. Figure 21 shows that in 2012 about 14 billion power supplies will be sold worldwide. This huge amount is due to an increase of nearly 2 billion pieces sold every year.

A cautious estimate says that at least 4 billion should be EPSs.

The yearly amount of material (and e-waste) can be estimated as: the number of EPSs (4 billion in 2012) multiplied by the mean weight of all classes (Figure 14) that is about 250 grams. This results in the impressive amount of about **1 million tons**. As a high percentage of the new EPSs are bought with new equipment to replace the obsolete one, **e-waste can easily be estimated to be at least half a million tons per year**. The overall power supply market can be estimated to be 3 to 4 million tons.

Figure 21: Worldwide power supplies market.



Source: Selantek Power Supply Report 2010

Another lesson learnt from Figure 11 through Figure 14 is the huge spread between lightest, mean weight and heaviest equipment. If all EPSs were weighting as the best in class for each group, then the amount of material could be reduced by 30%, **saving 300 thousand tons per year** of valuable (and polluting) material.

Remarks – *By combining market data and measured weight, it becomes clear that a huge quantity of material could be saved. A cautious estimate indicates that the aggregated amount, if electronics of EPSs is 1 million tons per year, is growing. At least half of it could be expected to be saved if a standardized solution is available.*

Because weight is directly linked to environmental impact, it would be advisable to urge manufacturers to optimize their products, aligning them with the best (lightest) in the corresponding category as it could reduce the use of resources (and the e-waste) by 300 thousand tons per year.

Nearly no equipment was provided with a detachable cable on the low voltage DC side. This is not a problem for EPSs designed to power fixed equipment; however, this is critical for those EPSs powering portable/mobile equipment as the frequent connection/disconnection and winding/unwinding of the cord leads to mechanical stress and failure to the wiring inside the cable. As most modern PSUs are made as monolithic block, there is no possibility to repair it even if the electronics is still fully operating. It results again into a **high volume of unnecessary e-waste**. This is a particular problem as Laptop PSUs are bulky and contain heavy electronics, and can weigh between 300 to 400 and sometimes even 600 grams each, while the DC cable alone weighs around 100 g. A Telecom Italy contribution to the January 2012 rapporteurs meeting of ITU-T SG5 WP3 has shown that in 9 out of 10 laptop EPSs reported as broken, the fault was located in the DC cable while the electronics was still fully operational.

5. Electrical features

5.1 Efficiency measurements

Figure 22 reports the energy-efficiency characteristic curves of the analyzed adapters. The energy efficiency curve is defined in each point as the ratio between the power provided at the DC side and the active power absorbed by the power supplies at the AC side. The tests were performed for each device up to its declared maximum current with steps of 50 mA or 100 mA as described above.

Most of the energy-efficiency curves have quite similar shapes: they rapidly increase and then flatten around a certain value, which represents the maximum efficiency level achievable by the adapter. Some of them are characterized by irregular slopes in the efficiency curves, and this behavior probably depends on internal circuitry design aiming at optimizing also the no-load behavior or the power factor at higher load.

Despite the similarity on the shapes of such curves, Figure 22 clearly shows that analyzed devices have highly heterogeneous values of maximum energy efficiency, and different paces to achieve these values.

Figure 22: Energy efficiency curves with variable loads for all the analyzed adapters. Each device has been tested up to its declared maximum value of DC current.

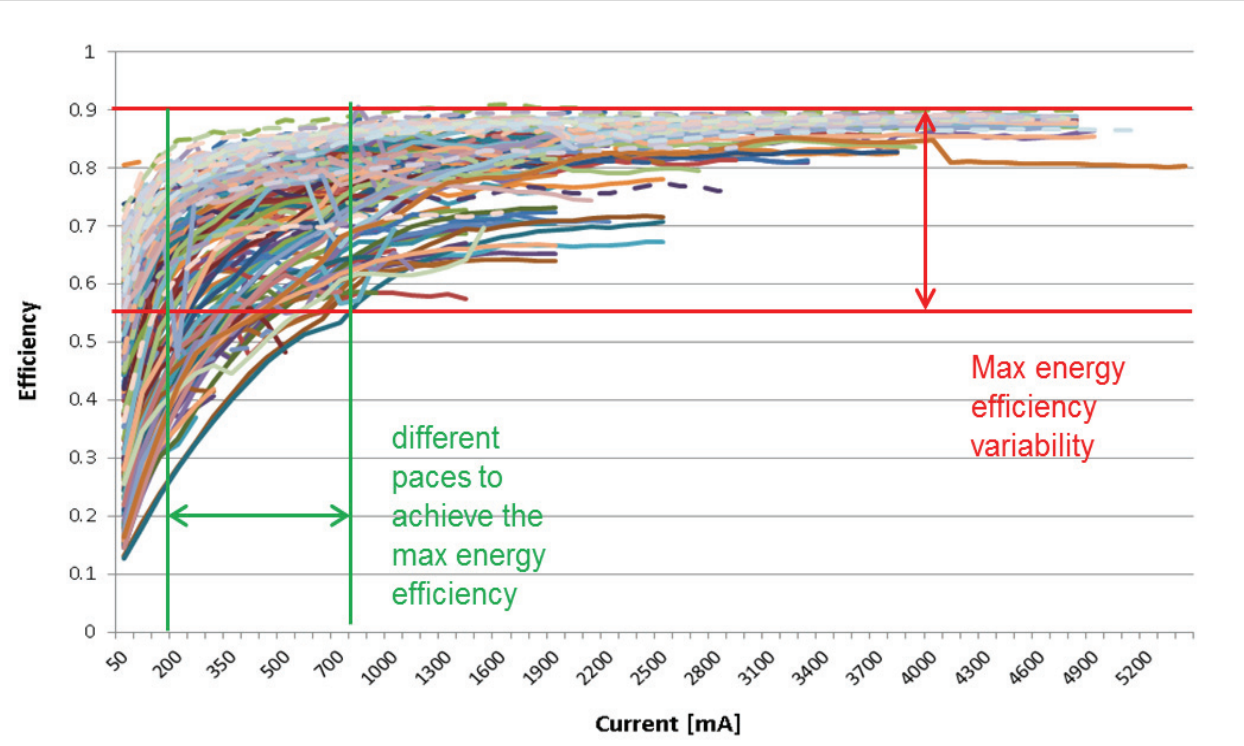
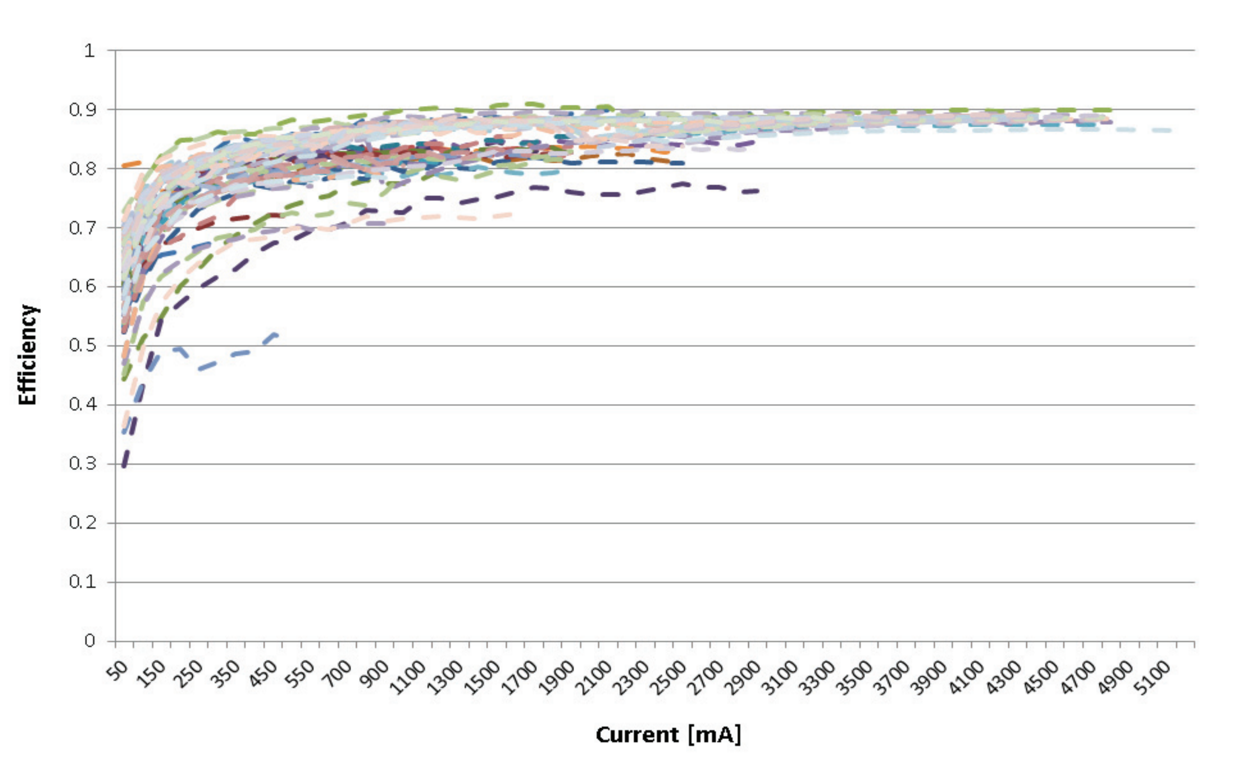


Figure 23 shows the efficiency curves only for the adapters with the Energy Star mark on their labels.

Figure 23: Energy efficiency curves with variable loads only for the analyzed adapters with the Energy Star mark. Each device has been tested up to its declared maximum value of DC current.



5.1.1 Efficiency measurements – subdivided per-class

To better understand the behavior of the adapters, it was decided to split the graph of Figure 22 according to the above defined (see the list before Table 1) categories of power supplies in terms of voltage, current and power, by obtaining ten graphs (Figures 23-32).

Figure 24: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category A).

Voltage < 12 V, Current: any, Power: any;

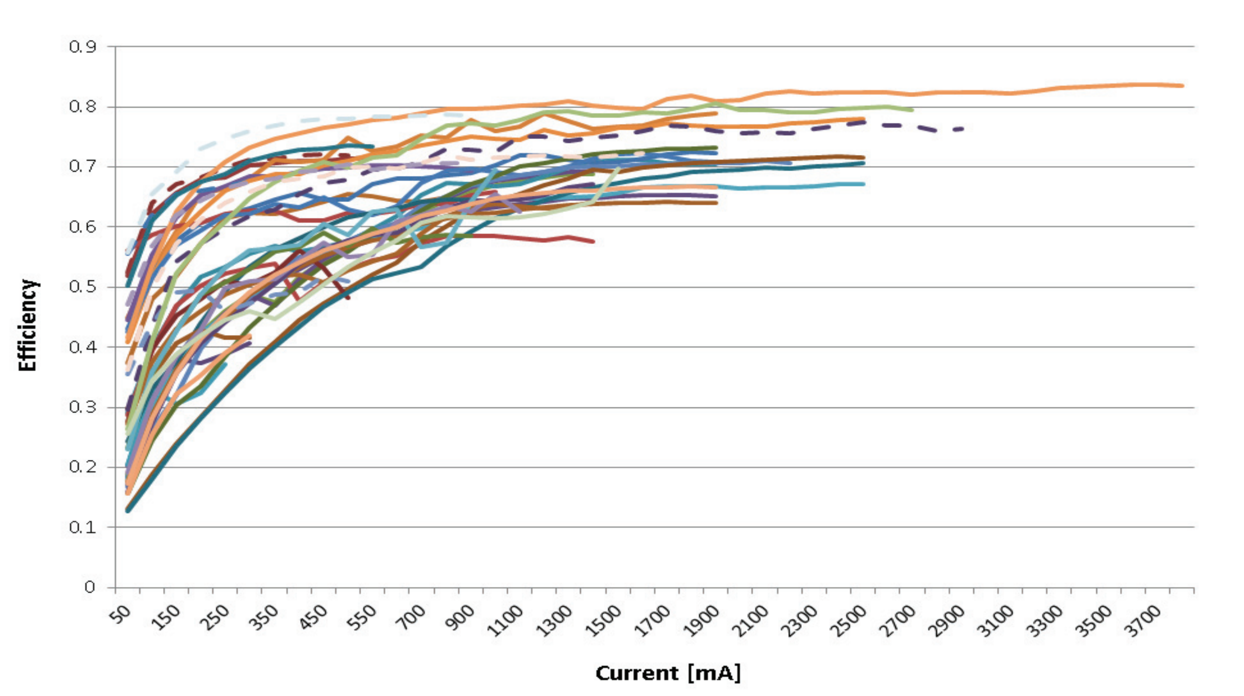


Figure 25: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category B).

Voltage = 12V, Current ≤ 1 A, Power: any;

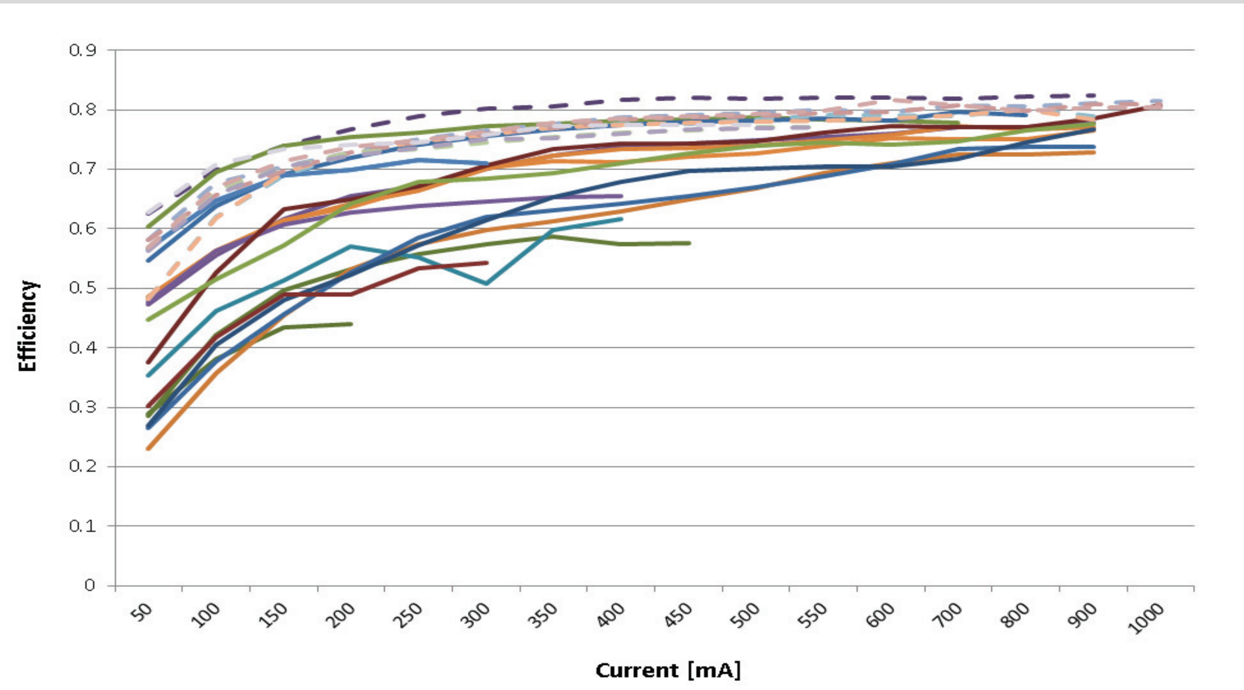


Figure 26: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category C).

Voltage = 12V, 1 A < Current ≤ 2 A, Power: any;

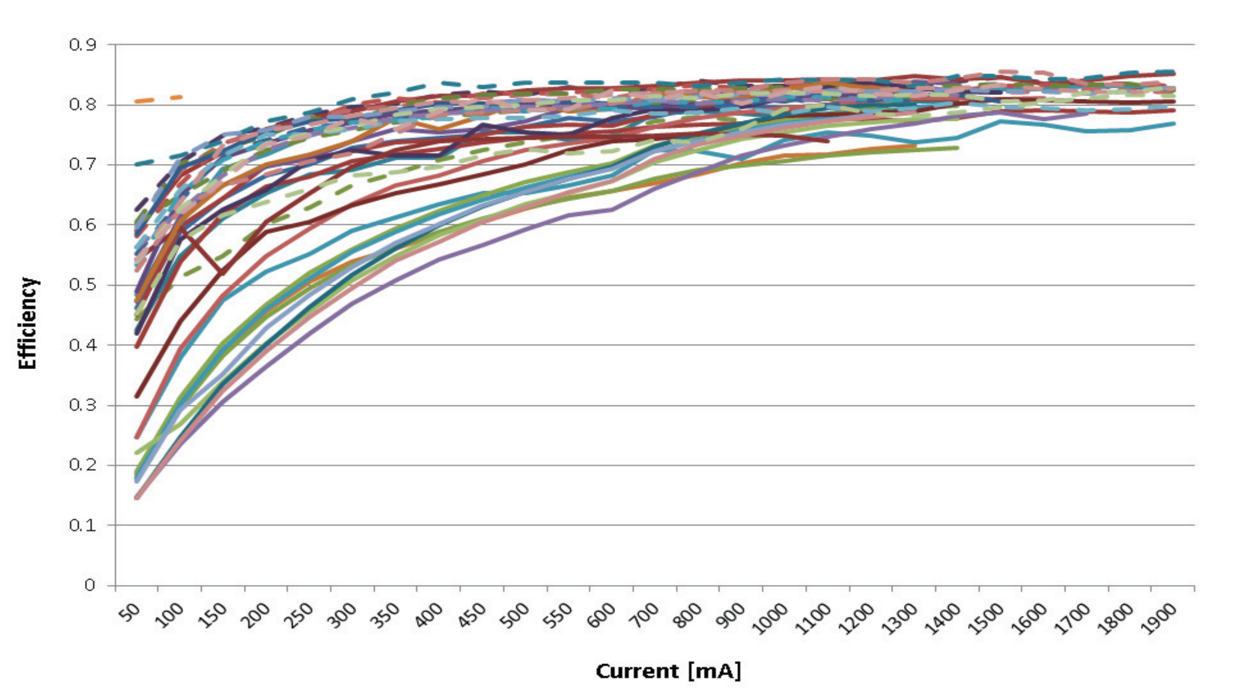


Figure 27: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category D).

Voltage = 12V, 2 A < Current ≤ 3.5 A, Power: any;

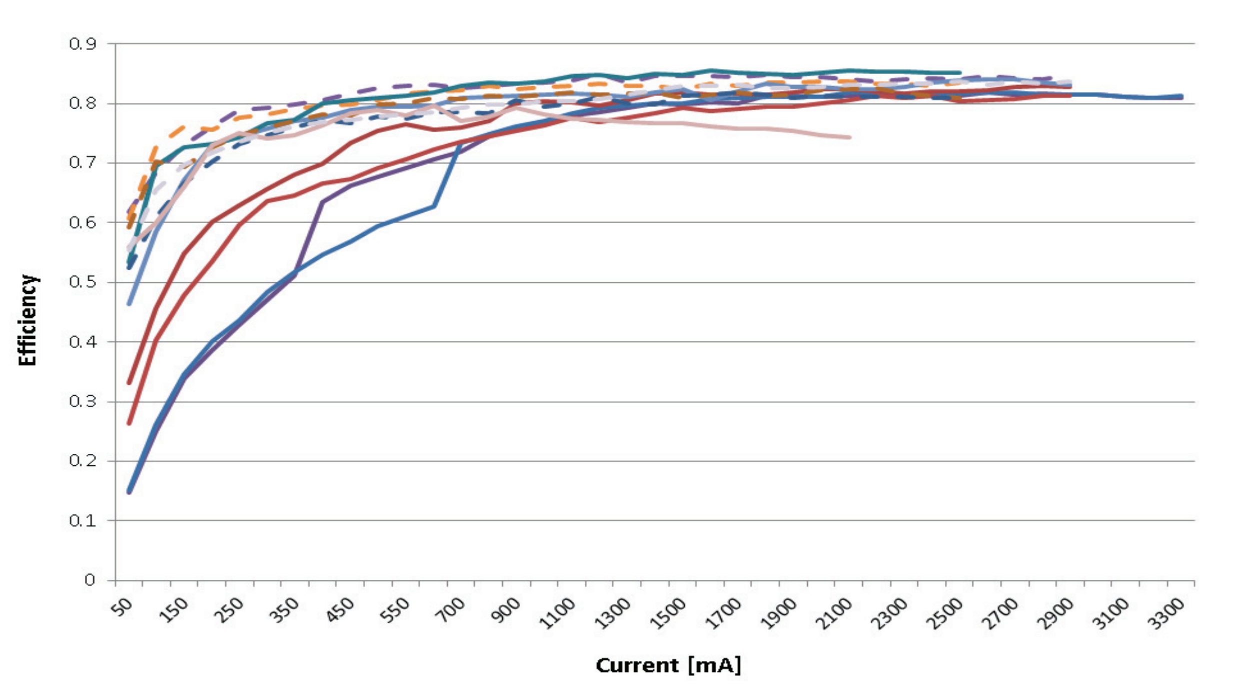


Figure 28: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category E).

Voltage = 12V, 3.5 A < Current ≤ 5 A, Power: any;

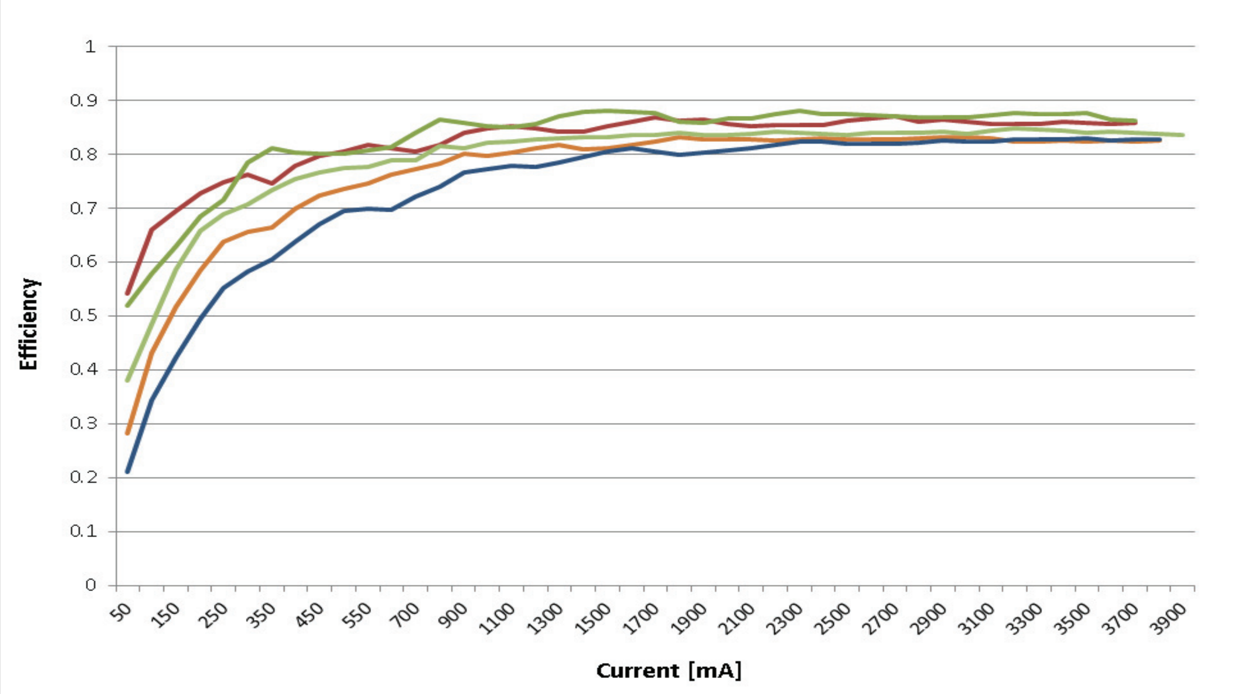


Figure 29: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category F).

12 V < Voltage < 18V, Current: any, Power: any;

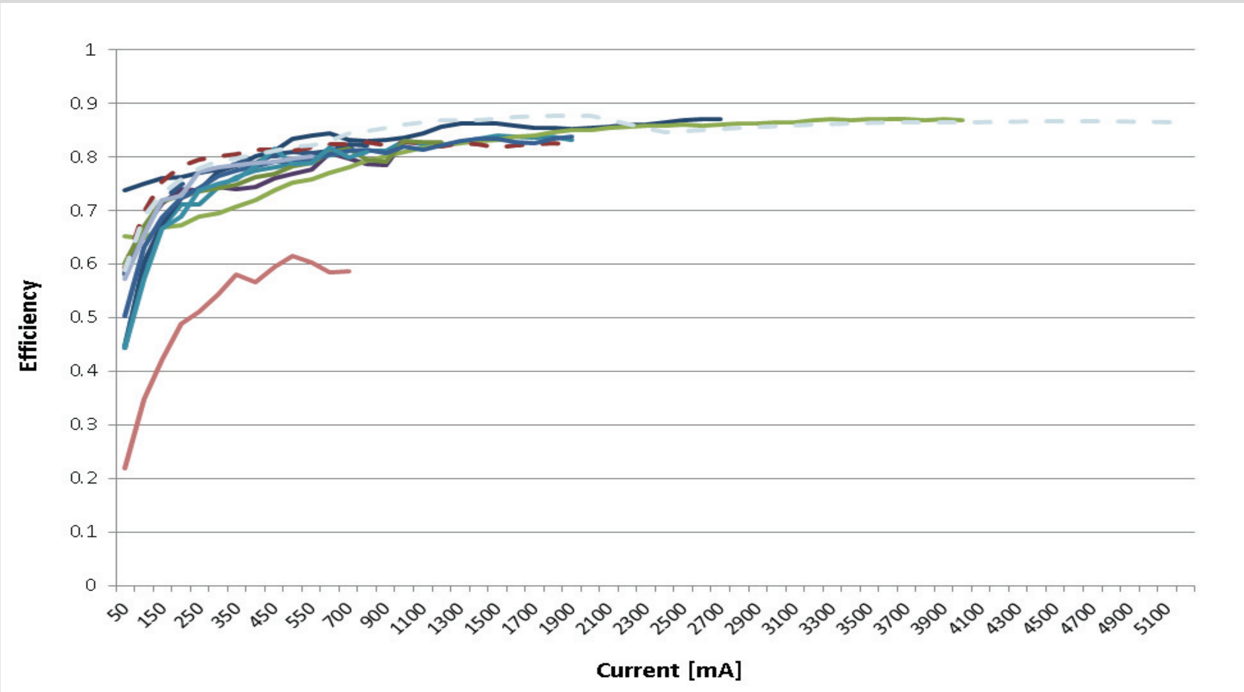


Figure 30: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category G).

Voltage ≥ 18V, Current: any, Power ≤ 45W;

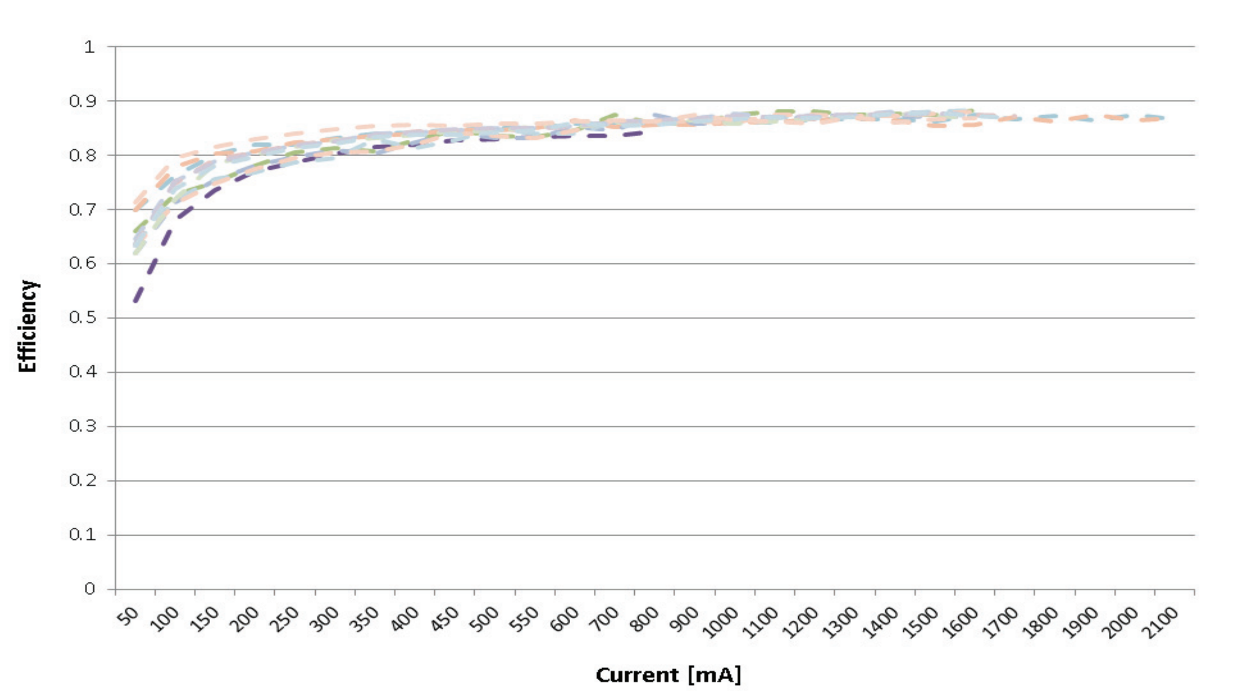


Figure 31: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category H).

Voltage ≥ 18V, Current: any, 45W < Power ≤ 70 W;

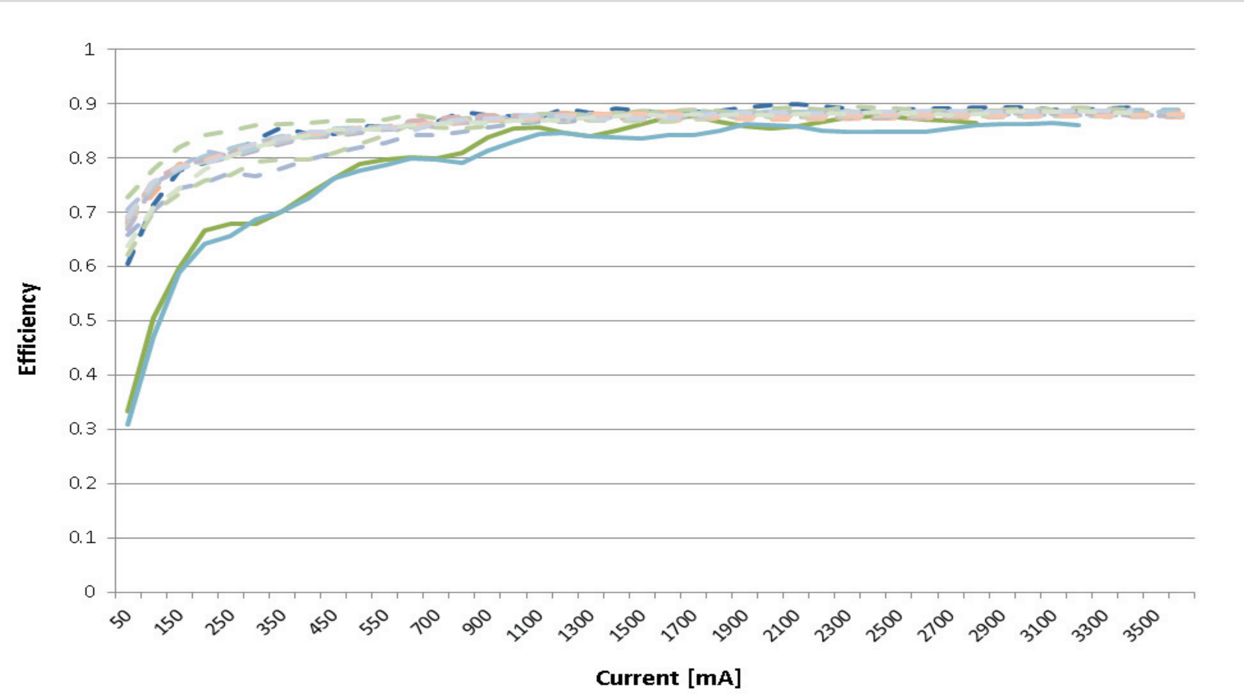


Figure 32: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category I).

Voltage ≥ 18V, Current: any, 70W < Power ≤ 95W;

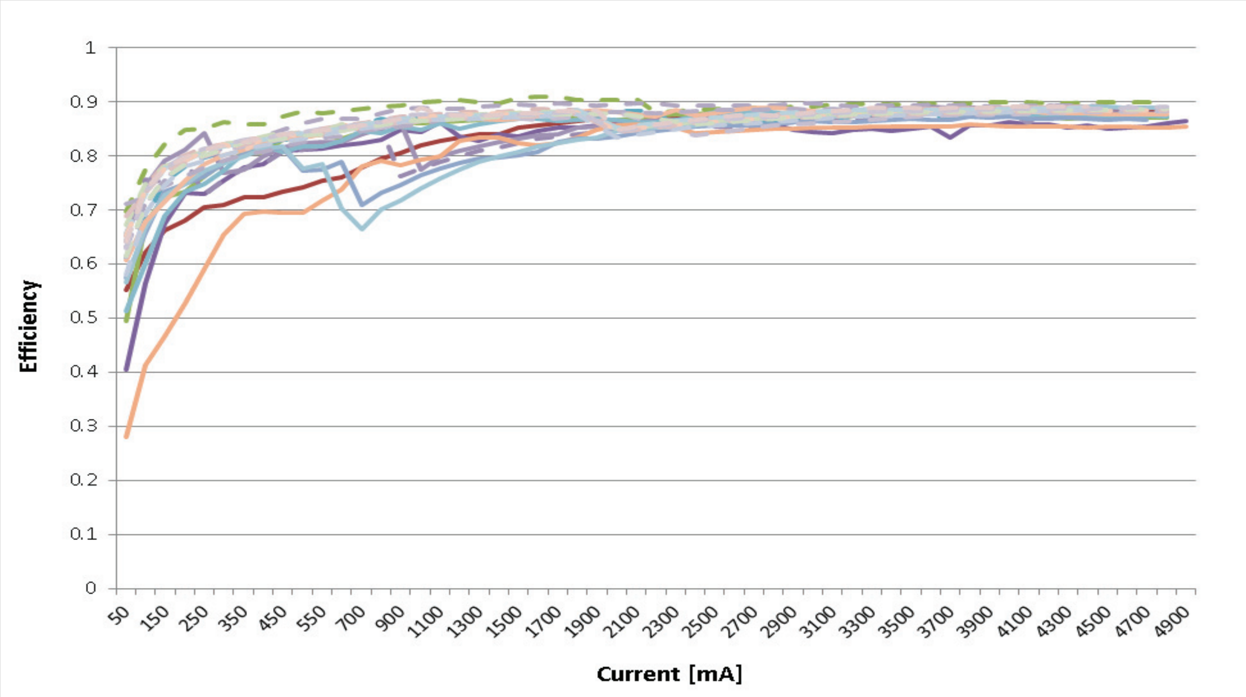
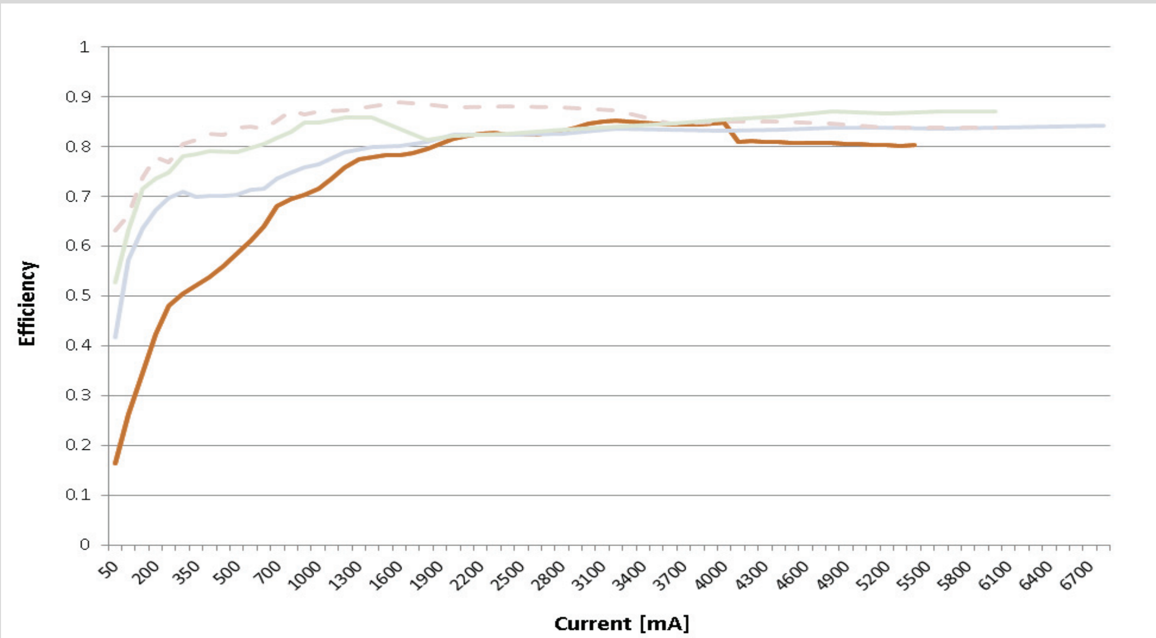


Figure 33: Energy efficiency curves with variable loads for the analyzed adapters. Each device has been tested up to its declared maximum value of DC current (Category J).

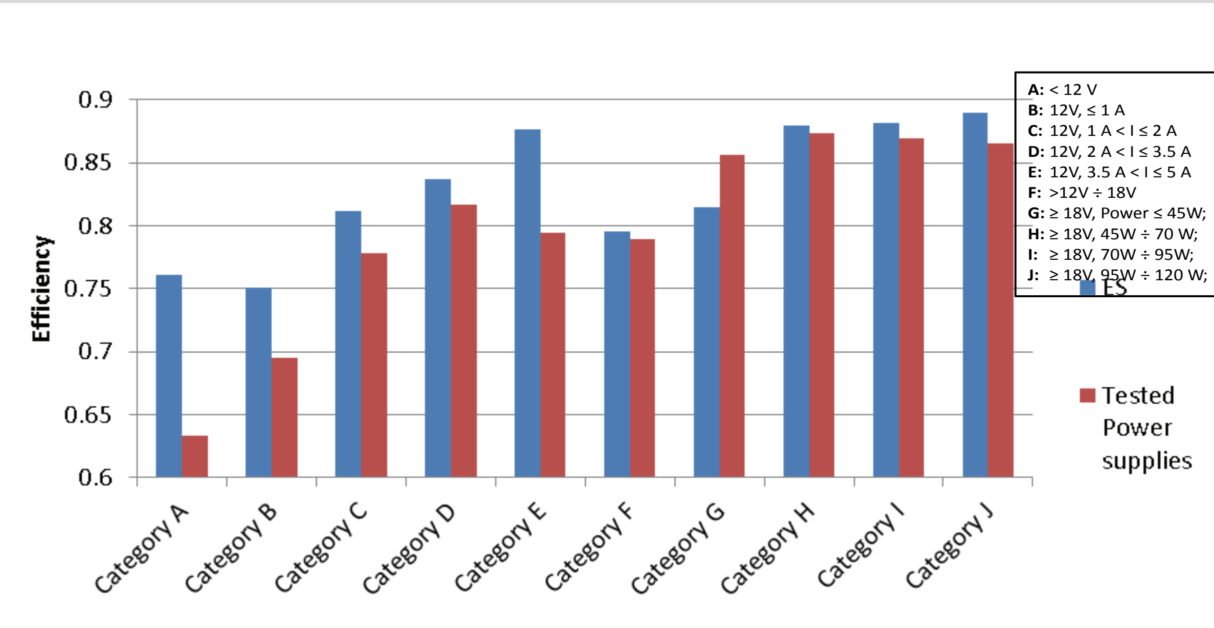
Voltage ≥ 18V, Current: any, 95W < Power ≤ 120 W;



Remarks – *Graphs 22-33 show a high dispersion on the adapter efficiencies both in general (see graph Figure 22) and inside the same class. This aspect suggests an important opportunity of improving the efficiency characteristics of these devices independently from their power capacity.*

In Figure 34, the efficiency result averages for each category are summarized and compared with the same values obtained from the filtered ESP list (see Section 2 and Figure 3). The comparison shows that the average values of the ESP list appear to be always better than the measured ones, except for category G. In some categories, the differences are rather quite small. However, the results demonstrate that once, at least, (ESP data from the end of 2010, they did not provides any improvement in the average efficiency level of the power supplies with a situation in which the difference among the devices cover a large range indicating a large space for improvements.

Figure 34: Average energy efficiency versus categories for both measured and ESP list devices.

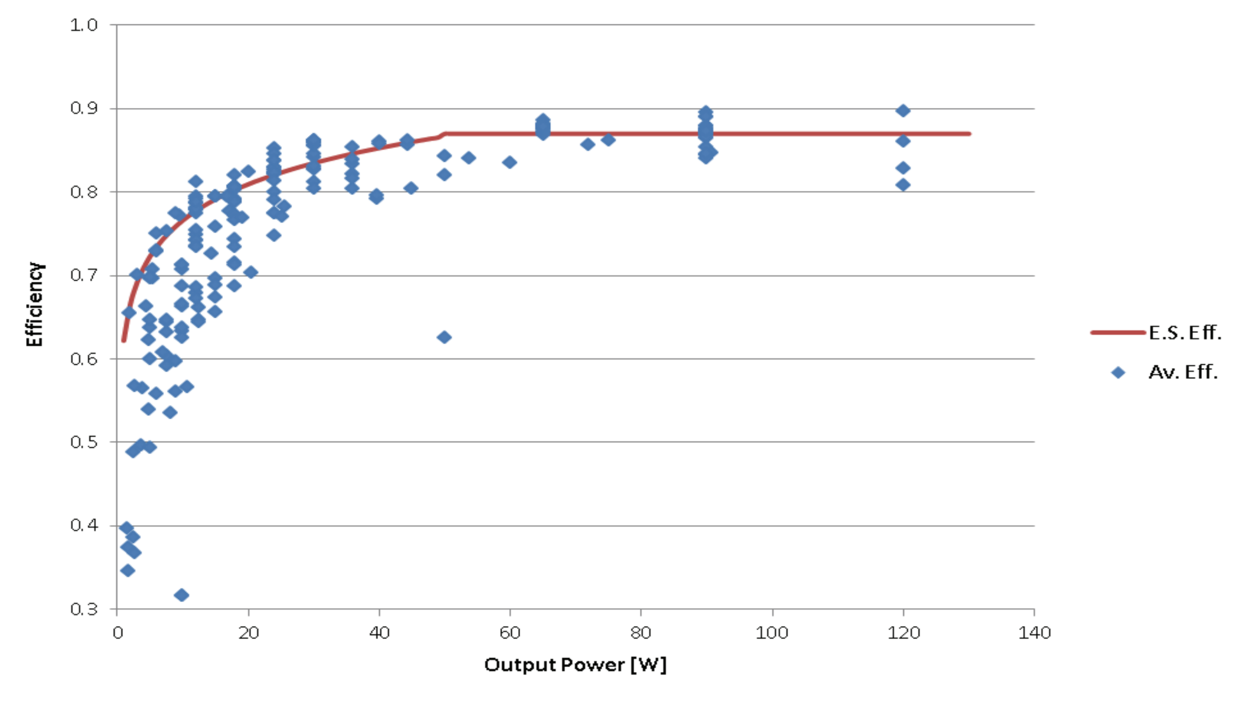


To be eligible for Energy Star qualification (class V), an external power supply model must meet or exceed a minimum average efficiency (mean of the measured values at 25%, 50%, 75% and 100% of the rated load), which varies based on the model's nameplate output power, from 1 to 49W, according to the following equation:

$$[0.063 * \ln(P_{no})] + 0.622$$

Where P_{no} is the rated output power of the device. Beyond 49W the average efficiency must be ≥ 0.87. Figure 35 reports the average efficiencies of the measured adapters, with the objective efficiency curve based on Energy Star requirements and the ecodesign regulation for external power supplies (published in April 2009). It is interesting to note that only 75 EPSs are above that curve.

Figure 35: Average efficiency of the measured EPS and the E.S. objective efficiency.



5.1.1.1 Comparison among equivalent equipment

Even in the same category, different values of efficiency can be noticed as well as the various method of achieving this. Figure 36 and Figure 37 give the efficiency curves of two pairs of power supplies, n. 42 and 148, n. 125 and 244, respectively. Although the differences in the efficiency behavior are clearly noticeable, the calculation of the average energy efficiencies (based on the Energy Star procedure: mean of the measured values at 25%, 50%, 75% and 100% of the rated load) gives very similar results in both cases, i.e., in the first pair (Figure 36) the average efficiencies differs of only 2%, while in the second pair (Figure 37) both devices have exactly the same value. The gap in the range up to the 20-30% of the maximum load is quite noticeable (5%-15%). This results in a significant increase in the overall energy consumption as several devices draw only a limited amount of energy for most of their operating time.

Figure 36: Energy efficiency curves with variable loads for a couple of adapters (42, blue line and 148, red line) with very similar average efficiencies.

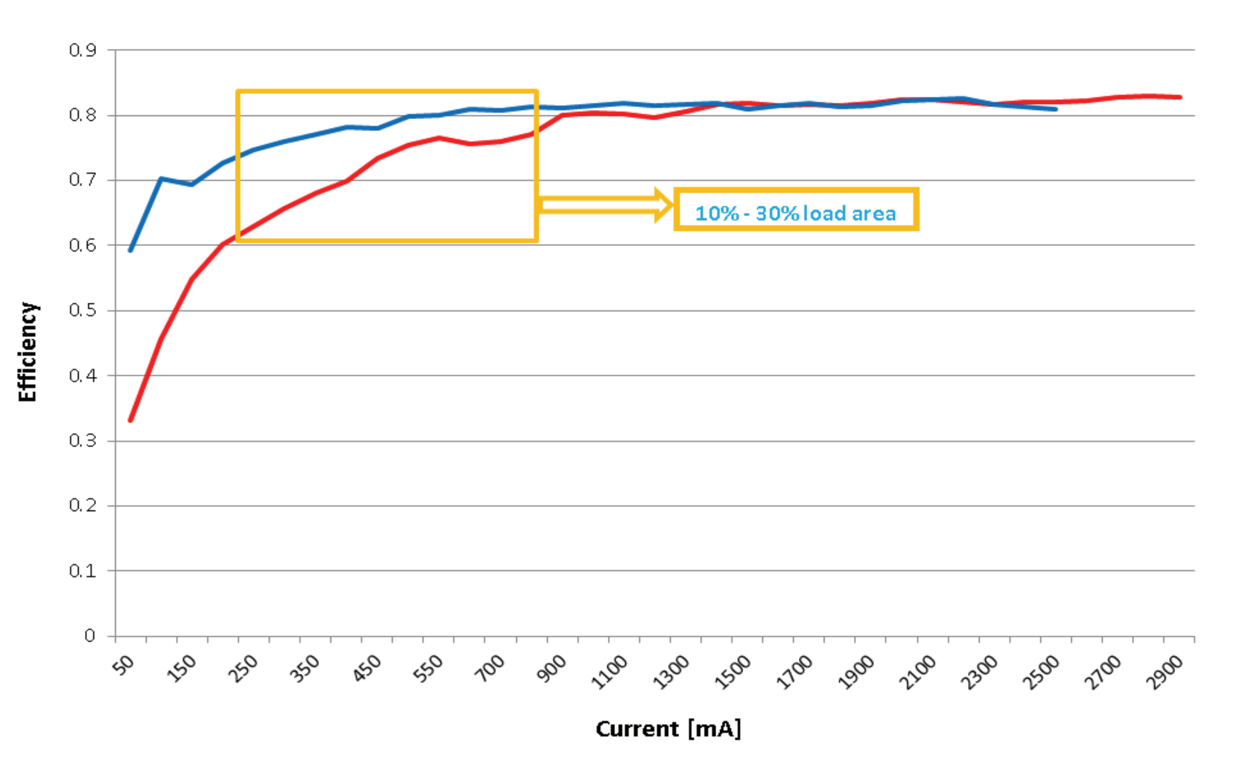
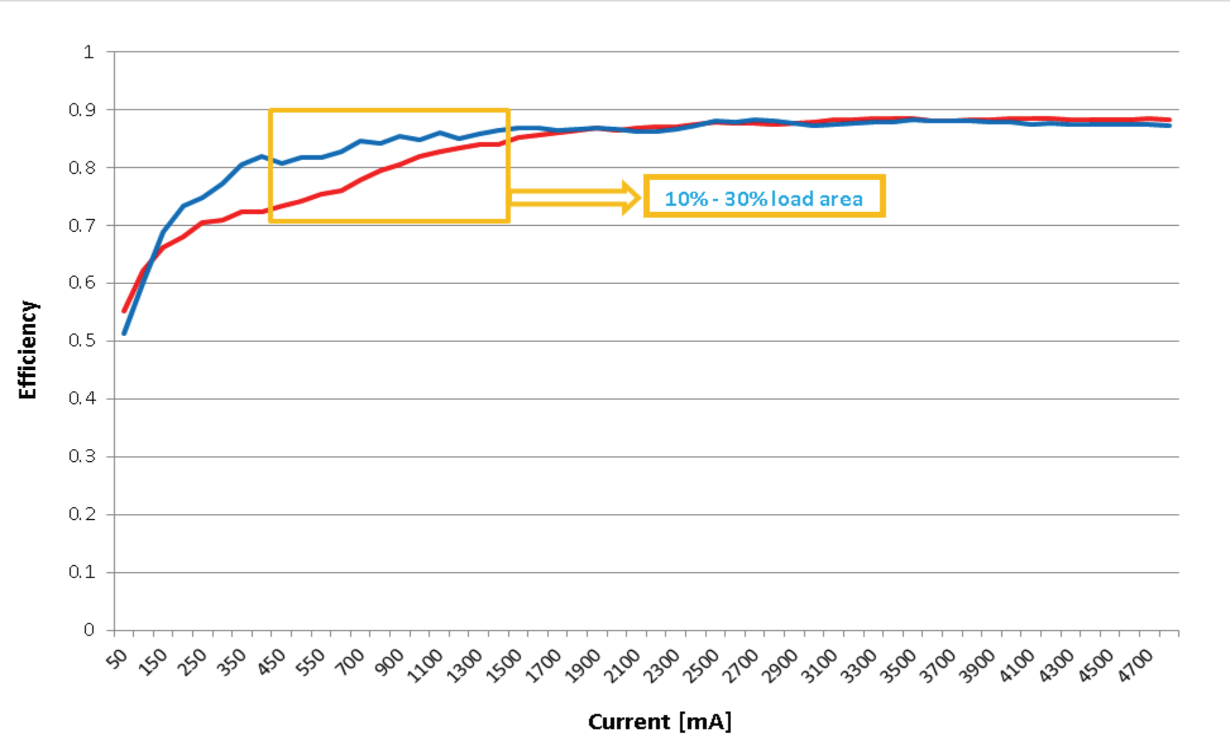


Figure 37: Energy efficiency curves with variable loads for a couple of adapters (125, red line and 244, blue line) with the same average efficiency (0.869).



5.1.2 Efficiency at lower load – impact on some products

As stated previously, a considerable amount of equipment has quite variable energy consumption and draws only a limited amount of energy for most of its operating time, laptops for example. While the battery is fully charged and there is a low request for computational power, laptops would require a very low quantity of energy from the EPS. This condition is most common in the life of such devices. Table 2 shows the results of a survey of the amount of power (as a percentage of the EPS capability) a set of laptops consumes when in normal operation. It ranges from 16 to 29%.

Table 2: Normal operation (low performances) consumption.

	PSU rating	Consumption	PSU utilization
	W	W	%
Laptop 1	65	18	28%
Laptop 2	65	14	22%
Laptop 3	90	17	19%
Laptop 4	65	19	29%
Laptop 5	120	18.5	15%
Laptop 6	120	19	16%

POS terminals are another example. Those terminals which populate shops, supermarkets and any modern cash register are normally into a quiescent, low power state, and turn into full activity (and consumption) only for the short time needed to process a payment.

A lot of energy is wasted as many power supplies are rather less efficient when the load is below 30%.

Remarks – Often, equivalent EPSs do show quite different efficiency at lower loads, while a lot of equipment have quite variable energy consumption and draw only a limited amount of energy for most of their operating time. The low-load efficiency difference results then in a significant increase in the overall energy consumption and should be avoided through optimizing the efficiency at 10-30% load.

Energy Star requires a power factor correction only for EPS rated 100W and above. In some other regions, such a requirement applies for EPSs when drawing an input power of 75W onward. The actual power factor is verified when the EPS is in a fully loaded condition.

Figure 38 shows the Cos φ values for all the analyzed power supplies. From the graph, it can be seen that almost every adapter with a high power factor value (more than 0.8) at 100% of the rated output power has a poor power factor when operating at lower power.

The graph in Figure 39 reports the energy efficiency and the power factor behavior versus the output loads of some adapters that have been not reported inside the previous figures, due to the apparent anomalous behavior of the efficiency curves. The efficiency values and the Cos φ values (Figure 39) have been coupled together to show that, in the range in which the efficiency has sudden changes in a strange manner, the Cos φ has a strong modification too. In this respect, these not conventional behaviors should depend on Cos φ control circuits. Figure 40 and Figure 41 report the same data for a single device each, to better clarify the above-described behavior. It can be argued that the power factor control mechanism described above is activated only when the load exceeds a predetermined threshold. This is probably aimed at obtaining good efficiency performances at lower output current values. **Whenever the power factor control enters into action, this results into a clear reduction of the efficiency values which implies remarkable energy losses**.

5.1.3 Power factor vs. load and efficiency

Figure 38: Cos φ curves with variable loads for all the analyzed adapters.

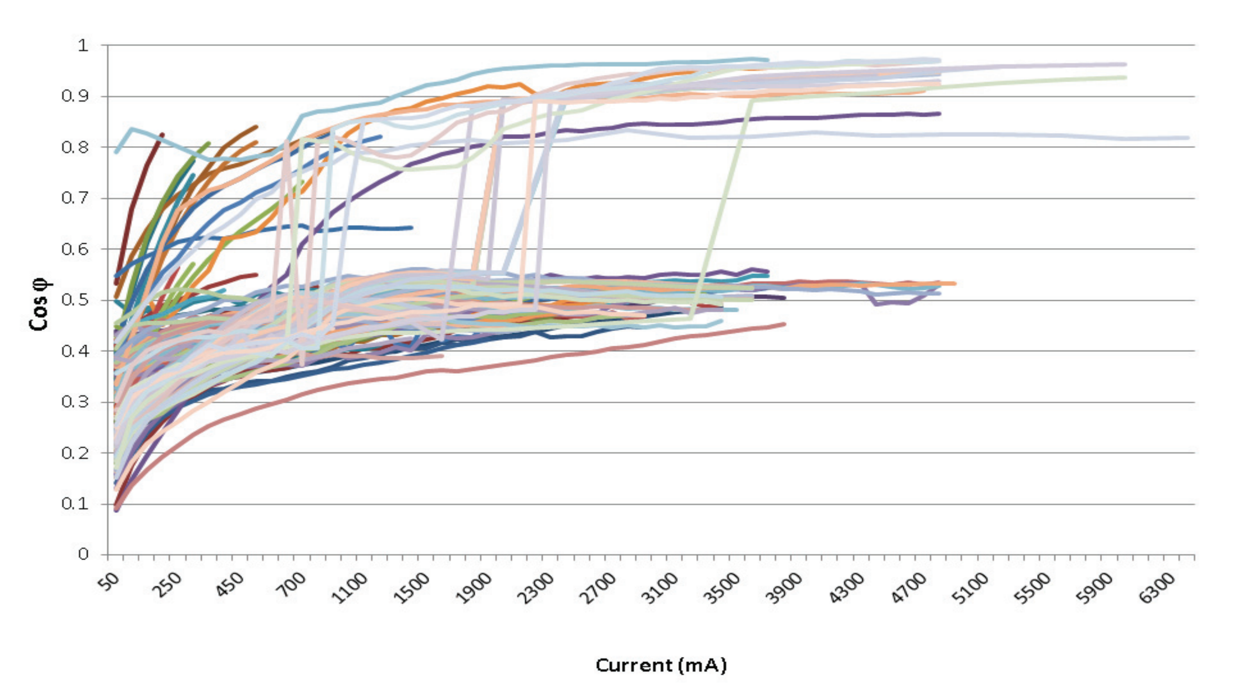


Figure 39: Energy efficiency and correlation with Cos ϕ curves for a set of adapters with some anomalous behaviors (not reported in the previous graphs).

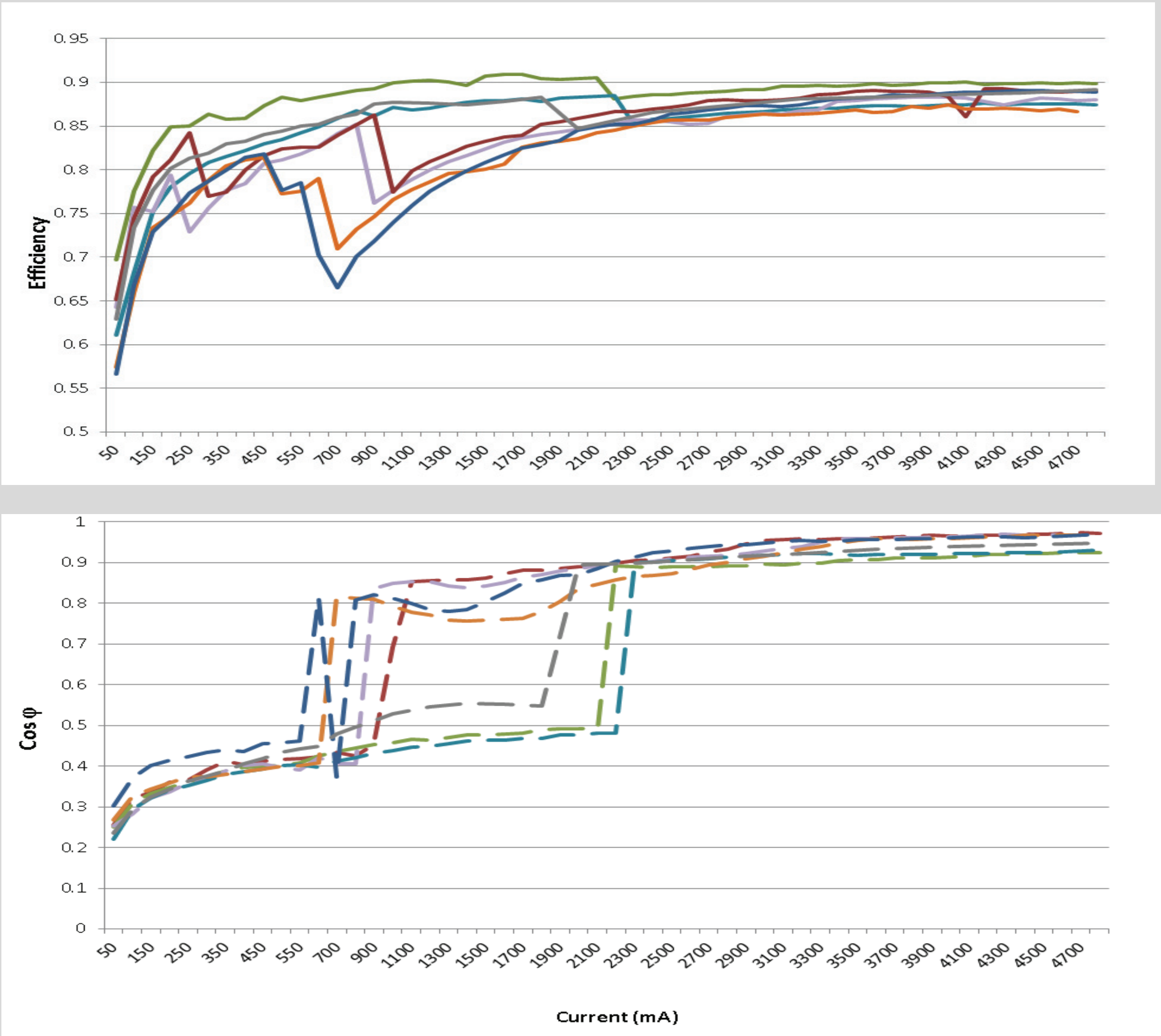


Figure 40: Energy efficiency and Cos □ curves with variable loads for the adapter number 193.

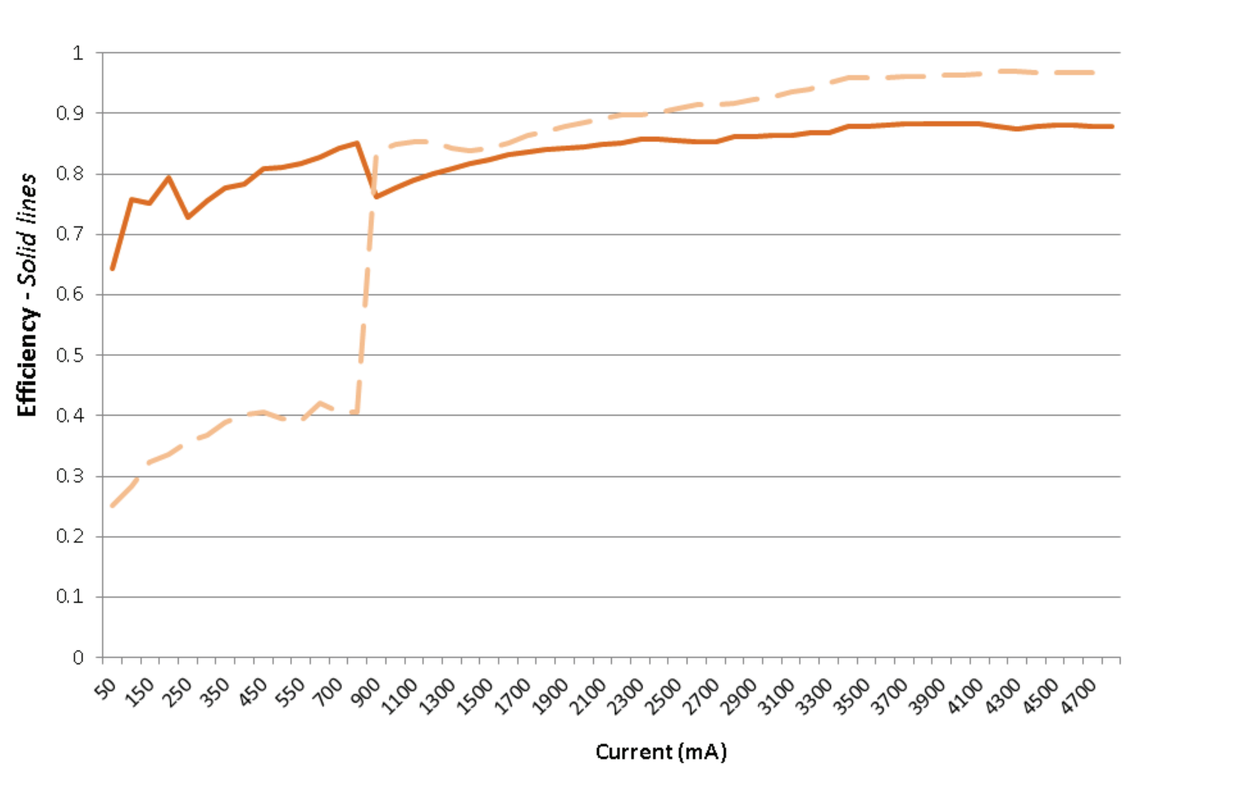
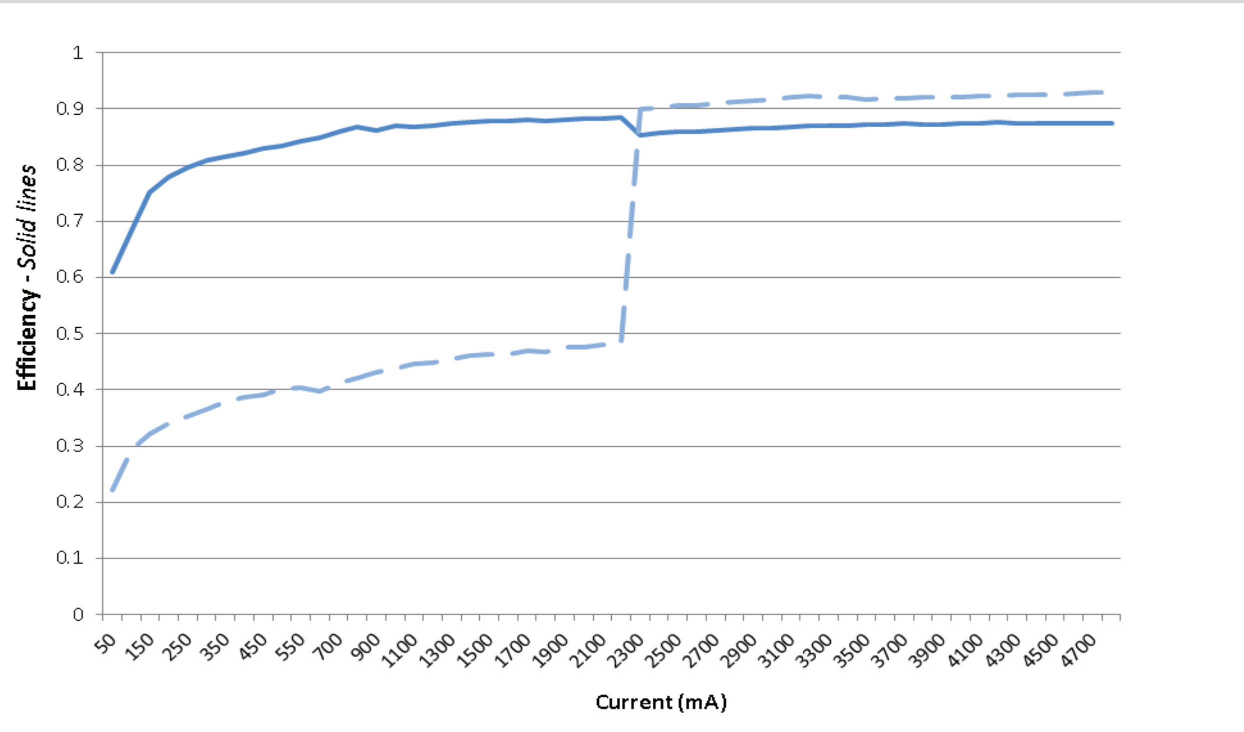


Figure 41: Energy efficiency and Cos □ curves with variable loads for the adapter number 204.



Remarks – *Many adapters having high power factor when at full load, actually show poor power factor at lower loads (*Figure 38*). As several devices (e.g., laptops) for most of the time draw only a minor amount of the rated energy of their power supplies, the above described behavior implies that, in real life, those EPSs will not benefit from the electrical network with a good power factor.*

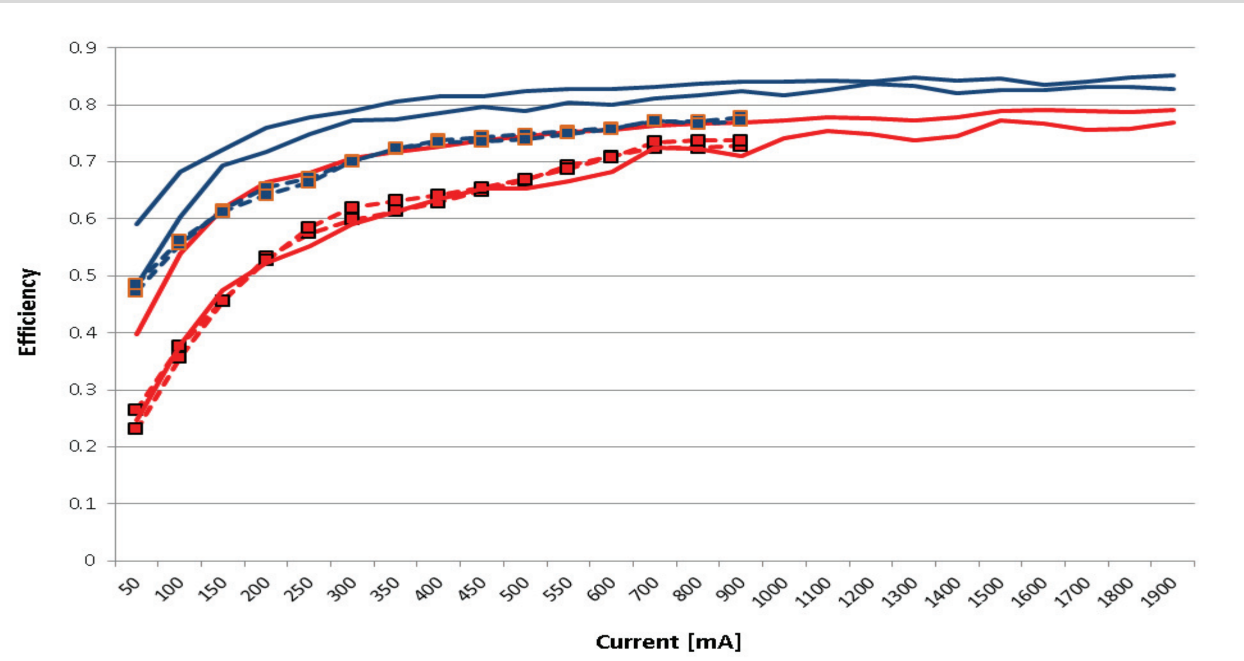
Designers and standard-makers should evaluate and specify the power factor limits also in the low load area where many devices operate for most of the time.

As the measurements have shown a severe negative correlation between the efficiency and power factor, this correlation should be evaluated in order to obtain the best overall effect.

5.2 Correlation between safety class and efficiency

Further analyses have shown another important aspect to be considered with respect to the safety class. As can be verified by analyzing Table 1, 65% of the entire set of considered power supplies belongs to safety class 2. Safety class 2 power supplies have to comply to much tougher requirements such as double insulation and increased resistibility to overvoltage, but this allows the use of the simpler, two pronged mains connector. The efficiency behavior of power supplies having the same ratings (voltage and current) but different safety classes have been compared so as to verify whether they could result into a different efficiency. In Figure 42, the blue lines identify a sub-set of safety class 2 adapters; red lines refer to safety class 1 adapter and solid and dotted lines identify groups of power supplies with the same name-plate characteristics.

Figure 42: Energy efficiency curves with variable loads for a subset of adapters belonging to safety class 1 (112, 116, 117, and 145, red lines) and 2 (102, 129, 143 and 146, blue lines). Solid lines and dotted lines identify devices with the same name plate characteristics.



Remarks – Figure 42 *clearly underlines in both groups a better behavior of the devices belonging to safety class 2. Considering the savings of material, the better compatibility of the class 2 mains connectors (2 pins) and the increased safety for clients, it might be advisable the complete switch-over to this kind of solution/connectors/cables.*

5.3 Replicability of the efficiency behaviour

Figure 43 and Figure 44 show the behavior of more instances of the same model in two cases. One of the five instances of Figure 44 (represented in the graph by the dark red line) has a version number more recent with respect to others and weighs more than 10% less than the others. It is interesting to note that the measurements show substantially the same efficiency behavior for all replica of the same model despite of the difference of version (M2 case).

Figure 43: Energy efficiency curves with variable loads for the same adapter model (M1).

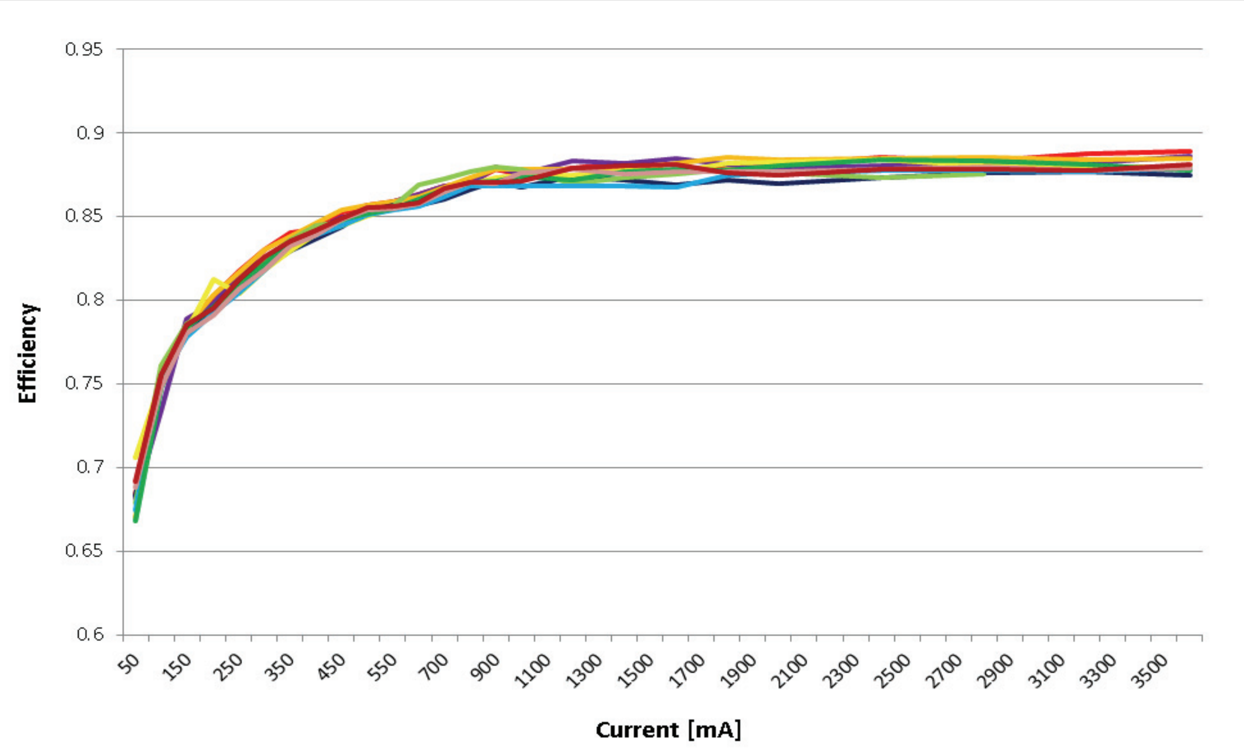
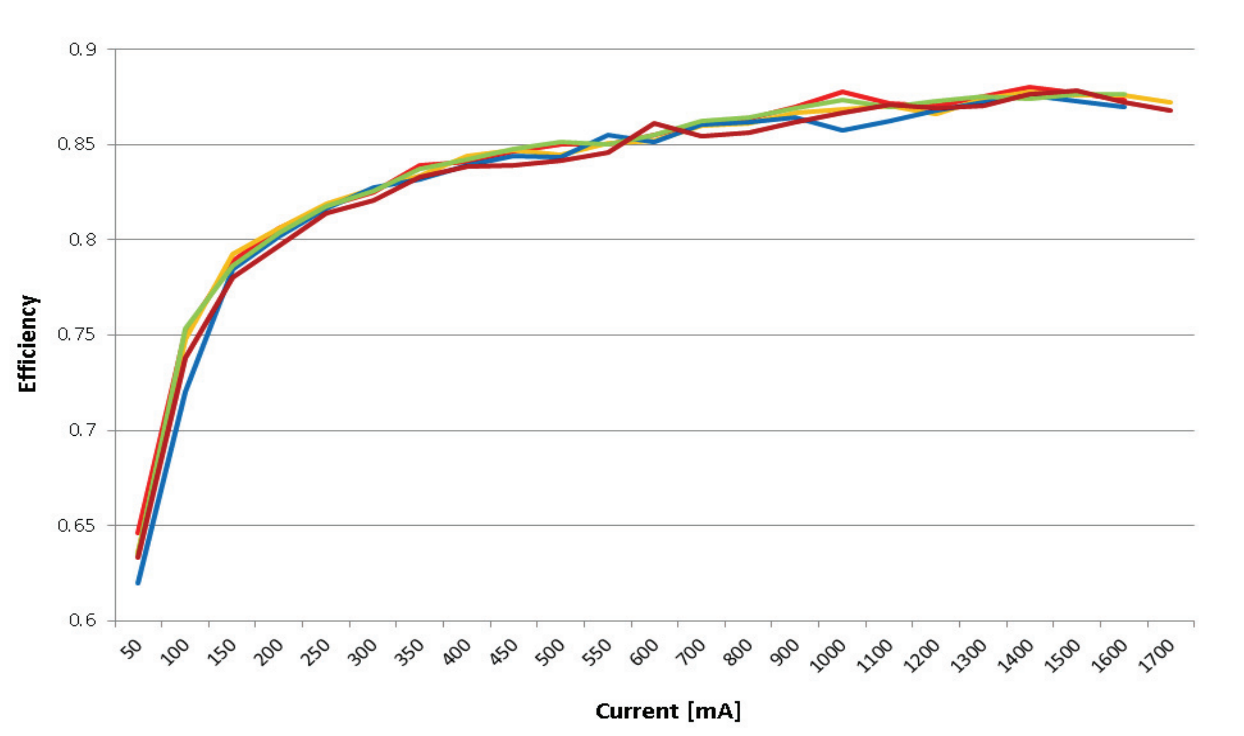


Figure 44: Energy efficiency curves with variable loads for the same adapter model (M2).



5.4 Analytical analysis

In order to synthetically describe the energy-aware performance of EPS, it was decided to fit the collected samples of the characteristic curves in Figure 22 with the following function:

$$f(i) = \alpha\left(1 - e^{-\beta i}\right)$$

Where i represent the value of the provided DC current, and α and β are the fitting parameters. In more detail, α obviously represents the maximum efficiency achievable by the adapter and the β parameter gives an indication on how fast the maximum efficiency levels are achieved.

For example, for having an efficiency correspondent to the 97% of α level for *I* > 150 mA, β values must be greater than 23.37. In this respect, the percentage of devices with β > 23.37 is only the 24% corresponding to 49 elements.

Table 3 reports α and β parameters, and the related standard error, obtained by fitting the characteristic curves of each charger in Figure 22 with the above model introduced. Standard errors clearly give useful feedbacks on the goodness of the fitting itself, but also on the regularity of the curve slopes.

Table 3: Results of the interpolation of energy-efficiency curves with respect to the fitting model. The values of α and β parameters are reported with the estimated standard error from the fitting process.

N.	α	α Std. Err.	β	β Std. Err.
3	0.828475	0.00792721	9.41292	0.0649115
4	0.760047	0.00815452	11.4739	0.0475043
5	0.734276	0.00838385	2.99299	0.0936424
7	0.784361	0.0101809	11.7506	0.0757043
8	0.640055	0.0102516	6.37881	0.120267
10	0.712363	0.00379922	2.45207	0.0839536
11	0.799402	0.00738683	13.8791	0.0685225
13	0.772344	0.00975137	6.83027	0.0621145
16	0.806674	0.00353529	3.43448	0.0449693
17	0.418279	0.00786153	22.9981	0.163557
18	0.725563	0.0107003	7.09053	0.105311
19	0.521124	0.00885661	14.3948	0.122168
20	0.692808	0.00496508	2.44179	0.371356
22	0.449296	0.00578511	20.145	0.279784
23	0.635337	0.00546395	5.05978	0.146769
24	0.808075	0.00452318	4.27628	0.140172
25	0.5361	0.00956241	15.726	0.157591
26	0.583758	0.00398669	9.08267	0.310142
28	0.74366	0.00601736	7.31539	0.150266
29	0.713679	0.00809963	21.5829	0.16503
31	0.593757	0.0129348	7.93641	0.143779
36	0.820119	0.00517953	24.5	0.188742
37	0.792284	0.00845351	22.1964	0.188431
39	0.815181	0.00562898	23.0397	0.191614
40	0.805604	0.00731444	26.0436	0.161055
41	0.828907	0.00613156	17.4074	0.202396
42	0.801077	0.00532712	22.7332	0.594017
43	0.798469	0.00482595	23.2145	0.274435
44	0.720736	0.0153135	18.0532	0.341378
45	0.784728	0.00870305	22.9846	0.232964
46	0.647781	0.00603002	4.71695	0.221282
47	0.829979	0.00663963	31.1096	0.382304
48	0.792361	0.00570169	15.8851	0.256281
49	0.81577	0.00342752	22.7708	0.311007
51	0.780515	0.00922649	25.0246	0.5274
52	0.797392	0.0086082	14.0456	0.354312
53	0.809768	0.00638759	15.2916	0.387469
55	0.772683	0.00435906	28.1988	0.465104
56	0.79822	0.00450006	16.9314	0.320539
60	0.789153	0.0057217	19.9839	0.665886
62	0.787151	0.00927982	13.428	0.419948
63	0.771645	0.00807693	20.5551	0.415496
67	0.730214	0.0123977	12.9624	0.402348
69	0.759423	0.0184313	4.21008	0.762848
74	0.791222	0.00559322	19.1775	0.892774
75	0.801185	0.00811256	16.7999	0.359919
76	0.701936	0.00711624	31.3995	0.659219
77	0.583611	0.00302447	12.912	0.424332
78	0.77537	0.00878252	24.2842	0.327513
79	0.707709	0.00508378	25.5434	0.292554
81	0.813131	0.00426201	2.87236	0.756251
82	0.637934	0.00650612	14.101	1.06381
84	0.406271	0.00902756	14.8897	0.485785

N.	α	α Std. Err.	β	β Std. Err.
85	0.762992	0.0095617	11.9738	0.378125
87	0.829481	0.00454196	7.95591	0.708787
88	0.699798	0.0057159	24.9962	0.742387
93	0.571693	0.0161706	17.6126	1.18616
97	0.485003	0.00852096	22.4556	1.19495
102	0.827712	0.00623694	20.0199	0.697187
103	0.759485	0.0140135	9.826	0.62796
105	0.791485	0.00797301	18.7977	1.02141
106	0.616347	0.0108985	8.14188	0.656876
108	0.639556	0.00469357	4.91567	0.988827
109	0.811402	0.00683158	12.4946	0.580141
110	0.706564	0.00740594	4.91486	0.985254
111	0.77482	0.00847748	14.0373	1.11063
112	0.76444	0.00561523	11.6541	0.820046
113	0.662326	0.0120936	4.59278	1.41294
114	0.680114	0.0124106	4.21554	4.0453
115	0.667779	0.0114156	7.07564	0.671815
116	0.716614	0.00878702	6.44441	0.309103
117	0.718559	0.0100749	6.78707	1.29335
119	0.773021	0.00776199	14.315	0.913909
120	0.714856	0.0059122	4.69044	0.682191
121	0.8107	0.00346362	3.30847	0.755531
123	0.815304	0.00429707	6.03414	1.11041
125	0.84723	0.00818185	11.3621	1.09665
128	0.819805	0.00643603	18.5675	0.889387
129	0.812869	0.00596295	14.1344	0.866879
131	0.751942	0.0081181	12.1497	1.46766
132	0.877029	0.00424362	18.785	1.47612
137	0.491784	0.0062617	24.9168	1.05118
141	0.838809	0.00582058	15.06	1.2134
142	0.856862	0.00634797	10.3901	1.2249
143	0.740453	0.0114916	14.8056	1.46364
145	0.742973	0.00884431	5.74094	1.55763
146	0.739559	0.0123469	15.1667	1.22424
147	0.813042	0.00449029	2.96506	1.1791
148	0.807232	0.00638411	6.77028	1.69608
149	0.783994	0.00783526	4.2907	1.64649
150	0.790631	0.00907248	14.4919	1.21552
151	0.77588	0.00756108	4.26062	1.05496
152	0.729218	0.0113791	15.9129	1.07996
153	0.600049	0.00571926	8.39505	1.12094
154	0.691209	0.00847967	14.2977	1.71222
157	0.624381	0.00867833	15.2207	1.13238
158	0.825889	0.00994343	7.4924	1.40321
159	0.693395	0.00490523	17.5654	0.816726
163	0.405762	0.0393367	12.6807	0.770721
165	0.662798	0.00622483	34.8857	1.1521
167	0.556428	0.00735982	12.4535	0.786705
168	0.845809	0.00739747	7.178	1.33129
169	0.780357	0.0050706	6.437	0.909983
170	0.603631	0.0112969	6.55527	2.47641
171	0.7856	0.00445291	21.5897	1.58199
172	0.449997	0.00956217	8.26225	0.963235
173	0.810147	0.00461753	23.9131	2.47846
174	0.63996	0.00703489	25.1189	3.04335
175	0.854751	0.00499255	25.24	1.10997

N.	α	α Std. Err.	β	β Std. Err.
176	0.747035	0.00627448	11.05	1.02782
177	0.674616	0.00838503	14.8684	1.74947
178	0.787919	0.00655524	5.54994	1.13558
182	0.890088	0.00249181	26.5633	1.62882
184	0.813083	0.0100345	14.1914	1.41949
185	0.832099	0.00490452	21.3122	2.06072
186	0.845404	0.00823703	25.3475	1.24408
187	0.818317	0.00401614	24.4936	1.62778
189	0.821985	0.00541147	19.8406	1.14897
190	0.862983	0.00364047	13.5193	1.33212
191	0.652733	0.00507309	4.81323	1.33281
192	0.844698	0.00293944	10.3756	1.85944
193	0.840958	0.00550728	25.6548	1.26002
194	0.837453	0.00569595	6.86048	1.5639
195	0.653532	0.00445514	4.79224	1.54785
197	0.773651	0.00765117	3.9554	0.93172
198	0.787833	0.00497754	3.34391	1.46736
199	0.761443	0.0108687	12.6243	1.68023
200	0.697508	0.00438058	3.9359	1.62838
201	0.790003	0.00698416	5.80951	1.59007
202	0.769762	0.0105459	3.68315	1.58536
203	0.77651	0.00668717	3.02255	1.67159
204	0.862398	0.00361245	18.554	1.31674
205	0.80894	0.00414467	10.2483	1.34327
206	0.816119	0.00451883	12.8717	1.87554
207	0.812906	0.004596	22.1585	1.96579
244	0.861394	0.00425149	11.9135	1.64477
245	0.839597	0.00460976	4.85959	3.3799
249	0.829292	0.00627078	18.9335	1.47249
251	0.813131	0.00466768	17.8778	2.40392
252	0.80362	0.00600613	16.9498	1.44065
253	0.689097	0.00615944	19.6464	1.80088
254	0.778546	0.0054694	16.861	1.67062
255	0.776011	0.00515279	17.0597	2.16326
256	0.784042	0.00807817	23.1817	2.2467
257	0.77968	0.00860821	22.7026	1.84166
258	0.749907	0.00707573	25.8401	1.04435
259	0.749612	0.00724868	25.1564	2.0697
301	0.777348	0.00990518	22.8692	2.42782
303	0.876834	0.00276121	31.3552	2.1993
304	0.881837	0.00398505	19.0059	1.75021
305	0.83301	0.00822023	17.9356	2.09086
307	0.867608	0.00439944	16.6428	1.41735
308	0.852808	0.00662099	22.4733	2.41494
309	0.782336	0.00752772	22.5446	1.88933
311	0.864727	0.00662916	18.605	1.68778
312	0.858405	0.0061629	27.6724	1.5689
313	0.853433	0.00413798	30.5756	2.64485
314	0.851254	0.003835	31.8229	1.62516
316	0.842439	0.00742328	22.204	1.55506
317	0.764104	0.00570518	20.018	2.14633
318	0.613514	0.0160143	5.40014	1.53966
320	0.864017	0.00461789	26.7344	1.77484
326	0.860475	0.00601226	27.4772	2.03605
327	0.859223	0.0064564	26.3878	2.27662
328	0.861307	0.00598794	25.8346	2.04542

N.	α	α Std. Err.	β	β Std. Err.
329	0.852349	0.00594688	28.09	1.54561
330	0.855423	0.00641226	30.1637	2.90542
331	0.855073	0.0062153	27.9289	1.76587
332	0.850208	0.00669973	27.6708	1.85026
333	0.856954	0.00603587	26.1028	1.7668
334	0.854758	0.00642367	28.0885	2.53323
335	0.85642	0.00603932	28.7142	2.71635
336	0.853992	0.0058104	23.7616	1.34137
337	0.858157	0.00580624	24.9871	2.94788
338	0.854383	0.00579812	26.7834	2.13896
339	0.849835	0.00584655	21.024	1.89197
340	0.854691	0.0062786	24.4899	2.17393
341	0.853579	0.00581005	24.5598	2.20597
342	0.847475	0.00630154	18.8977	2.3981
343	0.849378	0.00636521	27.924	1.3377
344	0.853446	0.00609974	20.8396	2.21789
345	0.857951	0.00549116	22.6395	2.31199
346	0.842617	0.00835329	23.4078	2.17658
347	0.842961	0.00818041	22.7054	2.3932
348	0.853222	0.00546843	25.1814	2.55914
349	0.853096	0.0049545	24.423	3.28235
350	0.850077	0.00536529	22.5128	2.79853
351	0.85317	0.00530059	24.4177	2.45514
352	0.84996	0.00555473	23.9061	2.67614
353	0.856213	0.00322878	33.8347	2.48475
354	0.867642	0.00443352	27.1392	1.49958
355	0.868495	0.00369087	22.4561	2.61177
356	0.866444	0.00483076	20.3385	3.03522
357	0.809102	0.00634496	17.8138	2.09334
358	0.84146	0.0068118	19.0725	3.49826
359	0.701531	0.00527181	12.0249	1.76081
360	0.846534	0.00702659	19.9641	2.09774
361	0.829975	0.00725806	15.2844	2.09513
362	0.758595	0.00588203	33.4604	2.38128
363	0.769411	0.00692569	22.224	1.77634
118b	0.787302	0.00980042	11.3497	2.39315

Figure 45 and Figure 46 show the values of α and β fitting parameters against the rated output power of the adapters. These results highlight the lack of correlation between β and the rated output power: different samples are heavily distributed in the graph. Also in such a case, it is reasonable to conclude that the β energy efficiency parameter mostly depends on the quality of the design and on the internal components of the ESPs, and not on the output power.

Figure 45: Values from the α parameter as in Table 3.

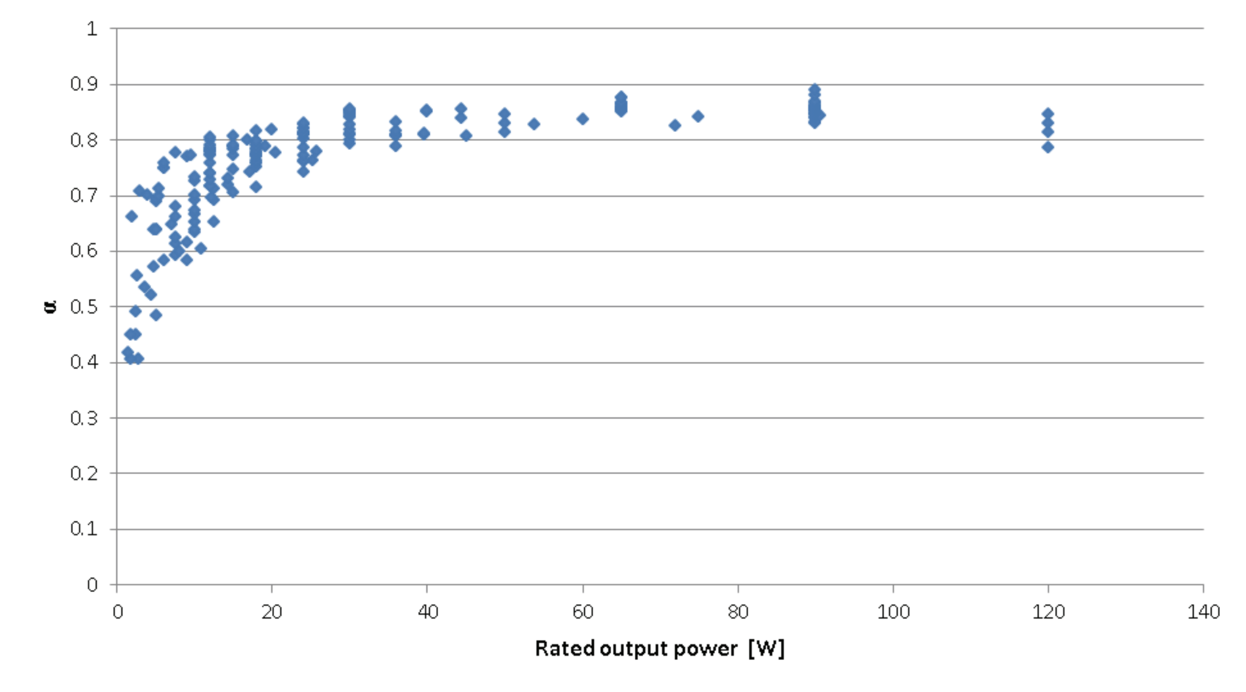
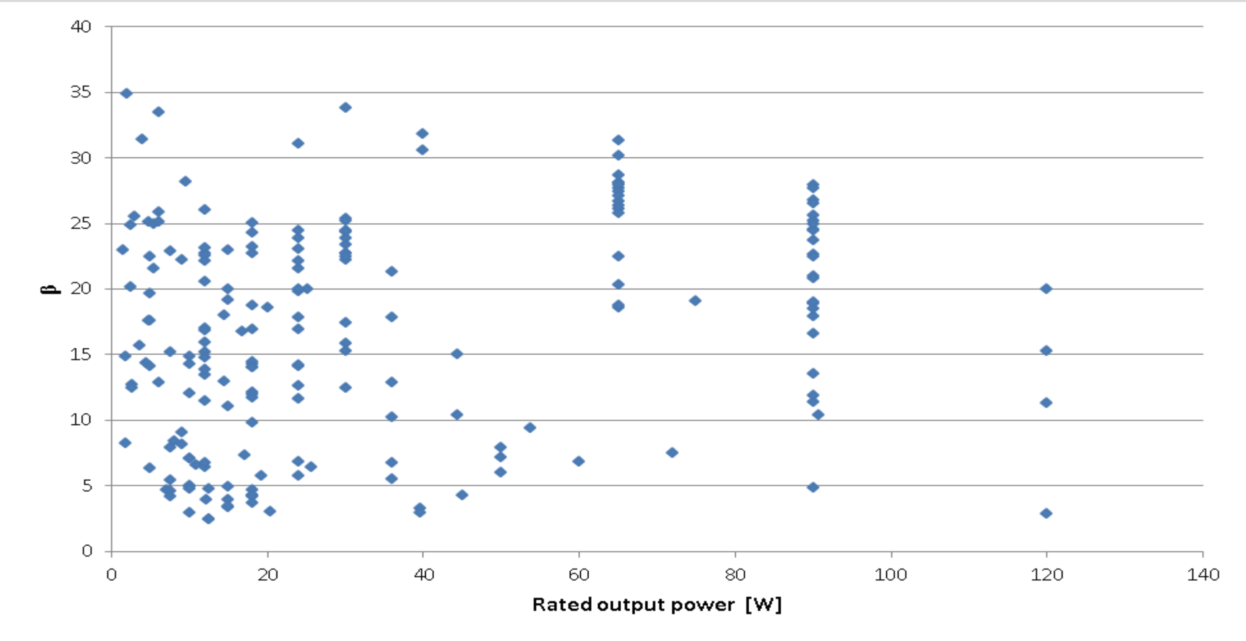


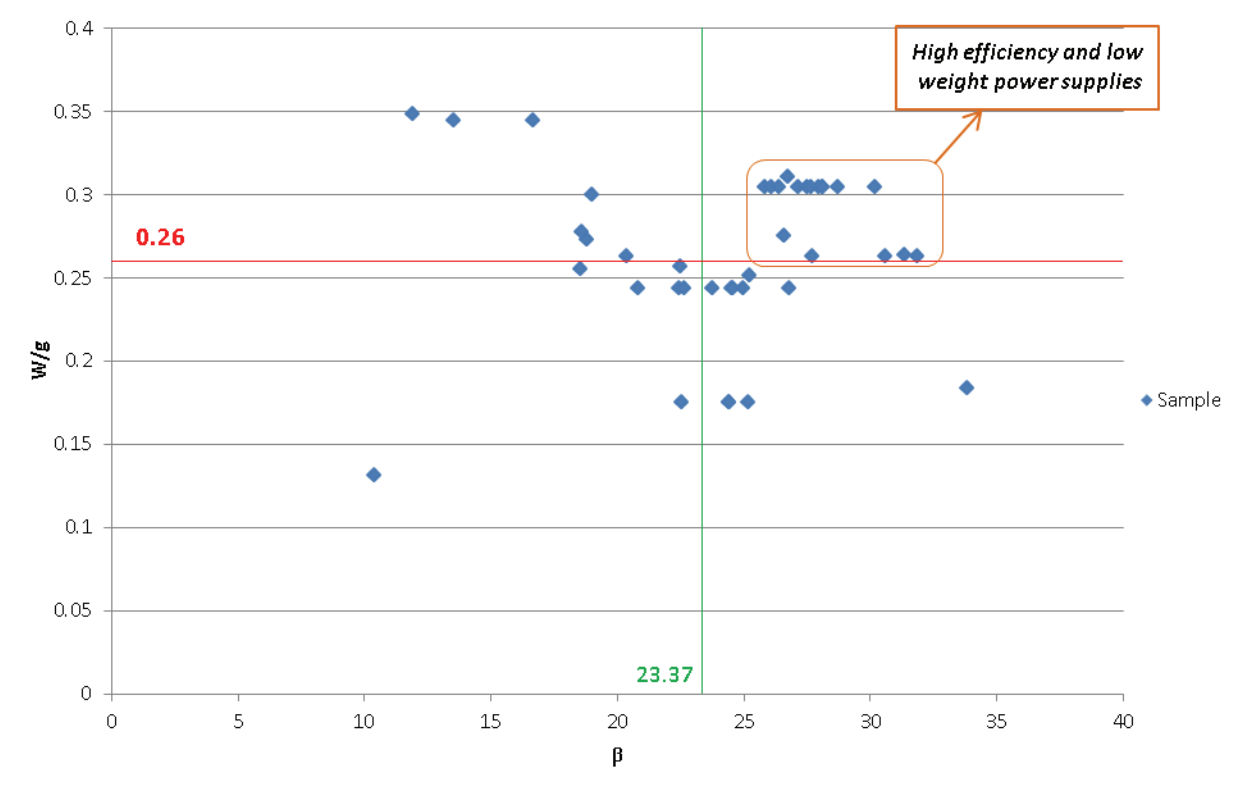
Figure 46: Values from the β parameter as in Table 3.



Remarks – *The analytical analysis with alpha and beta parameters indicates that only the 24% of the power supplies reach its efficiency target value at low output current. This would result into a very relevant increase in the overall energy consumption as several devices draw only limited amount of energy for a significant amount of time. It is interesting to note that, among these 49 "good" devices, 42 are rated in Energy Star class V or IV.*

Figure 47 represents the correlation between weight and efficiency results. The graph shows the values of power density with respect to weight (without cable), versus β values, for the best adapters in terms of efficiency (α > 0.85). In the figure, a green and a red line highlight respectively a β and a power density constraint above which a power supply has quite a satisfactory behavior. In the area beyond these constraints, a subset of 17 EPSs that show high efficiency and a large W/g ratio can be found.

Figure 47: Power density with respect to weight (without cable), versus β values for a subset of adapters with α > 0.85.



Remarks – *As* Figure 47 *underlines, a good compromise between weight and efficiency can be reached. This suggests again the opportunity of design improvements for a large part of current devices.*

5.5 Output voltage

The graphs in the following figures report the DC voltage provided by the analyzed set of power supplies according to the output current. In such a case, it can be underlined how some power supplies, which declare a nameplate DC voltage value, provide different voltage values in some parts of the measurement range. Moreover, in some other cases, the voltage levels decrease considerably according to output current.

In Figure 48, it can be noticed that a subset of the analyzed adapters shows, at low loads (50 mA), voltage values much higher than the declared one. Table 4 reports a list of this subset with the numerical values, to more clearly underline this misbehavior. Note that most of the devices with this behavior are linear ones.

Figure 48: DC voltage measurement at variable load in terms of provided output current.

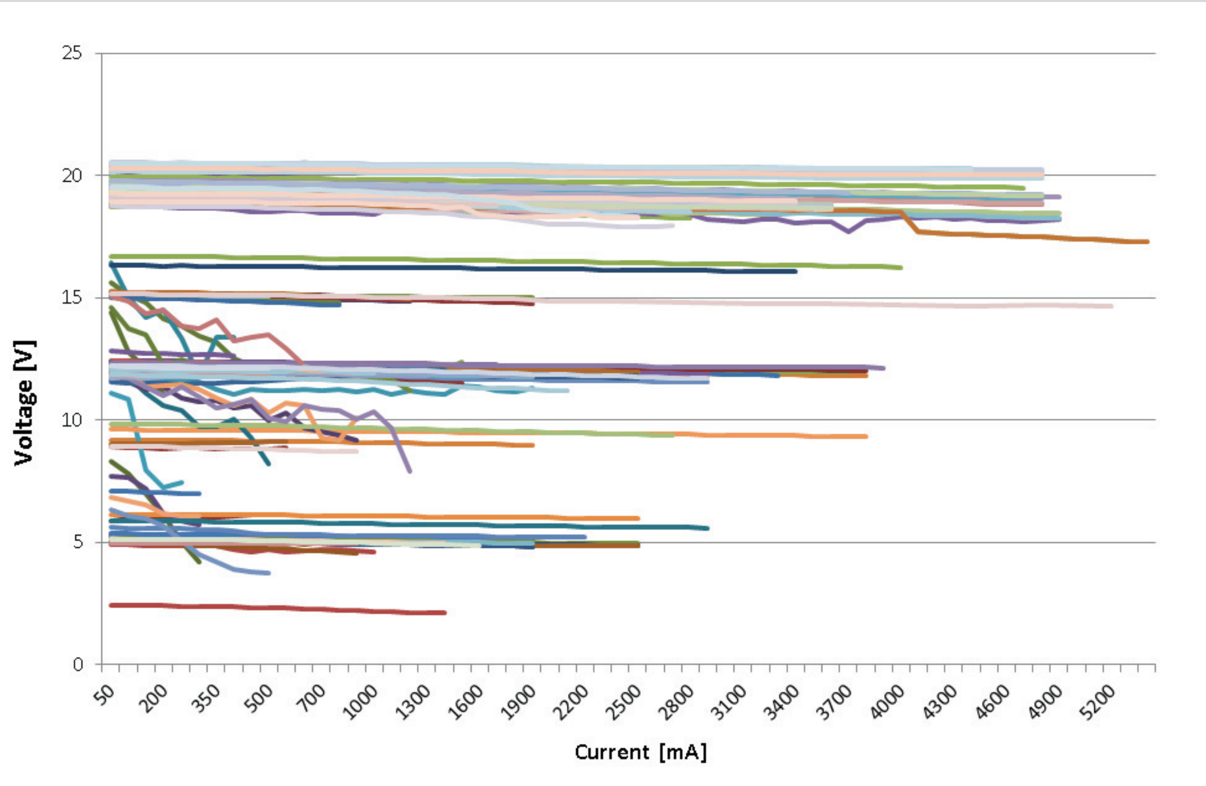


Table 4: Nameplate output and measured voltage at 50 mA for a subset of power supplies.

No.	Nameplate output voltage	Measured voltage (at 50 mA)	Δ (V)
17	5	8.3	3.3
19	9	12.4	3.4
22	12	14.4	2.4
25	12	14.6	2.6
26	9	11.9	2.9
77	12	15.6	3.6
84	6	7.7	1.7
93	12	16.4	4.4
106	9	11.9	2.9
153	13	15.0	2.0
163	9	11.1	2.1
170	9	11.9	2.9
172	6	6.9	0.9
174	12	12.8	0.8

Remarks – *Some adapters have shown an output voltage rather higher than what declared by producers and reported in their nameplate. This could create troubles for the connected devices, especially when the voltage value is far higher than the declared (*Figure 49 Figure 50 *and* Table 4*). In general, the ratings declared in the nameplate are expected to be accurate, and represent the real features of the power supply.*

As in the case of the efficiency, the graph has been split into three sub-graphs to better appreciate the adapters' behavior.

Figure 49: DC voltage measurement at variable load in terms of provided output current (Category A).

Voltage < 12 V, Current: any, Power: any;

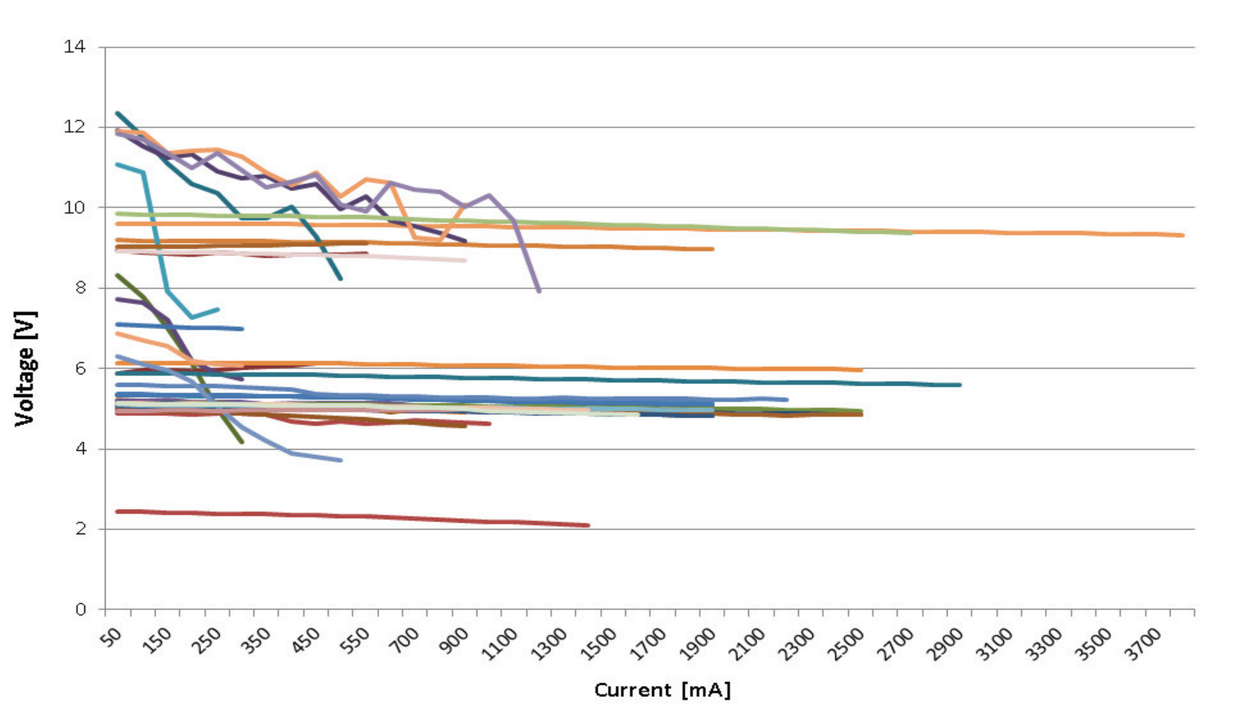


Figure 50: DC voltage measurement at variable load in terms of provided output current (Category B).

Voltage = 12V, Current ≤ 1 A, Power: any;

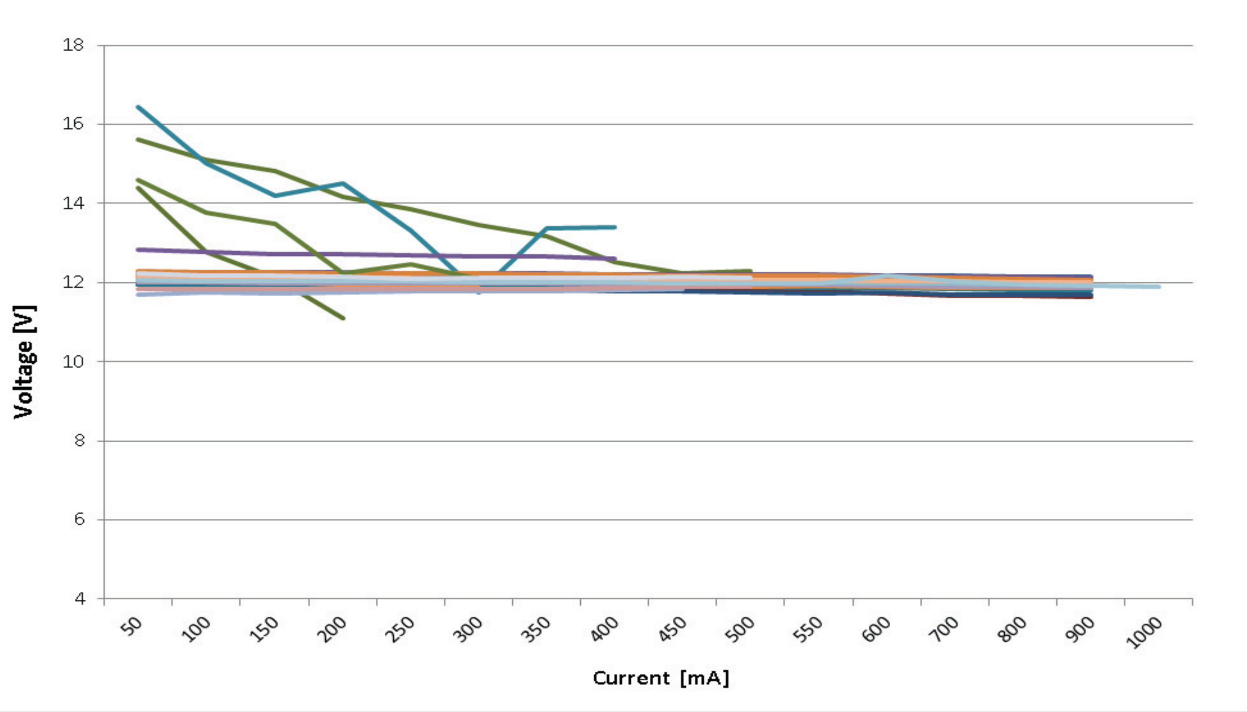


Figure 51: DC voltage measurement at variable load in terms of provided output current (Category C).

Voltage = 12V, 1 A < Current ≤ 2 A, Power: any;

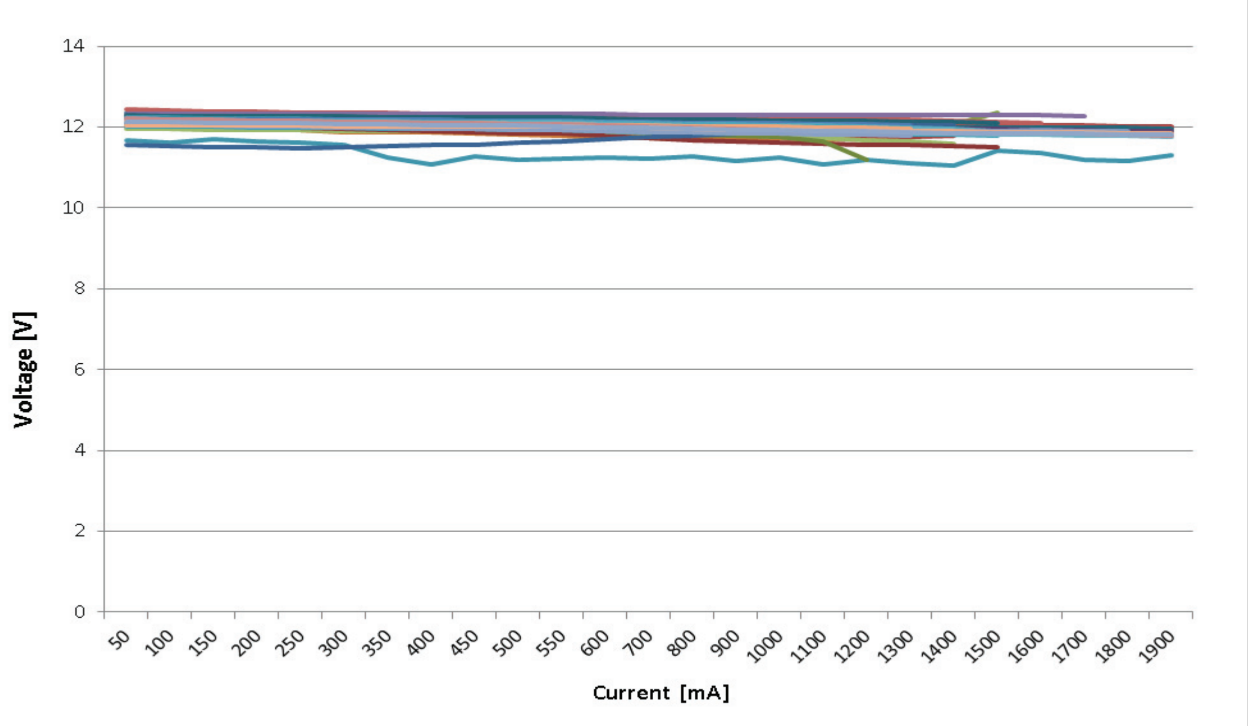


Figure 52: DC voltage measurement at variable load in terms of provided output current (Category D).

Voltage = 12V, 2 A < Current ≤ 3.5 A, Power: any;

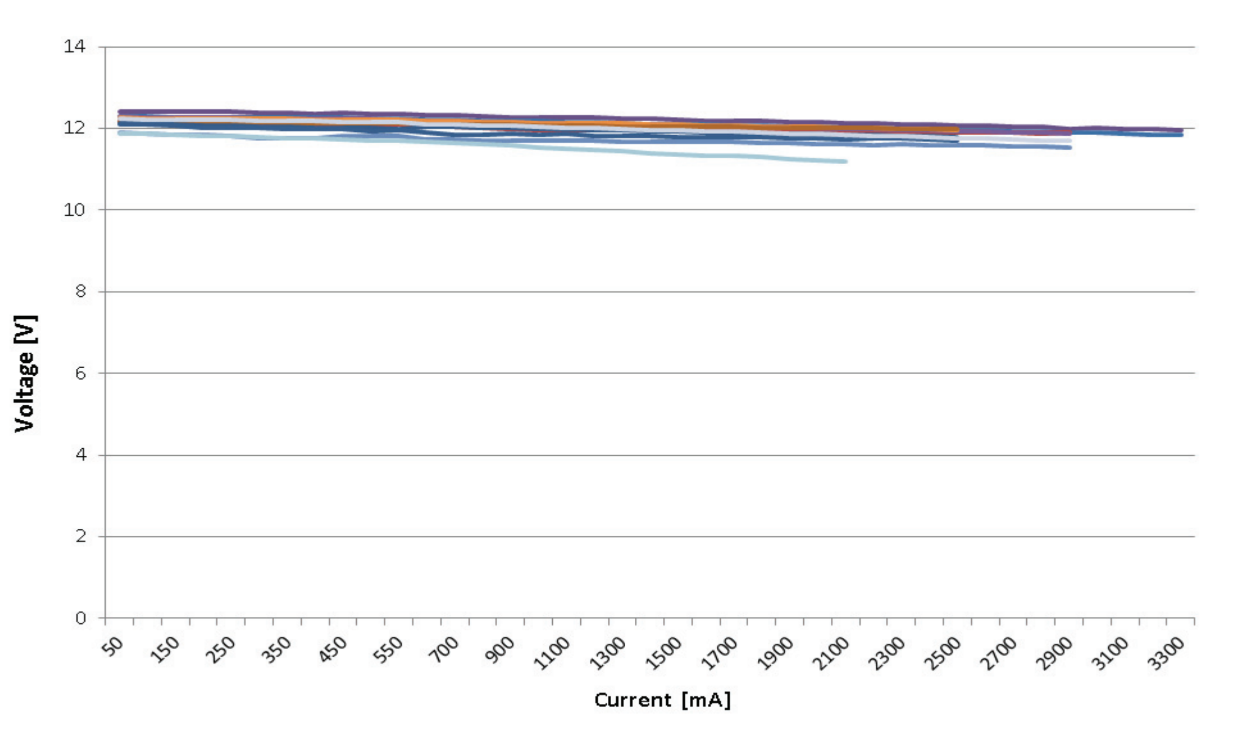


Figure 53: DC voltage measurement at variable load in terms of provided output current (Category E).

Voltage = 12V, 3.5 A < Current ≤ 5 A, Power: any;

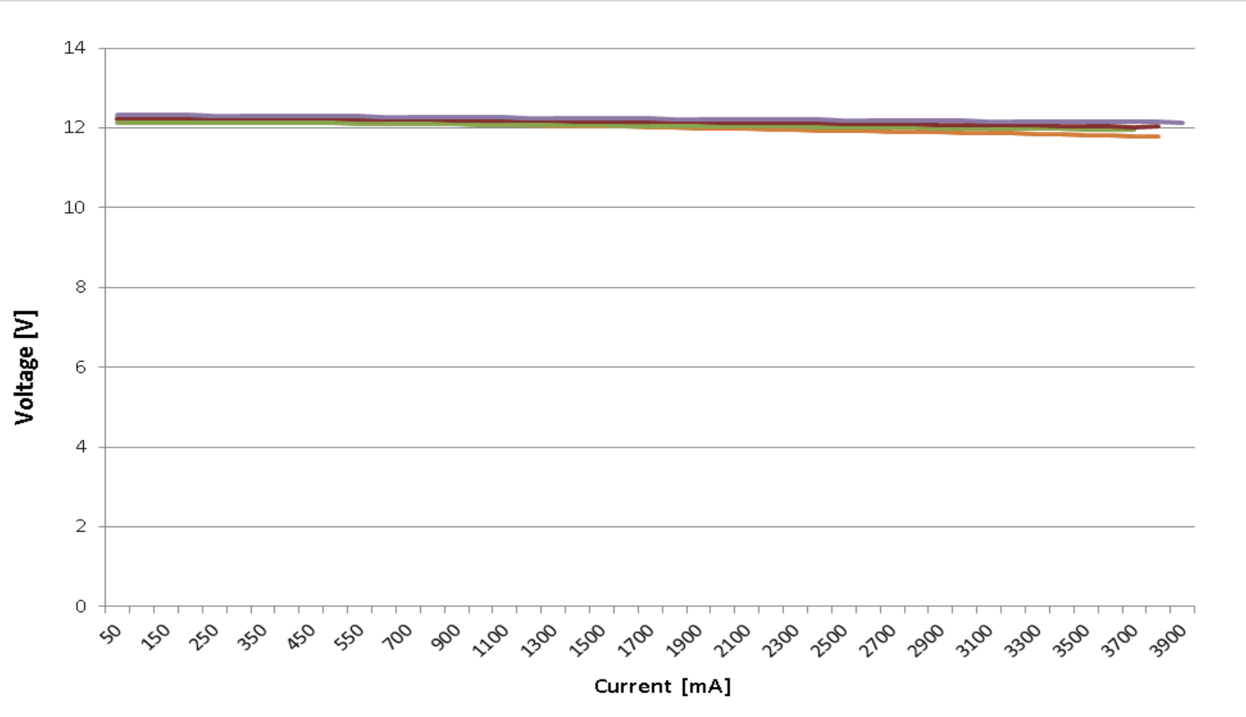


Figure 54: DC voltage measurement at variable load in terms of provided output current (Category F).

12 V < Voltage < 18V, Current: any, Power: any;

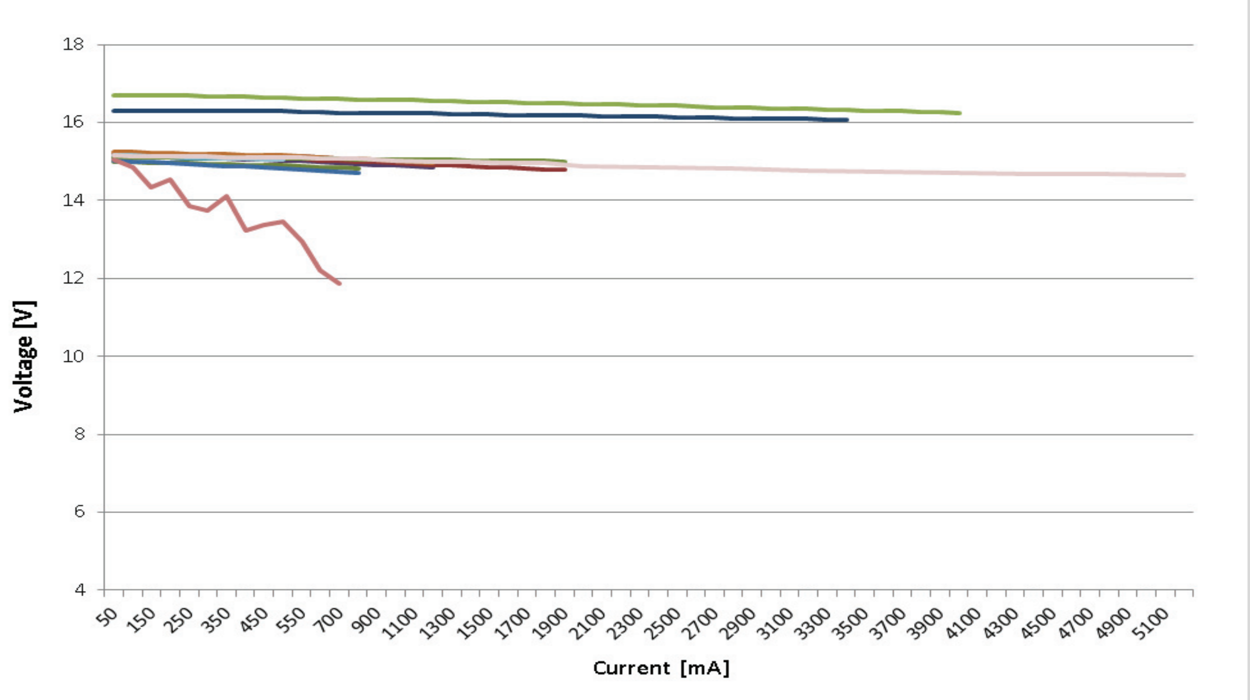


Figure 55: DC voltage measurement at variable load in terms of provided output current (Category G).

Voltage ≥ 18V, Current: any, Power ≤ 45W;

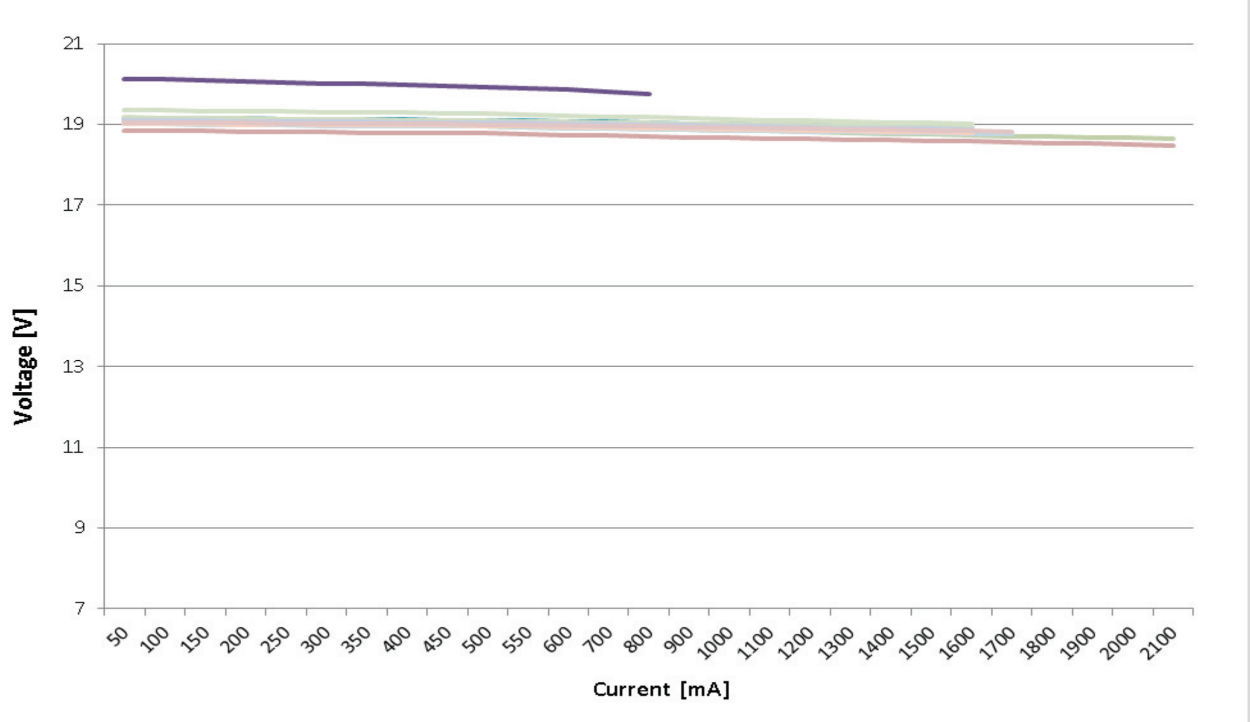


Figure 56: DC voltage measurement at variable load in terms of provided output current (Category H).

Voltage ≥ 18V, Current: any, 45W < Power ≤ 70 W;

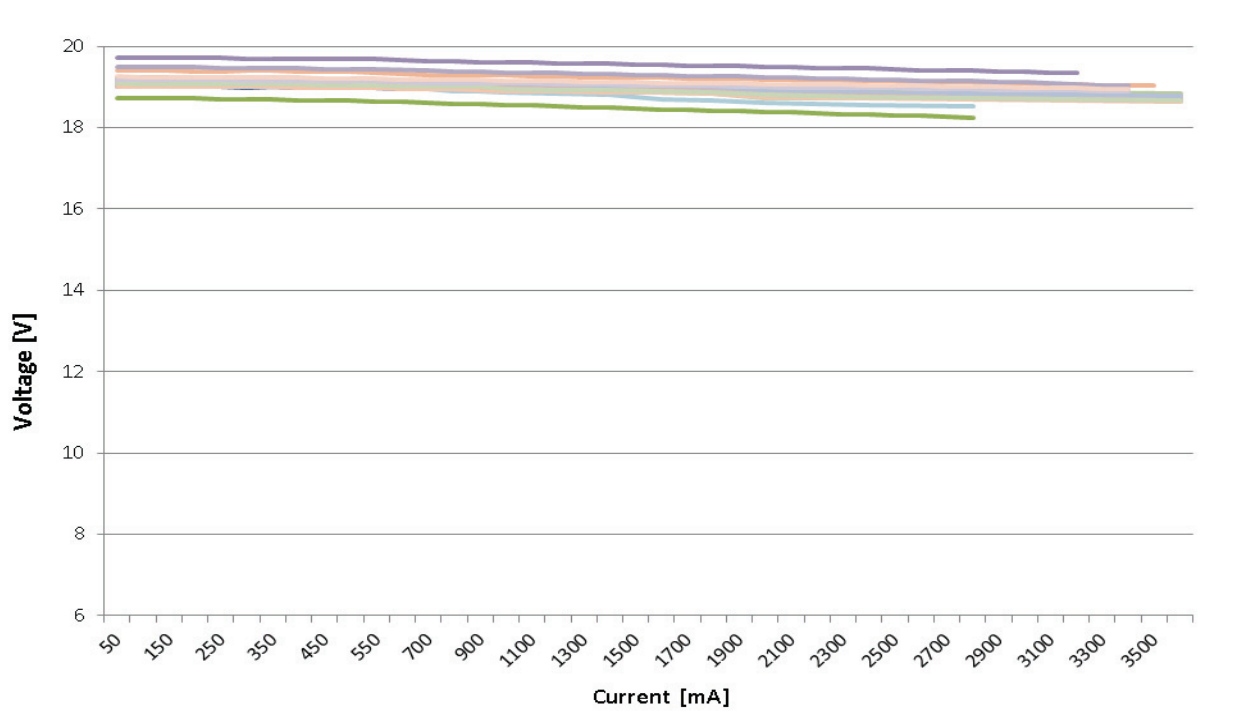


Figure 57: DC voltage measurement at variable load in terms of provided output current (Category I).

Voltage ≥ 18V, Current: any, 70W < Power ≤ 95W;

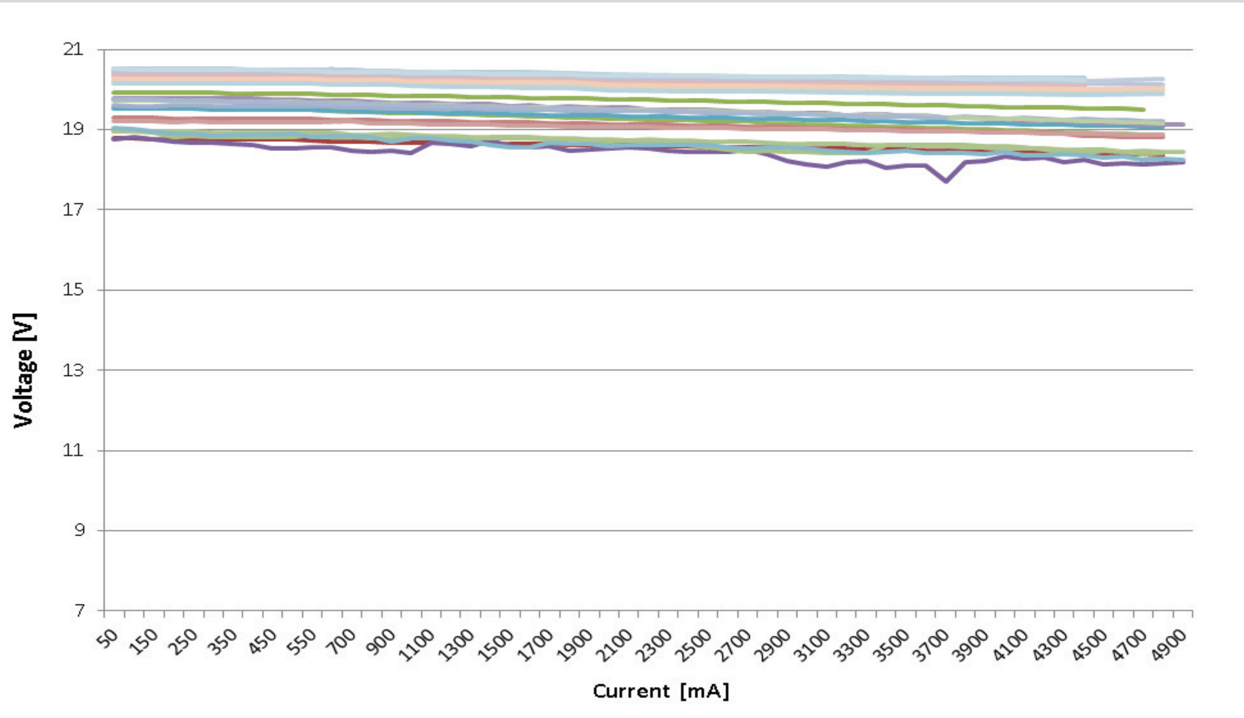
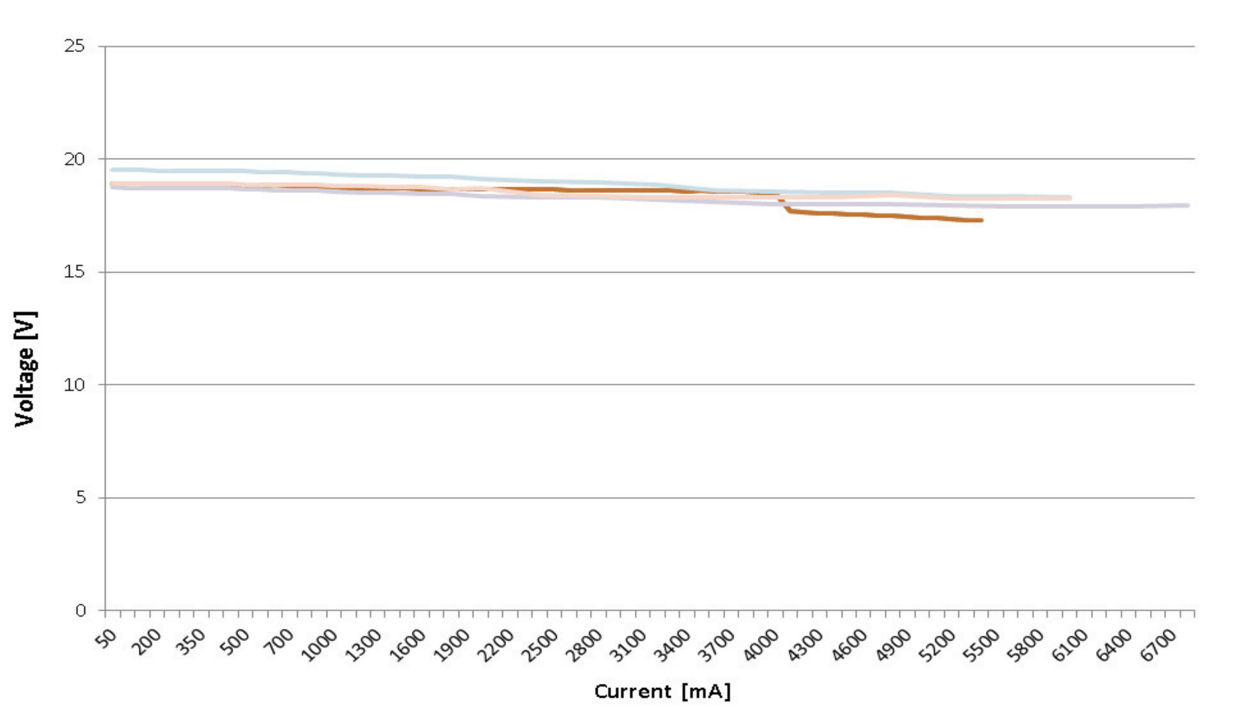


Figure 58: DC voltage measurement at variable load in terms of provided output current (Category J).

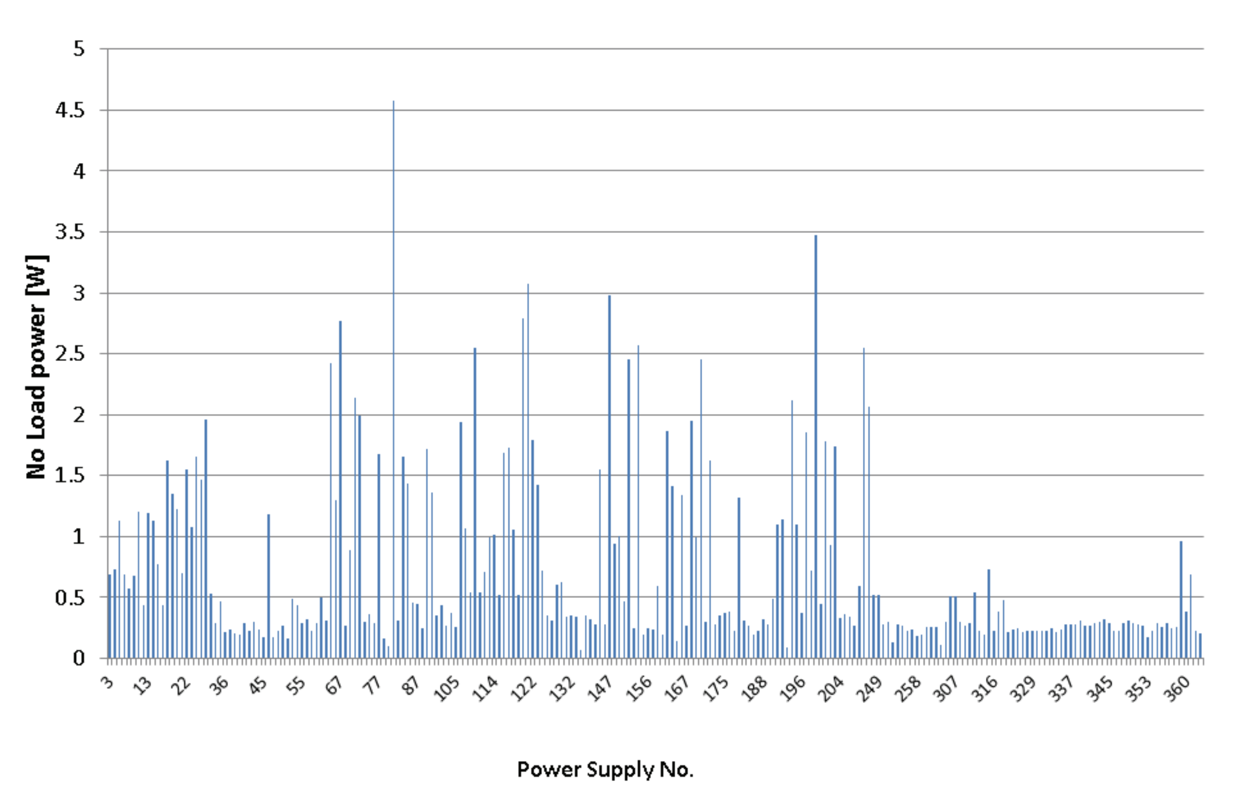
Voltage ≥ 18V, Current: any, 95W < Power ≤ 120 W;



5.6 No-load

The following figures report the results obtained in the no-load condition, i.e., with the device connected to the 230V energy supply by not being connected to the load. The first graph in Figure 59 shows the behavior of all the measured power supplies, while Figure 60 shows the same values but organized with respect to the rated output power. It is clear from the first picture that the range of efficiency in this particular condition is quite large, starting from very low and optimal values (about 0.1–0.15 W) up to very inefficient quantities (more that to 2W). Moreover, that figure shows the substantial absence of correlation between this type of performance and the size (in terms of output power) of the devices. Finally, Figure 61 reports the no-load results averaged for each category and for both the measured and the filtered Energy Star Program list described in the Section 2. It easy to see that the measured values are definitely worse than those reported in the ESP list. It can be useful to observe that for the few overlapping cases (i.e., device models present in both the measured and ESP lists), the measured values had equivalent results.

Figure 59: No-load absorbed power [W] of all the measured power supplies.



Remarks – *The large range of no-load efficiency clearly demonstrated by* Figure 59 *and* Figure 60*, together with the substantial absence of correlation between this quantity and output power, contribute again to suggest large opportunities of obtaining better average performances.*

Figure 60: No load absorbed power [W] versus the rated output power for all the measured devices.

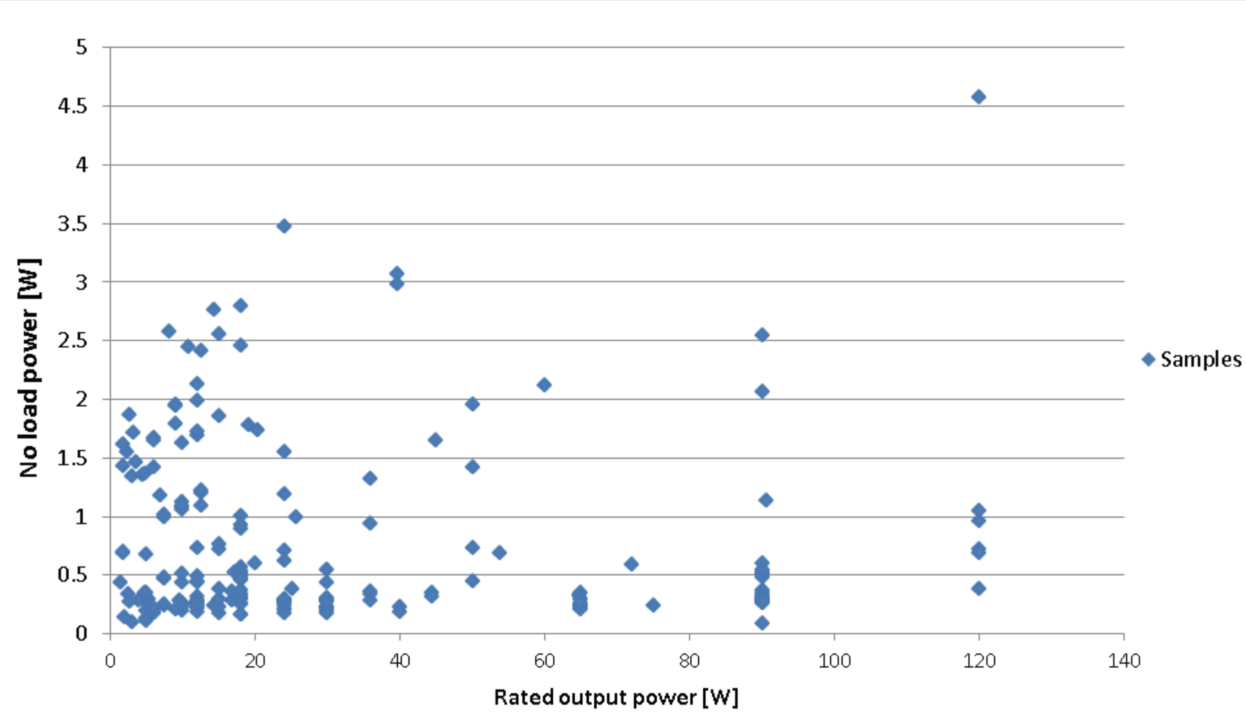
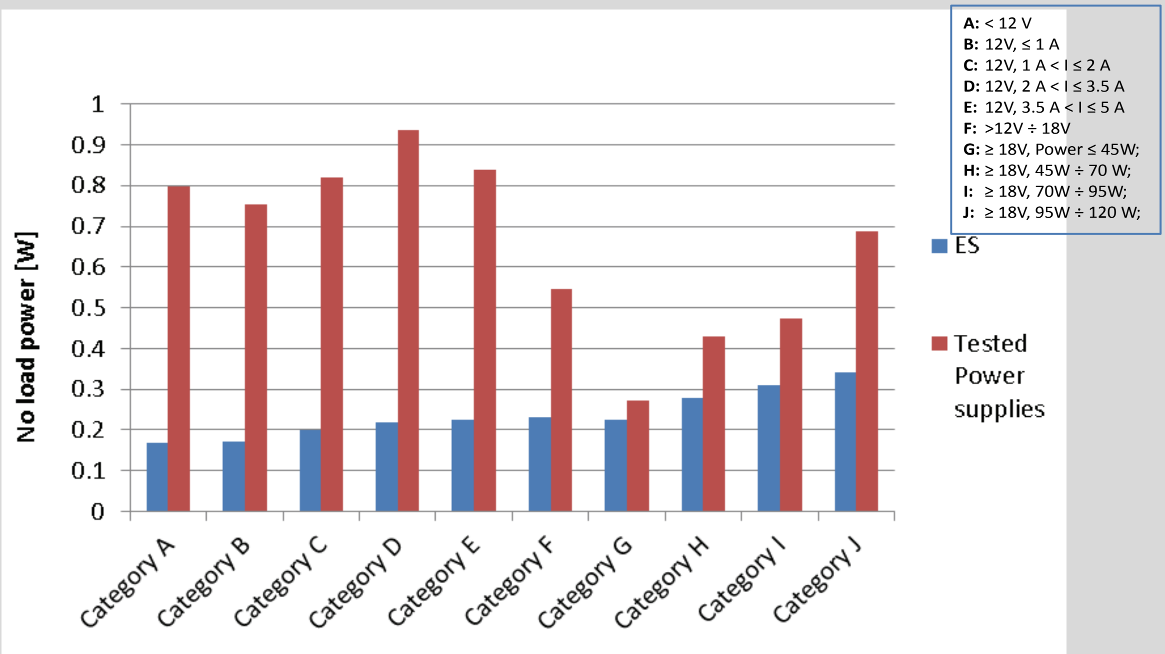


Figure 61: No load average absorbed power [W] versus categories for the measured and the ESP list devices.



6. Mass balance and environmental considerations

An environmental analysis of a subset of the 307 power supplies considered for the study has been performed. It has started from a mass balance, quantifying the amount of plastic materials and electronics used to manufacture the various devices. A number of power supplies have been considered, having in mind to distinguish three main categories depending on the nameplate output power they can provide. In addition, different technologies have been considered within the single category (switching or linear PS) to evaluate the different environmental burdens associated to them and verify if there is a proportional relationship between the total weight and the associated environmental impact (excluding any environmental consideration related to the energy efficiency of the single technology). Starting from the mass balance, a Life Cycle Assessment analysis has been elaborated, thanks to a devoted database enabling the association between the uses of a specific material/electronic part with its intrinsic environmental impact related to extraction/production processes. The final results are presented as referred to a number of impact assessment indexes, as indicated by ISO 14040 standard series. The entire study, carried out in cooperation with Politecnico di Torino, is reported in Appendix B.

Twelve PSUs were chosen as samples referred to three different levels of rated output power supplied to the equipment (Low Power, Medium Power, High Power): 19, 302, 31, 301 (low power), 63, 70 (the only with linear technology), 60 and 52 (medium power), 42, 53, 15 and 3 (high power). Starting from Inventory results (eco-balance of inputs and outputs of processes related to product manufacturing,) the conversion of data to common units and the aggregation of the converted results within environmental impact categories have been performed. The outcome of this operation is a numerical indicator result. For this analysis a number of impact categories are considered, including for example:

- Greenhouse effect (also referred as GWP, Global Warming Potential)
- Ozone Depletion Potential (ODP)
- Photochemical Ozone Creation Potential (POCP)
- Gross Energy Requirement (GER, also referred to as CED, Cumulative Energy Demand)

A few graphs are reported below as examples, for the Global Warming Potential impact category.

6.1 Global Warming Potential, GWP

Figure 62: Low Power PSU GWP results

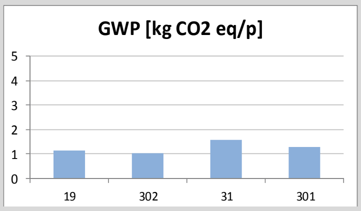


Figure 63: Medium Power PSU GWP results.

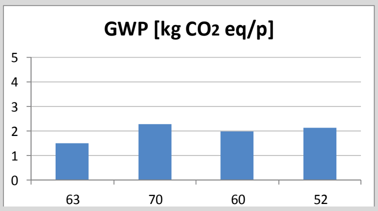
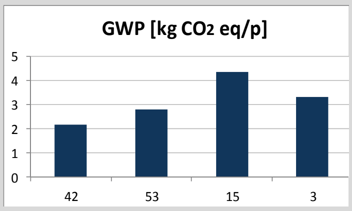


Figure 64: High Power PSU GWP results.



The environmental and energy results reported in previous sections are referred to the functional unit (1 PSU) but they have also been normalized and referred to 1 W (output power), instead of to the functional unit of 1 PSU. The following preliminary conclusions can be drawn:

- Environmental and energy impacts do not depend only on weight characteristics; the behavior also depend on the different design choices especially for the electronics, and is at any rate different depending on the single impact category analyzed;
- Environmental and energetic impacts do not depend only on output power. In some cases, high power PSU has very similar impacts in comparison to medium power PSU, and the same applies to the comparison between the medium power and low power category. This fact demonstrates the importance of adopting accurate design choices (especially for electronics, but also for the plastics) for minimizing the environmental burdens associated to the single product;
- Within the same impact category, it is always possible to identify one example of PSU coupling good use-performance as well as good environmental and energetic performances. Depending on the single impact categories, the best in class for the single category can improve the performances of the worst one of a mean percentage around 25-30%, up to 50% in some specific cases. Again, this demonstrates the importance of adopting design rules optimizing the environmental aspects.

A more detailed analysis of the general up-described framework should be necessary in order to assess how the environmental impacts depend on the design of electronics as well as on the design of the object (in terms of material selection).

7. Conclusion

In general, this work shows that there are many aspects where an aggressive standardization action can act in the direction of safety, better customer usage and, especially, better performance with respect to the environmental impact. More specifically, the main indications of this study can be summarized in the following points:

- Only 47% shows the ES label and, moreover, this label is found very seldom in lower power adapters (< 40W).However, low power adapters constitute an important part of the market and both the absence of the ES label and the efficiency measurement results indicate poor efficiency values for many of these devices. This point suggests the presence of a serious problem and it seems to be not in line with the conclusions of the Energy Star Programme (i.e., the market was already mature and capable to behave autonomously as per the EPS requirements).
- It can be easily noticed that voltage, current and especially power values seem to tend to common ratings. This fact makes one think of a kind of "de facto" standardization. This condition is particularly evident in two specific cases:
  - ◊ The low voltage connectors: the five most used connector types represent 86 % of the total
  - ◊ The output voltage: where the large majority of the devices (81%) have an output voltage of 5, 12 or 19 V.
- Adapters with a very different output voltage often have the same connector type. This creates further confusion among users and could generate problems and risks for the users in case they would use one of them to power different products. An evaluation should be done to decide on whether it would be better to standardize the use of the existing connectors defined by HGI and ETSI, or to define new connectors (one for each category) such us the ones under study in other standardization activities.
- A high dispersion on weights of adapters having the same ratings has been demonstrated. In particular for the lower power equipment, there is a substantial independence between weight and power, with the higher power equipment appearing to be more aligned amongst each other and showing a sort of linear dependence between power and weight. Moreover, there is a huge difference between the best and the worst adapter, in terms of weight, for each category. For most of the categories, the percentage of power supplies that weigh more than the best plus the 20% is very large. As weight can be directly linked to the environmental impact, it would be advisable to urge manufacturers to consider this issue and optimize their products aligning to other already achieved.

- Because of the weight of the charger is relatively high for portable computers and for portable devices and because the main cause of failure on all portable devices is the weak point at the output of the power supply, it is highly recommended to have a detachable cable on the DC side allowing replacement. This confirms the need for standardizing connectors for each family of devices to avoid errors, unless a sufficiently reliable configuration protocol can be standardized.
- Combining market data and measured weight, it is clear that a huge quantity of material could be saved. A cautious estimate indicates that the aggregated amount, if electronics of EPSs is 1 million tons per year, is growing. At least half of it could be expected to be saved if a standardized solution is available. Because weight is directly linked to environmental impact, it would be advisable to urge manufacturers to optimize their products, aligning them with the best (lightest) in the corresponding category as it could reduce the use of resources (and e-waste) by 300 thousand tons per year.
- As for efficiency versus the output current, a high dispersion of adapter efficiencies both in general and inside the same class has been underlined by the measurements. This aspect suggests an important opportunity of improving the efficiency characteristics independently from their power capacity.
- Often, equivalent EPSs do show quite different efficiency at lower loads, while a lot of equipment have quite variable energy consumption and draw only a limited amount of energy for most of their operating time. The low-load efficiency difference results then in a significant increase in the overall energy consumption and should be avoided through optimizing the efficiency at 10-30% load.
- Many adapters having high power factor when at full load actually show poor power factor at lower loads (Figure 38). As several devices (e.g., laptops) for most of the time draw only a minor amount of the rated energy of their power supplies, the above described behavior implies that, in real life, those EPSs will not from benefit the electrical network with good power factor. Designers and standardizers should evaluate and specify the power factor limits also in low load areas where many devices operate for most of the time.
- The analytical analysis with alpha and beta parameters indicates that only 24% of the power supplies reach their efficiency target value at low output current. This would result into a very relevant increase in the overall energy consumption as several devices draw only a limited amount of energy for a significant amount of time.
- As the measurements have shown a severe negative correlation between the efficiency and power factor, it should be evaluated which is the most import in order to obtain the best overall effect.
- The devices belonging to safety class 2 have a better efficiency behavior. Considering the savings of material, the better compatibility of the class 2 mains connectors (2 pins) and the increased safety for clients, it might be advisable to switch over completely to this kind of solution/connectors/cables.
- Some adapters have shown an output voltage rather higher than what is declared by producers and reported in their nameplate. This could create problems for the connected devices, especially when the voltage value is far higher than what is declared. In general, the ratings declared in the nameplate are expected to be accurate, and represent the real features of the power supply.
- The range of no-load efficiency is quite large, starting from very low and optimal values (about 0.1–0.15 W) up to very inefficient quantities (more that to 2W). Moreover, there is substantial absence of correlation between this type of performance and the size (in terms of output power) of the devices. Finally, the no-load results averaged for each category are definitely worse than those reported in the ESP list. These observations again suggest large opportunities of obtaining better average performances.
- The environmental analysis performed on a subset of devices included in the study shows that the dependency between environmental impacts and weight or output power characteristics is partial; this fact demonstrates the importance of adopting accurate design choices (especially for electronics, but also for the plastics) for minimizing the environmental burdens associated to the single product. Furthermore, within the same impact category, it is always possible to identify one example of PSU

coupling good use-performance as well as good environmental and energetic performances. Depending on the single impact categories, the best in classes can improve the performances of the worst ones of a mean percentage around 25-30%, up to 50% in some specific cases. Again, this demonstrates the importance of adopting design rules optimizing the environmental aspects; a more detailed analysis should be necessary in order to evaluate in detail the single sources of impact that are causing the highlighted differences.

ITU-T Study Group 5 (SG5), which is responsible for studying ICT environmental aspects of electromagnetic phenomena and climate change, is currently discussing the development of a recommendation which would provide high level requirements for a universal common power supply solution for ICT devices.

The aim would be to reduce the number of power adapters and chargers produced and recycled by widening their application to more devices and by increasing their lifetime. The solution would also aim to reduce energy consumption.

8. References

- Bolla R., Bruschi R., D'Agostino L. – An Energy-aware Survey on Mobile-Phone Chargers
- L.adapter phase2 – efficiency versus load and equipment behavior
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9. Appendix A

9.1 Test bed

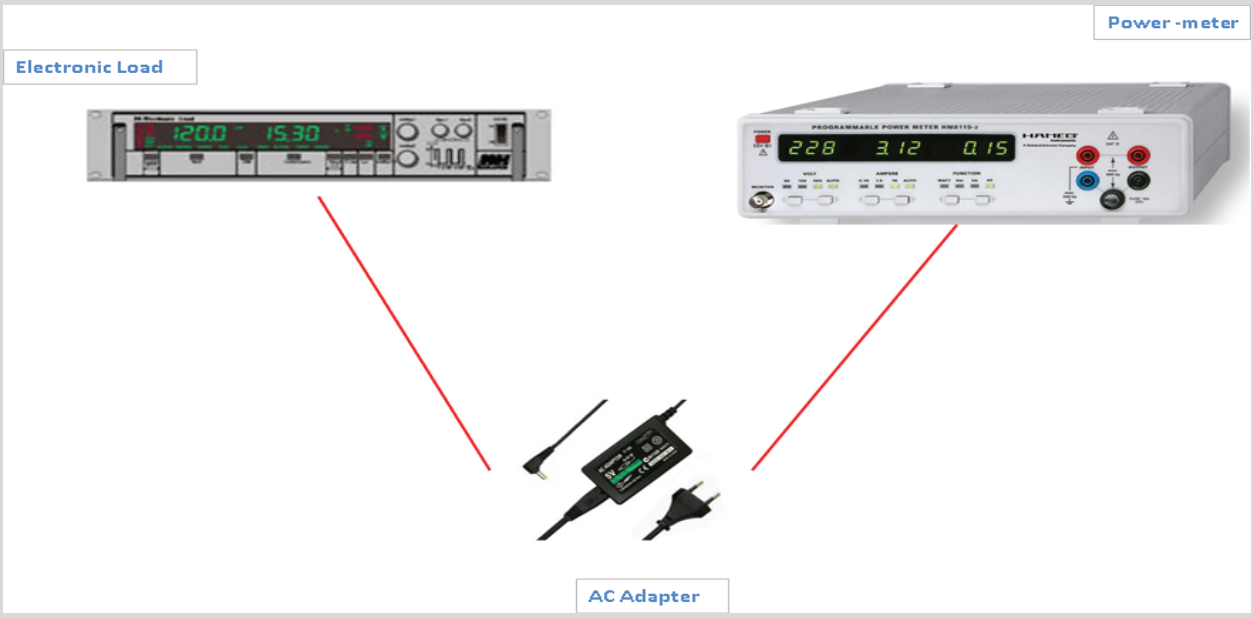
This section introduces the description of the test bed used to measure the electrical features of the devices analyzed. The accuracy obtained is considered consistent with the test aims (mainly for comparison purposes among equipment).

Figure 65 shows the set-up test bed. The power supplies have been connected to a Hameg HM 8115-2 power-meter, to measure:

- Apparent Power = VA = S
- Reactive Power = Var = Q
- Active Power = W = P

From these values, Power Factor = Cos φ = PF = P/S can be determined.

Figure 65: Measurements test bed.



As can be seen in Figure 65, the output of the power adapter has been connected to the H&H ZS 506-4 Electronic load. Through this device, the load applied to the adapter can be changed modifying the current drawn.

To obtain efficiency curves, the current has been increased from 50 mA to 600 mA with steps of 50mA and from 600 mA to the declared maximum power of every power adapter with steps of 100 mA. Together with the change of current increment also the resolution of the measurements has been changed.

10. Appendix B

LIFE CYCLE ASSESSMENT METHODOLOGY APPLIED TO POWER SUPPLIES FOR CUSTOMER PREMISES EQUIPMENT *

Emission: 21 December 2011

* Appendix B is currently being updated in order to comply with Recommendation ITU-T L.1410, which had not yet been approved at the time of writing of this appendix.

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Table of content

1 Introduction 69
1.1 Analyzed products 69
1.2 Data collection procedure 69
1.3 Framework of the report 70
2 Goal definition and scoping 71
2.1 Goal and scope definition 71
2.2 Functional unit 71
2.3 System boundaries 71
2.4 Data categories 72
2.5 Data quality requirements 72
3 Life Cycle Inventory (LCI) 73
3.1 Low power PSU 73
3.2 Medium power PSU 74
3.3 High power PSU 74
4 Life Cycle Impact Assessment 75
4.1 Emissions classification and characterization 76
4.2 Impact categories 76
4.3 Classification and characterization results 77
5 Interpretation 87
5.1 Contributors to Low power PSU 88
5.2 Contributors to Medium power PSU 89
5.3 Contributors to High power PSU 90
5.4 LCIA referred to the maximum output power 91
6 Preliminary Conclusions 96
7 References 97
8 Acronyms & Symbols 97
9 Appendix: Environmental Indicators 98
9.1 Environmental indicators 98

1 *Introduction*

This report represents Deliverable 4 of the research contract established between **Telecom Italy SpA** (hereinafter "Telecom") and the **Department of Materials Science and Chemical Engineering of Politecnico di Torino** (hereinafter "**Politecnico di Torino**").

The goal of this report is to describe the environmental and energy performance of different voltage Power Supplies Units (PSUs) for customer premises equipment (CPE), chosen as representatives of the current market.

1.1 Analyzed products

For the goal of the present analysis, twelve PSUs were chosen as samples referred to three different levels of rated output power supplied to the equipment, such as:

- Low Power
- Medium Power
- High Power

In Table 1.1, it is possible to appreciate the nameplate characteristics of the selected twelve PSUs.

Table 1.1 - Nameplate characteristics of the selected PSU.

		Voltage		Current		Power
		INPUT	OUTPUT	INPUT	OUTPUT	MAXIMUM
	PSU Device	[V]	[V]	[mA]	[mA]	[W]
Low Power	19	230	9	50	500	4,5
	302	240	5	200	1000	5
	31	230	5	200	1500	7,5
	301	230	15	120	500	7,5
Medium Power	63	100-240	12	500	1000	12,0
	70	230	12	105	1000	12,0
	60	100-240	12	600	1250	15,0
	52	200-240	12	400	1500	18,0
High Power	42	100-240	12	800	2500	30,0
	53	100-240	15	800	2000	30,0
	15	100-240	12	1000	3300	39,6
	3	100-240	16	700-1300	3360	53,8

Within each of the three levels of rated output power supplied to the equipment, PSU devices were organized according to the increasing output power in Watts, where applicable.

1.2 Data collection procedure

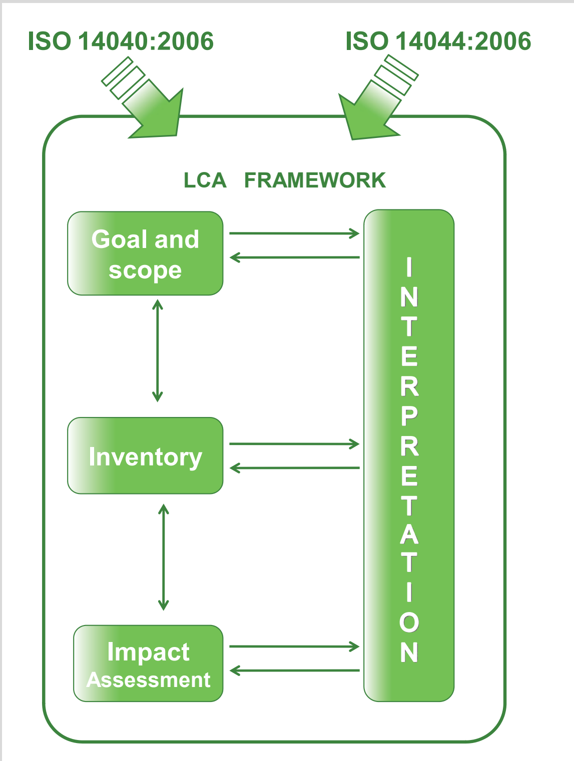
The selected PSUs were disassembled in parts and weighted distinguishing between electronic and plastic/connectors parts. The produced inventories are fully described in the Inventory phase (Chapter 3).

1.3 Framework of the report

The Ecodesign considers product and service following a Life Cycle Thinking approach: product designers are called to select design pathways not only according to material and performance criteria, but also from the energy and environmental burdens of these selections. This is the reason why the framework of this report follows the indications provided by the ISO 14040 and 14044 Standards. In order to facilitate the approach within the mentioned framework of standards and to unify the way of reporting within this LCA study, each phase of the report is introduced by a technical brief definition provided by the specific standard.

The following figure shows a general scheme of the LCA methodology as provided by ISO 14040: each main phase reported in the figure is then briefly introduced.

Figure 1.1 - The LCA structure defined by the ISO 14040



Goal and definition of scope: it is the preliminary phase in which the aim of the study, the functional unit, the system boundaries, the data categories, the assumptions and the limits are defined.

Life Cycle Inventory: it is the main section of the work, dedicated to the study of the life cycle of the system product. This phase is mainly concerned with the data collection and calculation procedures. The goal is to provide a detailed description (operational model) of the raw materials and fuels entering the system (inputs) as well as solid, liquid and gaseous waste exiting the system (outputs). A software tool is normally used to support the modeling procedures and to provide database information.

Life Cycle Impact Assessment: it assists the understanding of Inventory results, making them more manageable in relation to the natural environment, human health and resources and may identify the relative significance of the Inventory results.

Life Cycle Interpretation: it is the conclusive phase of a LCA study in which the findings of either the Inventory or the Impact Assessment or both are combined with the defined goal and scope in order to reach conclusions and formulate recommendations. Once the improvements concerning the considered system have been suggested or implemented, the inventory is performed again to see if the expected changes have occurred but also to identify if any unwanted side effects have accidentally been introduced.

A glossary, an overview on calculation procedures and the meaning of terms used to describe the LCA results are reported in the Appendix.

2 Goal, definition and scope

2.1 Goal and definition of scope

The goal and scope of an LCA shall be clearly defined and shall be consistent with the intended application. Due to the iterative nature of LCA, the scope may have to be refined during the study. In defining the goal of an LCA, the following items shall be unambiguously stated: the intended application, the reasons for carrying out the study, the intended audience, i.e. to whom the results of the study are intended to be communicated, and whether the results are intended to be used in comparative assertions intended to be disclosed to the public. In defining the scope of an LCA, the following items shall be considered and clearly described: the product system to be studied; the functions of the product system or, in the case of comparative studies, the systems; the functional unit; the system boundary; allocation procedures; impact categories selected and methodology of impact assessment, and subsequent interpretation to be used; data requirements; assumptions; limitations; initial data quality requirements; type of critical review, if any; type and format of the report required for the study. (ISO 14044:2006, Par. 4.2.2 – 4.2.3).

The aims of this study are:

- To develop the assessment of the environmental burden for the implemented materials used to make twelve PSUs by means of the Ecodesign approach.
- To organize the LCA results in a standard way, according to ISO 14044:2006 and to the needs of Telecom Italy.

2.2 Functional unit

The functional unit defines the quantification of the identified functions (performance characteristics) of the product. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results. Comparability of LCA results is particularly critical when different systems are being assessed, to ensure that such comparisons are made on a common basis. It is important to determine the reference flow in each product system, in order to fulfill the intended function i.e. the amount of products needed to fulfill the function (ISO 14040:2006, Par. 5.2.2).

The function of the considered system is **one PSU**.

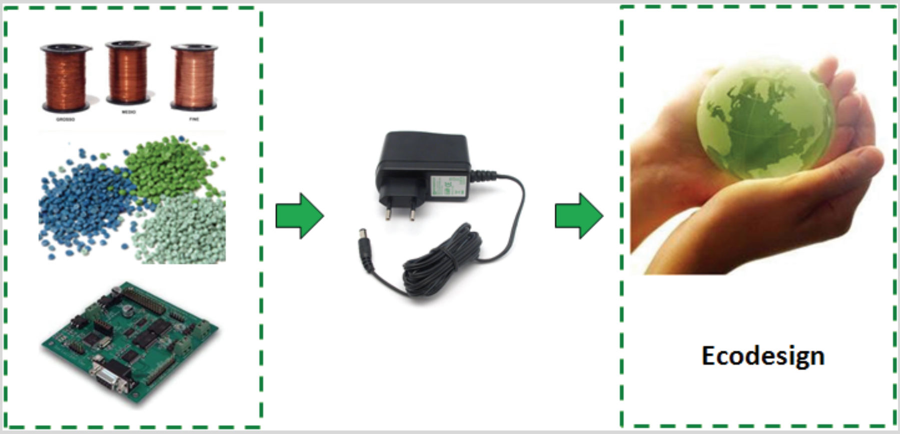
2.3 System boundaries

The system boundary defines the unit processes to be included in the system. Ideally, the product system should be modeled in such a manner that inputs and outputs at its boundary are elementary flows. However, resources need not be expended on the quantification of such inputs and outputs that will not significantly change the overall conclusions of the study. (ISO 14040: 2006, Par. 5.2.3).

The boundaries of the system include materials and components used in the PSU production phase.

The present study does not include in the system boundaries the phases of assembly in the factory, packaging & transport, use phase and end of life.

Figure 2.1 - System Boundaries



2.4 Data categories

Data selected for an LCA depend on the goal and scope of the study. Such data may be collected from the production sites associated with the unit processes within the system boundary, or they may be obtained or calculated from other sources. In practice, all data may include a mixture of measured, calculated or estimated data (ISO 14044:2006, par. 4.2.3.5).

Data and information used in LCA studies can be divided into two main categories, primary data and secondary data:

- **primary data** are collected directly from the selected PSU disassembly and weighting: this assures a high level of precision;
- **secondary data** come from databases, other previous analysis or published reports, for example, inventory data set related to single plastic and electronic components. Normally, these data concern the production of fuels and materials as well as transports operations in terms of energy and resource consumption and emissions to the environment. These data assure a high level of representativeness.

2.5 Data quality requirements

Data quality requirements specify in general terms the characteristics of the data needed for the study. Descriptions of data quality are important to understand the reliability of the study results and properly interpret the outcome of the study. (ISO 14040, Par. 5.2.4).

Data collection on the selected PSU is pertinent to the year 2011.

The software tool used to perform the Inventory analysis is SimaPro v.7; the database included in this software (EcoInvent v.2 and Industry Data LCI) is also used to complete the information necessary to create the model of the product system (secondary data). Further secondary data sources are literature, published technical reports and other LCA databases.

According to ISO 14040 prescriptions, the following information is given:

- The EcoInvent database contains “energy mix” data that are the available official data of the International Energy Agency (IEA);
- Any assumption is documented where appropriate;

- For accuracy, raw information for Inventory calculations was taken directly from an accurate mass analysis of the selected twelve PSUs;
- Throughout this work, gross calorific values (higher heating value) of fuels are used in all LCA calculations.

3 *Life Cycle Inventory (LCI)*

Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. The process of conducting an inventory analysis is iterative. As data are collected and more is learned about the system, new data requirements or limitations may be identified that require a change in the data collection procedures so that the goals of the study will still be met. Sometimes, issues may be identified that require revisions to the goal or scope of the study. (ISO 14044: 2006, par. 5.3.1).

The second phase of a LCA consists in the Life Cycle Inventory (LCI) analysis of the product or system. The aim is to provide a detailed description of the inputs of energy and raw materials into the system and the outputs of solids, liquids and gaseous waste from the system by means of a customized operative (analogical) model. Results arising from this stage are presented in the following paragraphs. They are then integrated with an interpretation that is intended to identify the most significant materials and components, in terms of total energy consumption and environmental impact. The whole analysis is broken down below into three different levels of rated output power supplied to the equipment according to Table 1.1:

- Low Power
- Medium Power
- High Power

For the PSU in question, an Excel file with specific data for the twelve selected items was organized. The LCA model was developed by Politecnico di Torino within the latest version of SimaPro (LCA software by PRé Consultants), integrated with Ecoinvent database and Industry Data LCI. In this chapter, the unit processes and hypotheses considered during the analysis of the system are defined.

The overall mass balance for the selected PSU is reported in Table 3.1.

Table 3.1 - Mass balance of the selected PSU according to main components.

		Housing			Electronics		Totals
	Device	Plastic case	Cables	Other parts	Transformers	PCB&components	[g]
Low Power	**19**	42,81	24,30	6,89	174,03	5,92	**253,95**
	302	16,00	16,00	16,00	6,00	15,50	**69,50**
	31	33,40	29,73	25,24	13,96	18,08	**120,41**
	301	16,00	22,00	20,00	6,00	18,00	**82,00**
Medium Power	**63**	29,92	24,95	7,02	15,11	28,38	**105,38**
	70	66,17	25,90	9,75	421,35	7,57	**530,74**
	60	34,22	25,73	6,95	18,30	34,95	**120,15**
	52	30,78	19,15	21,43	15,07	30,94	**117,37**
High Power	**42**	33,01	31,56	97,26	33,87	40,07	**235,77**
	53	49,49	98,04	57,92	42,78	42,93	**291,16**
	15	52,63	62,23	42,65	53,68	96,15	**307,34**
	3	38,11	40,73	69,12	37,61	63,81	**249,38**

3.1 *Low power PSU*

This section groups the Low power PSU inventories. Table 3.2 presents the mass figures involved in the Low power PSU group.

Table 3.2 – Low power PSU component characteristics.

Component	unit	63	70	60	52
Case PC	g	-	-	33,40	-
Case ABS	g	42,81	-	-	-
Case PC + ABS	g	-	16,00	-	16,00
Metal supports	g	4,00	-	-	-
Cable	g	24,30	16,00	29,73	22,00
Plug & Connectors	g	2,89	16,00	12,86	20,00
Plastic Protections	g	-	-	-	-
PCB	g	2,15	7,00	9,19	8,00
Transformer	g	174,03	6,00	13,96	6,00
Capacitors	g	3,77	6,50	7,71	7,00
Inductors	g	-	-	1,18	1,00
Transistors	g	-	1,00	-	-
Other Electronic Components	g	-	1,00	12,38	2,00
Total	g	**253,95**	**69,50**	**120,41**	**82,00**

3.2 Medium power PSU

This section groups the Medium power PSU inventories. The following Table presents the mass figures involved in the Medium power PSU group.

Table 3.3 – Medium PSU component characteristics.

Component	unit	63	70	60	52
Case PC	g	-	-	-	-
Case ABS	g	-	-	-	-
Case PC + ABS	g	29,92	66,17	34,22	30,78
Metal supports	g	4,00	6,97	7,66	21,43
Cable	g	24,95	25,9	25,73	19,15
Plug & Connectors	g	3,02	2,78	2,95	
Plastic Protections	g	-	-	-	-
PCB	g	8,88	3,64	9,96	10,91
Transformer	g	15,11	421,35	18,30	15,07
Capacitors	g	11,63	3,93	12,47	11,22
Inductors	g	4,89	-	5,22	5,28
Transistors	g	2,04	-	1,61	2,00
Other Electronic Components	g	0,94	-	2,03	1,53
Total	g	**105,38**	**530,74**	**120,15**	**117,37**

3.3 High power PSU

This section groups the high power PSU inventories. The following Table presents the mass figures involved in the high power PSU group.

Table 3.4 – High PSU component characteristics.

Component	unit	42	53	15	3
Case PC	g	-	-	-	38,11
Case ABS	g	-	-	-	-
Case PC + ABS	g	33,01	49,49	52,63	-
Metal supports	g	14,52	25,39	23,88	48,34
Cable	g	79,72	98,04	62,23	40,73
Plug & Connectors	g	34,58	32,53	18,26	10,14
Plastic Protections	g	-	-	0,51	10,64
PCB	g	14,34	14,60	29,94	18,87
Transformer	g	33,87	42,78	53,68	37,61
Capacitors	g	22,21	19,99	29,31	26,38
Inductors	g	2,01	3,88	31,40	11,75
Transistors	g	1,00	2,00	4,20	3,39
Other Electronic Components	g	0,51	2,46	1,30	3,42
Total	g	**235,77**	**291,16**	**307,34**	**249,38**

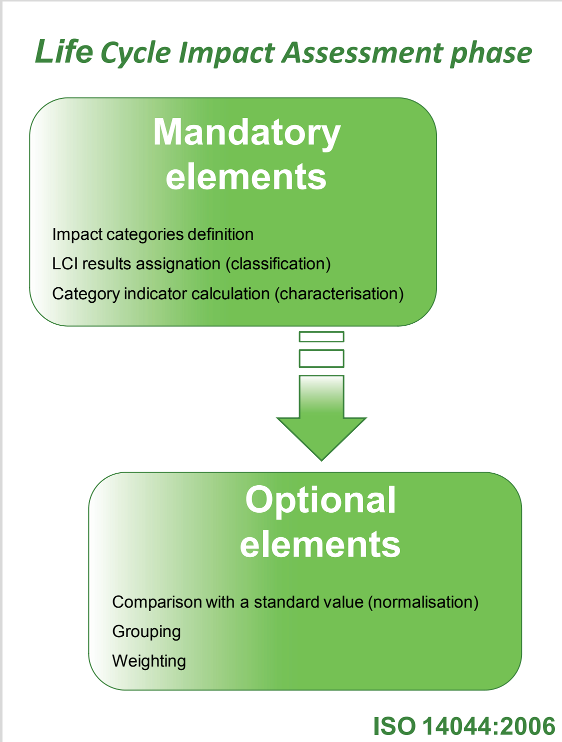
Subsequently, data from Table 3.2, Table 3.3 and Table 3.4 have been organized to build a LCA model for each PSU, by means of the SimaPro software. EcoInvent database (which contains international industrial life cycle inventory data on energy supply, resource extraction, air emissions, water emissions and solid waste flows) has been used to match each single item of the inventories with a dataset, mainly in the field of electronic components and devices, plastics and metals. For each material and component available in the software, it is possible to know the environmental impacts. As a result, it is also possible to calculate all PSUs final impact assessments which are presented in the following chapter.

4 *Life Cycle Impact Assessment*

The impact assessment phase of LCA is aimed at evaluating the significance of potential environmental impacts using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, thereby attempting to understand these impacts. The LCIA phase also provides information for the life cycle interpretation phase. The impact assessment may include the iterative process of reviewing the goal and scope of the LCA study to determine if the objectives of the study have been met, or to modify the goal and scope if the assessment indicates that they cannot be achieved. Issues such as choice, modelling and evaluation of impact categories can introduce subjectivity into the LCIA phase. Therefore, transparency is critical to the impact assessment to ensure that assumptions are clearly described and reported. (ISO 14040, par. 5.4.1).

According to ISO 14044 Standard schematically reported in Figure 4.1, the general framework of the Assessment phase is composed of several mandatory elements that convert Inventory results to environmental indicators. In addition, there are optional elements for grouping, transformation of the indicator results and data quality assessment techniques.

Figure 4.1 – Main steps of the Impact Assessment phase



4.1 Emission classification and characterization

Classification is the assignment of Inventory results to impact categories whereas characterization involves the calculation of category indicator results, which means the conversion of Inventory results to common units and the aggregation of the converted results within the impact categories. The outcome of this operation is a numerical indicator result.

4.2 Impact categories

Emission classification and characterization are respectively based on the definition of some environmental impact potentials and, moreover, on the calculation of a numerical indicator resulting on the base of a characterization factor.

For this analysis, the following impact categories[3] are considered:

- Greenhouse effect (also referred as GWP, Global Warming Potential)
- Ozone Depletion Potential (ODP)
- Photochemical Ozone Creation Potential (POCP)
- Acidification Potential (AP)
- Eutrophication Potential (EP)
- Gross Energy Requirement (GER, also referred as CED, Cumulative Energy Demand)
- Water use

[3] A brief description of each impact category is available in Appendix.

4.3 Classification and characterization results

The results of the classification and characterization phases, calculated by using the environmental indicators of the previous paragraph and the general rules reported in the Appendix, are presented in the following table.

Table 4.1 - Environmental and energy results.

IMPACT CATEGORY	Low power				Medium power				High power			
	19	302	31	301	63	70	60	52	42	53	15	3
GWP [kg CO_2 eq/p]	1,15	1,03	1,58	1,28	1,50	2,28	1,98	2,13	2,19	2,80	4,37	3,33
ODP [kg CFC-11 eq/p]	5,8E-08	6,7E-08	1,8E-07	9,8E-08	9,3E-08	1,1E-07	1,3E-07	1,5E-07	1,4E-07	1,7E-07	2,8E-07	2,2E-07
POCP [kg C_2H_4 eq/p]	0,0017	0,0029	0,0049	0,0026	0,0059	0,0028	0,0057	0,0055	0,0075	0,0080	0,0161	0,0111
AP [kg SO_2 eq/p]	0,0078	0,0279	0,0447	0,0232	0,0533	0,0161	0,0463	0,0425	0,0638	0,0641	0,1148	0,0801
EP [kg PO_4^{3-} eq/p]	0,0007	0,0006	0,0010	0,0008	0,0008	0,0014	0,0010	0,0013	0,0012	0,0015	0,0024	0,0019
GER [MJ/p]	22,85	20,92	29,57	25,20	30,2	43,0	39,8	42,1	44,8	57,5	87,5	64,5
Water use [kg/p]	9,72	12,07	20,77	13,31	18,7	19,1	22,8	23,8	25,2	31,0	54,1	40,9

4.3.1 Global Warming Potential, GWP

Figure 4.2 – Low Power PSU GWP results.

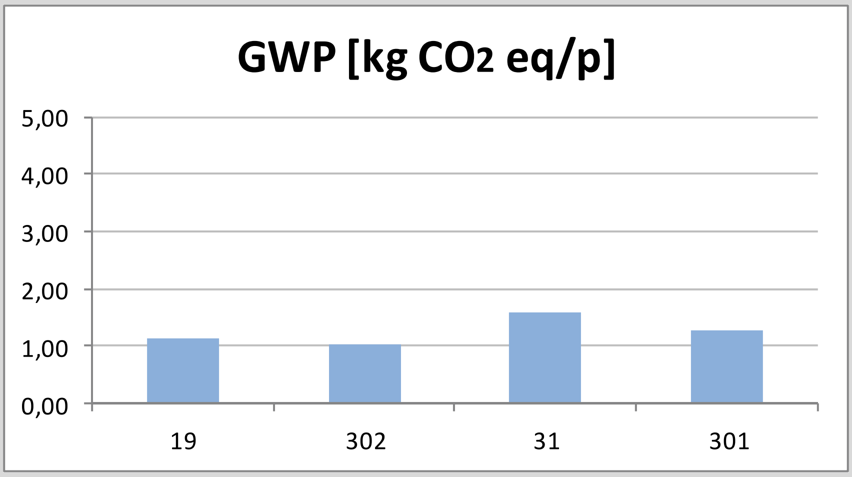


Figure 4.3 – Medium Power PSU GWP results.

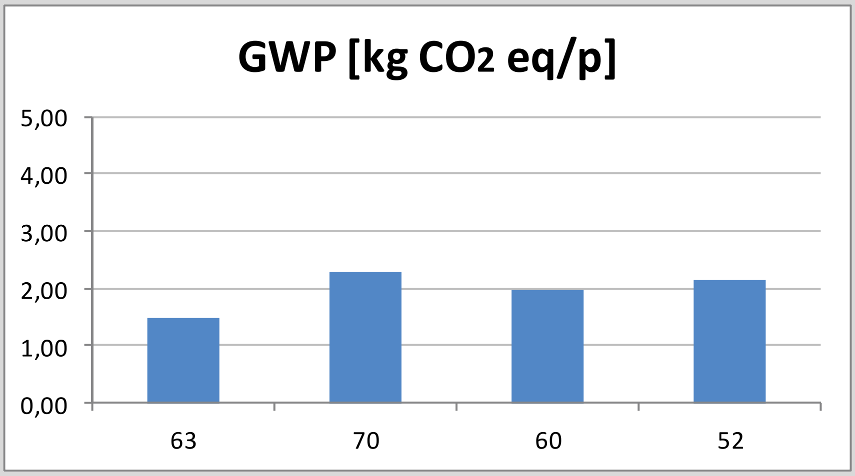
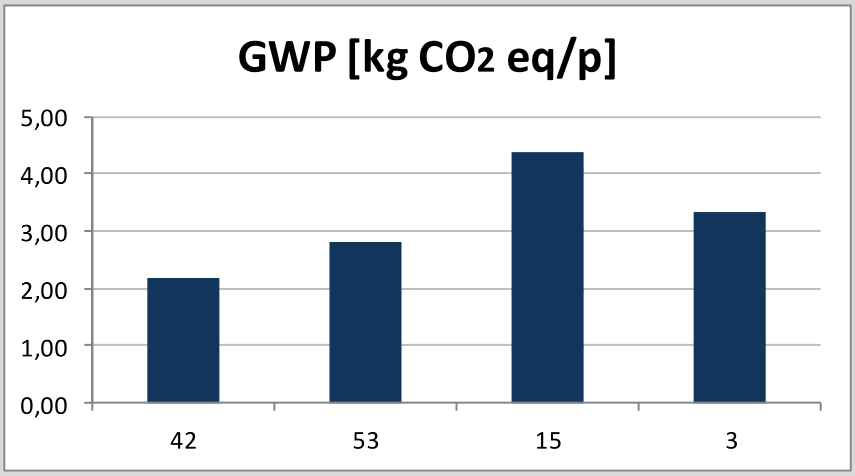


Figure 4.4 – High Power PSU GWP results.



4.3.2 Ozone Depletion Potential, ODP

Figure 4.5 – Low Power PSU ODP results.

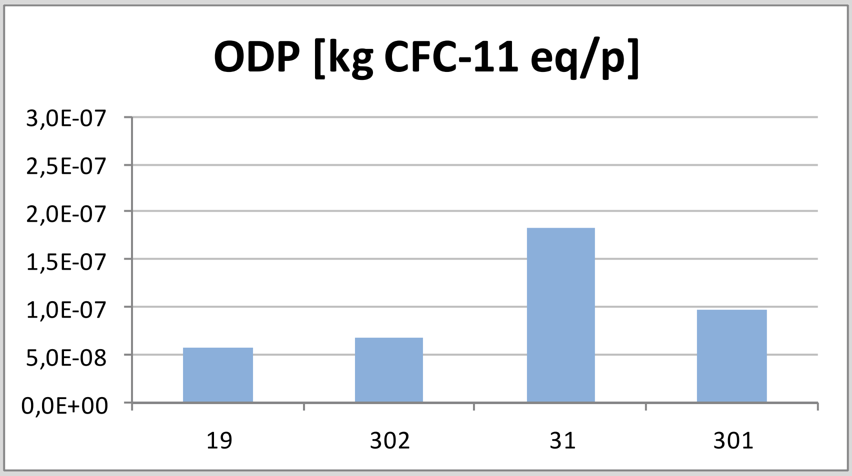


Figure 4.6 – Medium Power PSU ODP results.

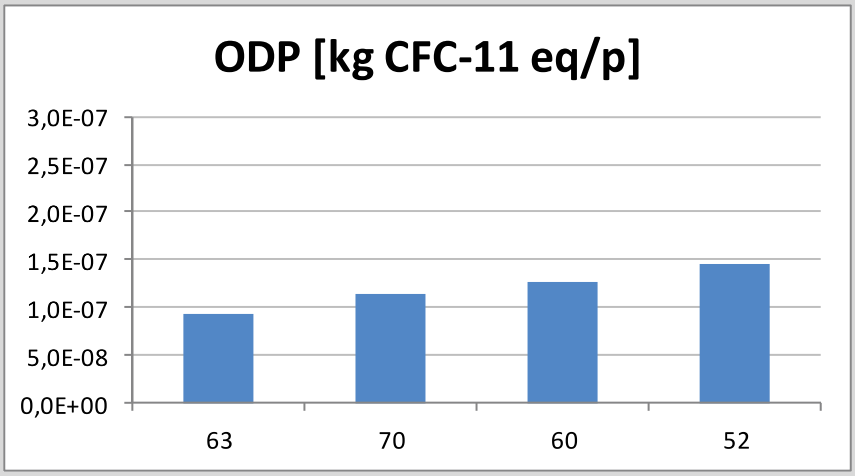
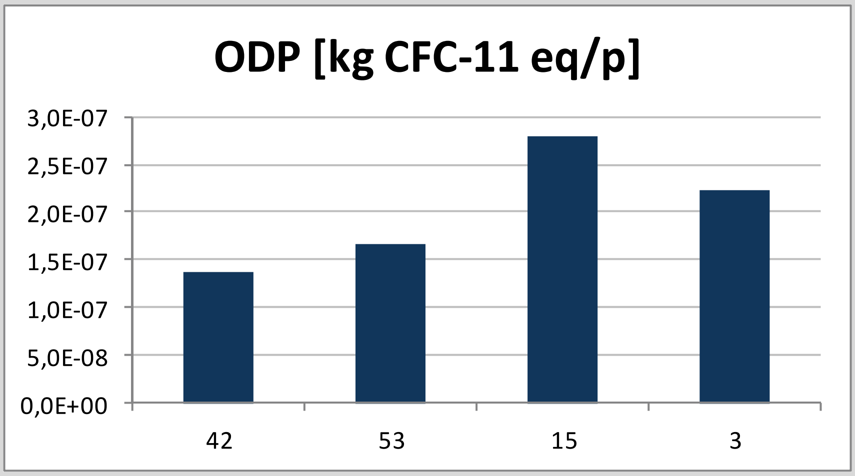


Figure 4.7 – High Power PSU ODP results.



4.3.3 Photochemical Ozone Creation Potential, POCP

Figure 4.8 – Low Power PSU POCP results.

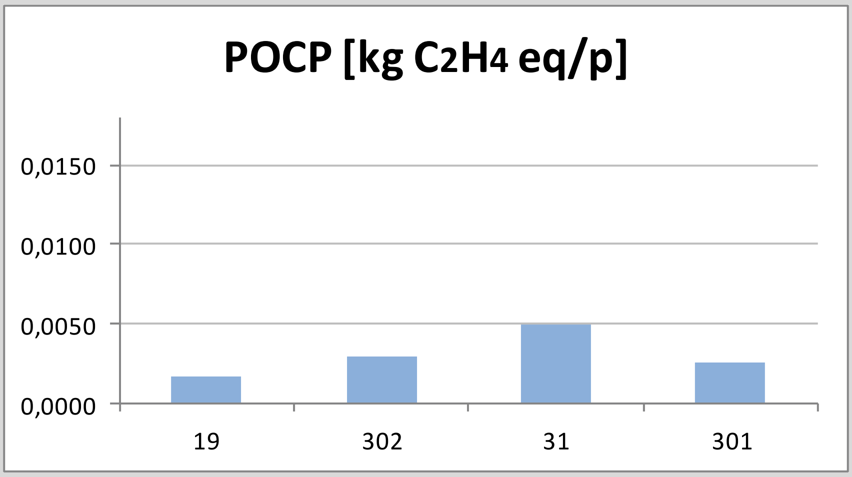


Figure 4.9 – Medium Power PSU POCP results.

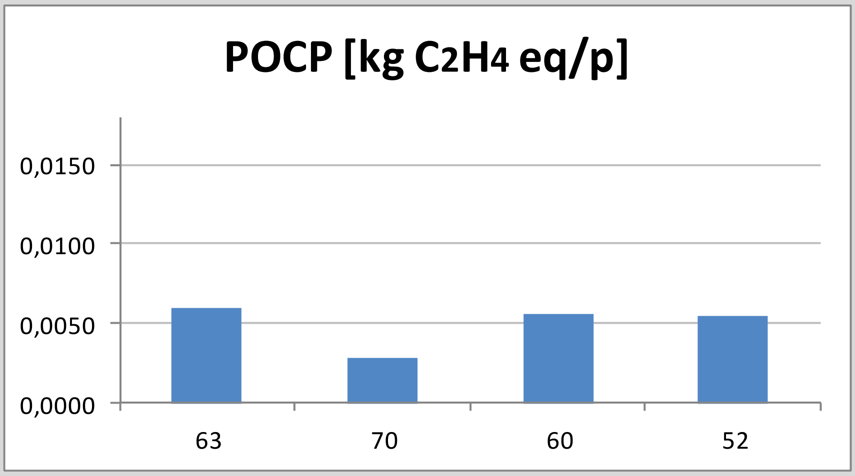
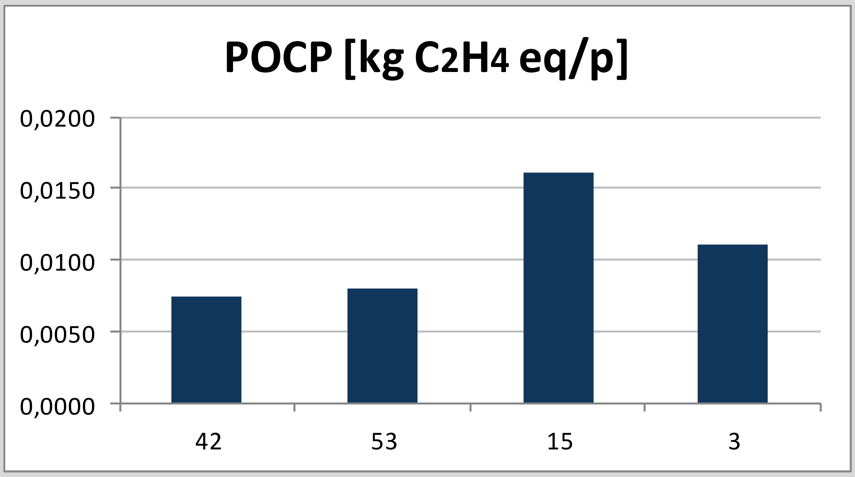


Figure 4.10 – High Power PSU POCP results.



4.3.4 Acidification Potential, AP

Figure 4.11 – Low Power PSU AP results.

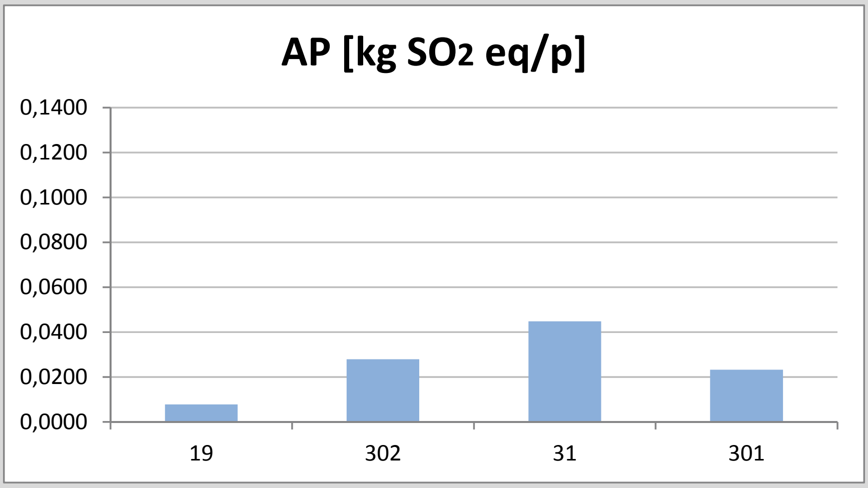


Figure 4.12 – Medium Power PSU AP results.

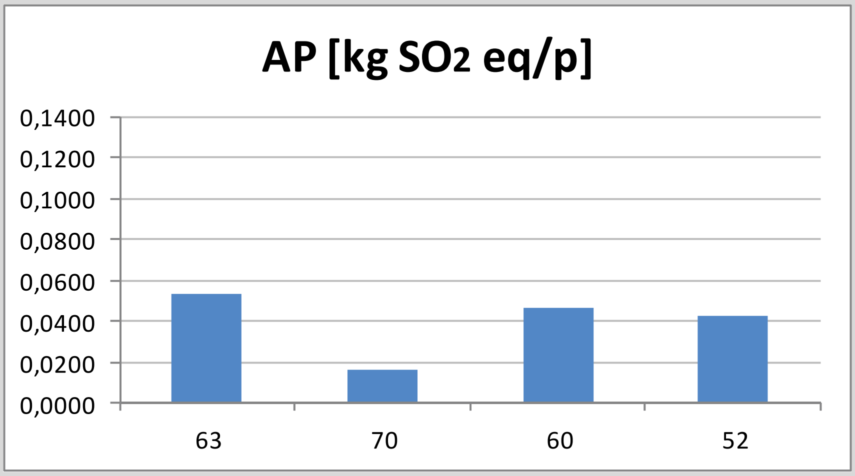
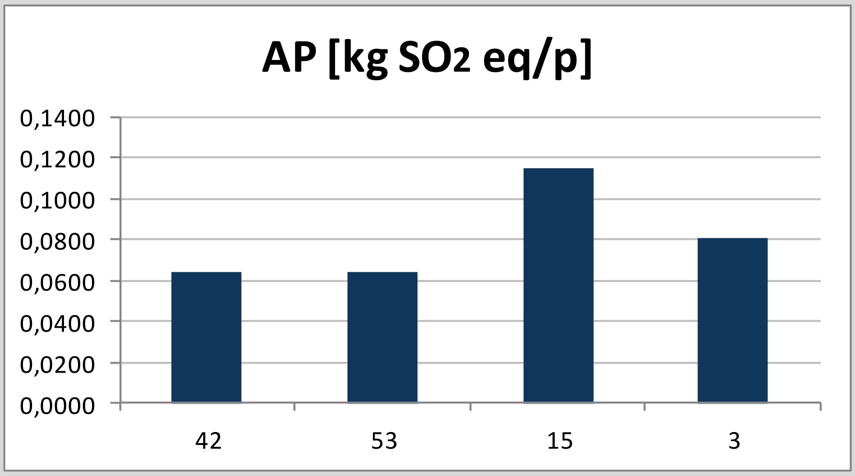


Figure 4.13 – High Power PSU AP results.



4.3.5 Eutrophication Potential, EP

Figure 4.14 – Low Power PSU EP results.

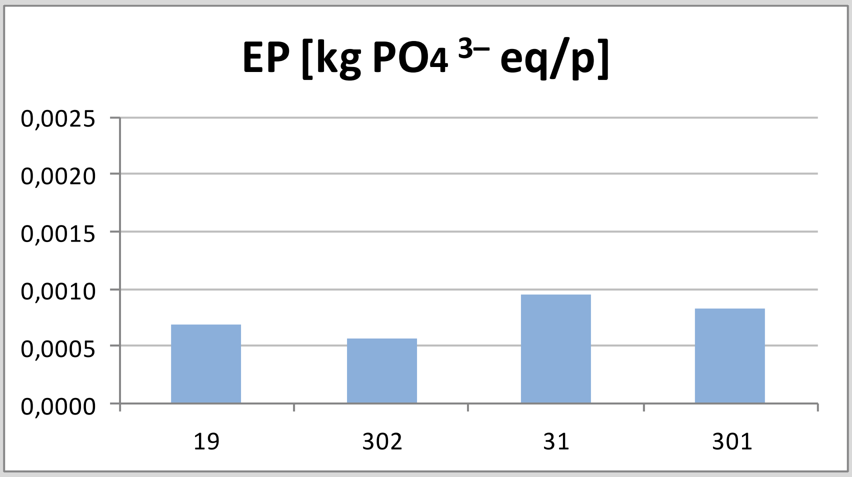


Figure 4.15 – Medium Power PSU EP results.

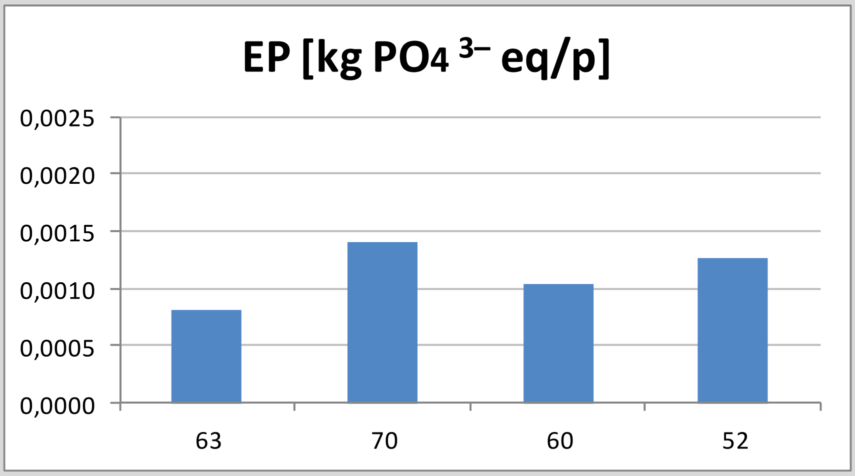
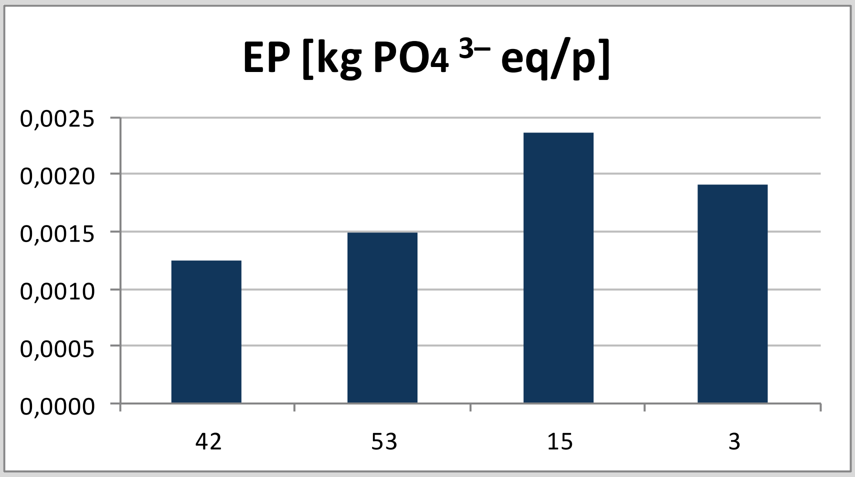


Figure 4.16 – High Power PSU EP results.



4.3.6 Gross Energy Requirement, GER

Figure 4.17 – Low Power PSU GER results.

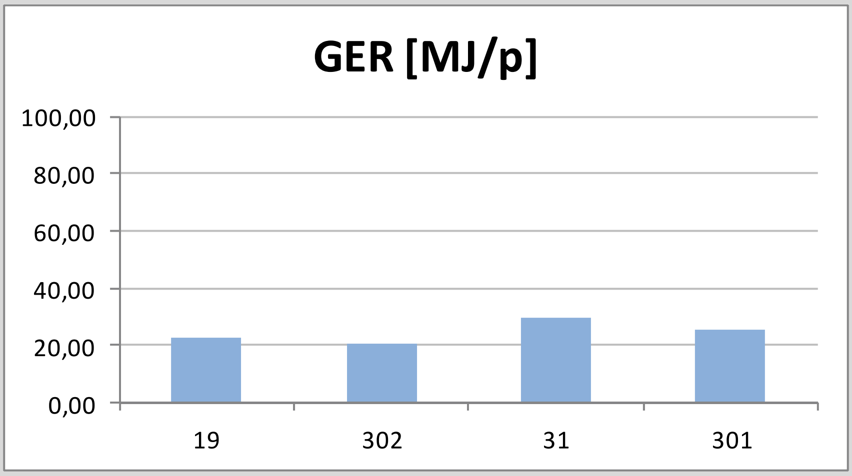


Figure 4.18 – Medium Power PSU GER results.

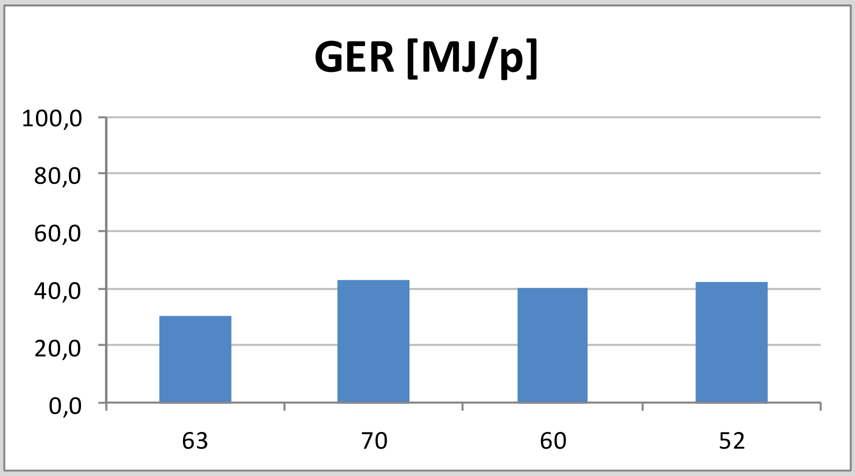
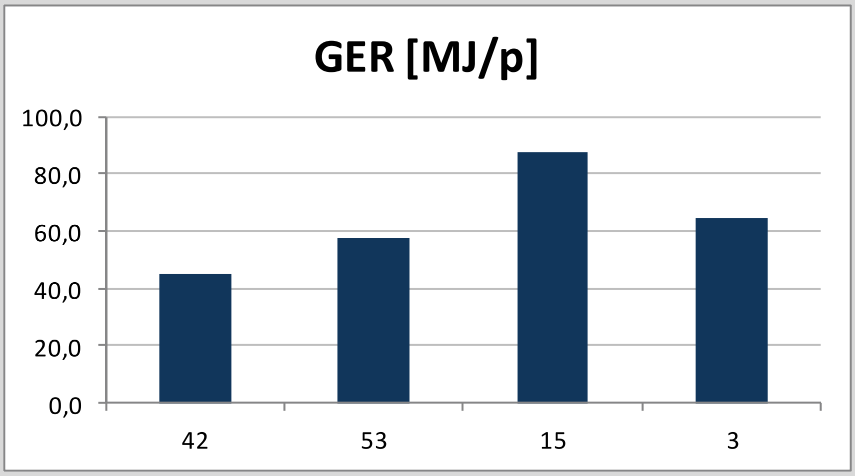


Figure 4.19 – High Power PSU GER results.



4.3.7 Water use

Figure 4.20 – Low Power PSU Water Use results.

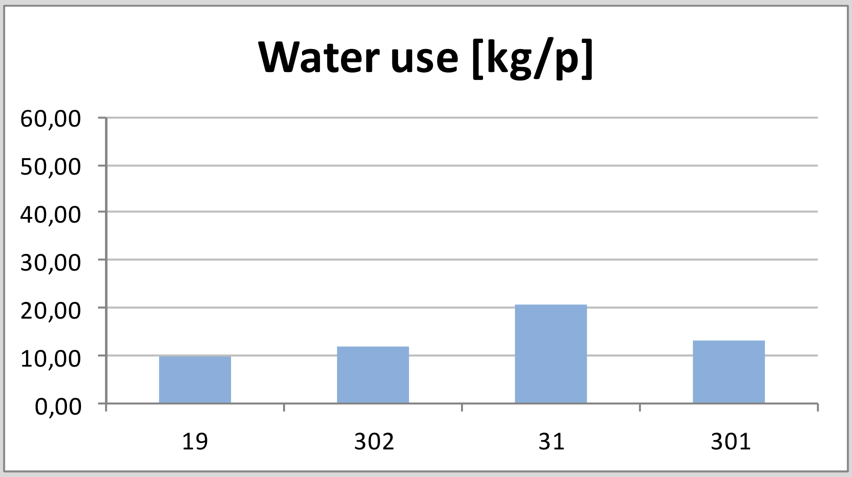


Figure 4.21 – Medium Power PSU Water Use results.

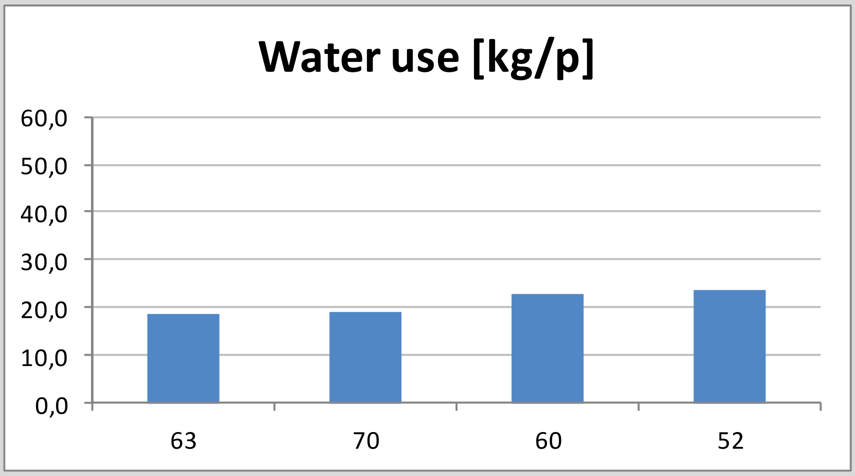
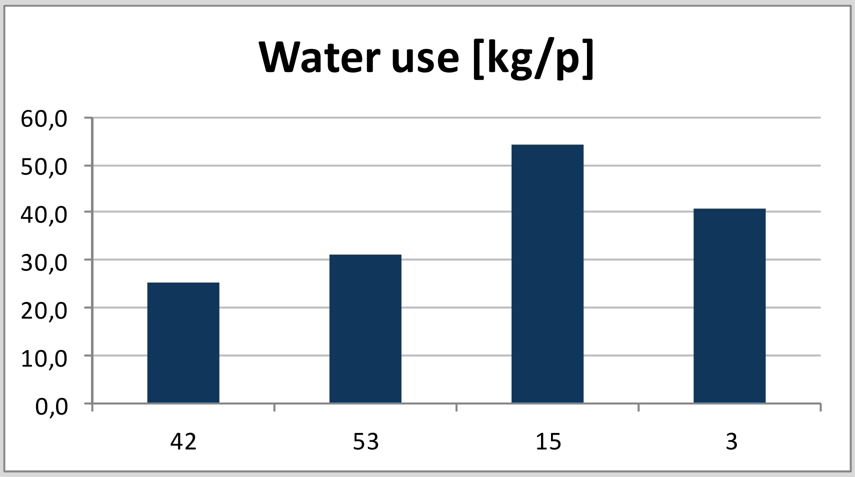


Figure 4.22 – High Power PSU Water Use results.



5 Interpretation

Interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are considered together or, in the case of LCI studies, the findings of the inventory analysis only. The interpretation phase should deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations. The interpretation should reflect the fact that the LCIA results are based on a relative approach, that they indicate potential environmental effects, and that they do not predict actual impacts on category endpoints, the exceeding of thresholds or safety margins or risks. The findings of this interpretation may take the form of conclusions and recommendations to decision-makers, consistent with the goal and scope of the study. Life cycle interpretation is also intended to provide a readily understandable, complete and consistent presentation of the results of an LCA, in accordance with the goal and scope definition of the study. The interpretation phase may involve the iterative process of reviewing and revising the scope of the LCA, as well as the nature and quality of the data collected in a way which is consistent with the defined goal. (ISO 14040, Par. 5.5).

Life Cycle Assessment results might be used for several purposes: as a base for process improvement, products innovation, according to sustainable production, or the development of an environmental policy strategy.

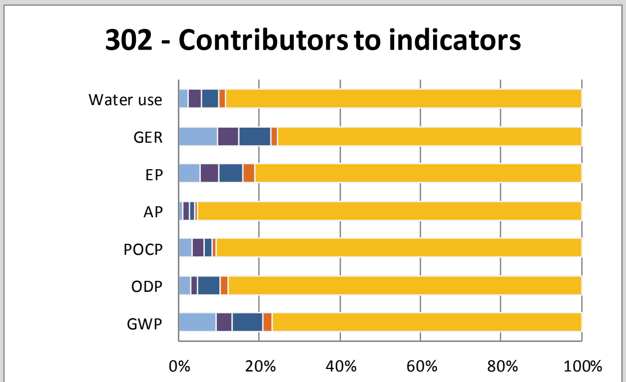
In this report, environmental impacts have been organized for the purposes of the study addressed to ITU according to High, Medium and Low Power PSU categories. In the following paragraphs, it is possible to appreciate the contributors to the environmental indicators (GWP, ODP, POCP, AP, EP, GER, Water use) according to the following main areas:

- Plastic Case
- Cables
- Other Parts
- Transformers
- PCB & components

The following graphs show the percentage contribution of these five areas to each environmental indicator, referred to the total figures of Table 4.1.

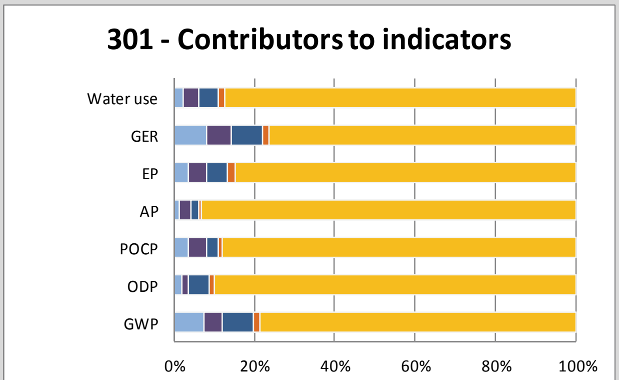
5.1 Contributors to Low power PSU

Figure 5.1 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 302 PSUs.



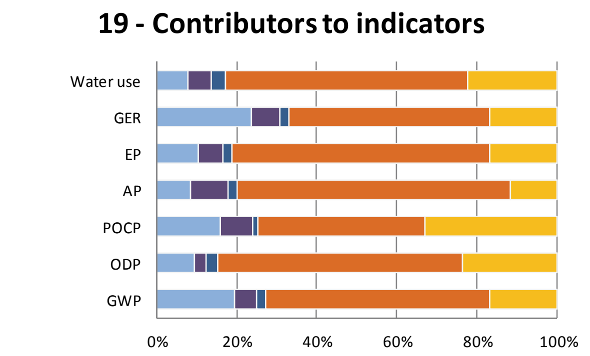
	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	9%	3%	3%	1%	5%	10%	2%
Cables	4%	2%	3%	2%	5%	5%	3%
Other parts	8%	6%	2%	1%	6%	8%	4%
Transformers	2%	2%	1%	1%	3%	2%	2%
PCB&components	77%	88%	91%	95%	81%	75%	88%

Figure 5.2 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 301 PSUs.



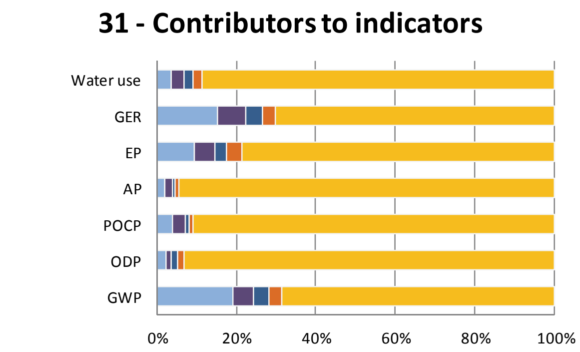
	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	7%	2%	4%	1%	4%	8%	2%
Cables	5%	2%	5%	3%	4%	6%	4%
Other parts	8%	5%	3%	2%	5%	8%	5%
Transformers	2%	1%	1%	1%	2%	2%	2%
PCB&components	79%	90%	88%	93%	85%	76%	87%

Figure 5.3 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 19 PSUs.



	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	19%	9%	16%	8%	10%	24%	8%
Cables	6%	3%	8%	10%	6%	7%	6%
Other parts	2%	3%	1%	2%	2%	2%	3%
Transformers	56%	61%	42%	68%	64%	50%	61%
PCB&components	17%	24%	33%	12%	17%	17%	22%

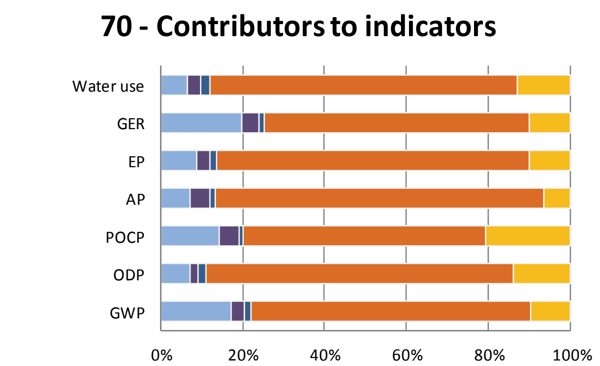
Figure 5.4 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 31 PSUs.



	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	19%	2%	4%	2%	9%	15%	4%
Cables	5%	1%	3%	2%	5%	7%	3%
Other parts	4%	2%	1%	1%	3%	4%	2%
Transformers	3%	2%	1%	1%	4%	3%	2%
PCB&components	69%	93%	91%	94%	79%	70%	89%

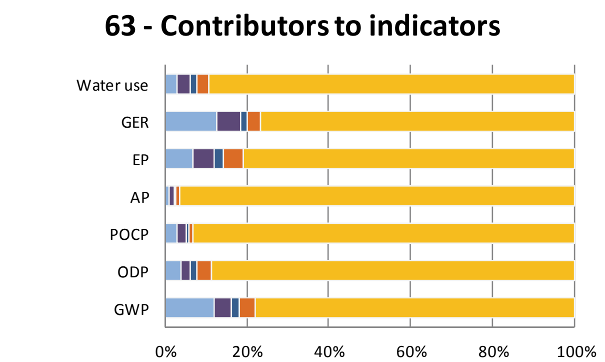
5.2 Contributors to Medium power PSU

Figure 5.5 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 70 PSUs.



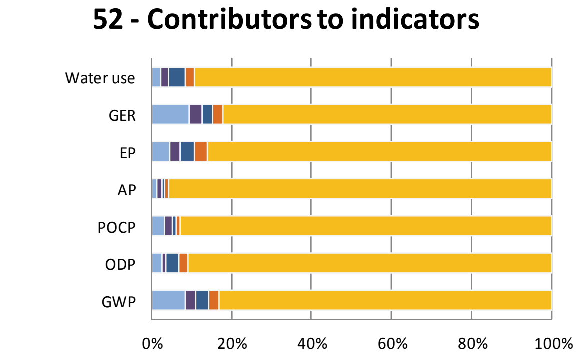
	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	17%	7%	14%	7%	9%	20%	6%
Cables	3%	2%	5%	5%	3%	4%	3%
Other parts	2%	2%	1%	1%	2%	1%	2%
Transformers	68%	75%	59%	80%	76%	65%	75%
PCB&components	10%	14%	21%	7%	10%	10%	13%

Figure 5.6 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 63 PSUs.



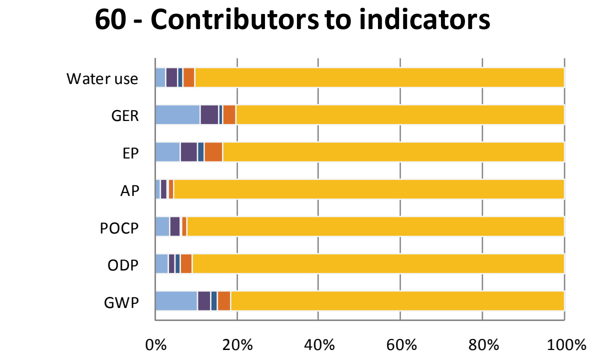
	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	12%	4%	3%	1%	7%	13%	3%
Cables	4%	2%	2%	1%	5%	6%	3%
Other parts	2%	2%	0%	0%	2%	2%	2%
Transformers	4%	3%	1%	1%	5%	3%	3%
PCB&components	78%	89%	93%	96%	81%	77%	89%

Figure 5.7 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 52 PSUs.



	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	9%	3%	3%	1%	5%	9%	2%
Cables	2%	1%	2%	1%	3%	3%	2%
Other parts	3%	3%	1%	1%	4%	3%	4%
Transformers	3%	2%	1%	1%	3%	2%	2%
PCB&components	83%	91%	93%	96%	86%	82%	89%

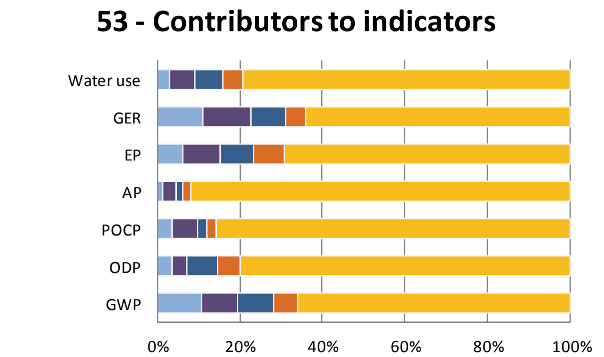
Figure 5.8 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 60 PSUs.



	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	10%	3%	4%	1%	6%	11%	3%
Cables	3%	2%	2%	2%	4%	4%	3%
Other parts	1%	1%	0%	0%	2%	1%	1%
Transformers	3%	3%	1%	1%	5%	3%	3%
PCB&components	81%	91%	92%	95%	83%	80%	90%

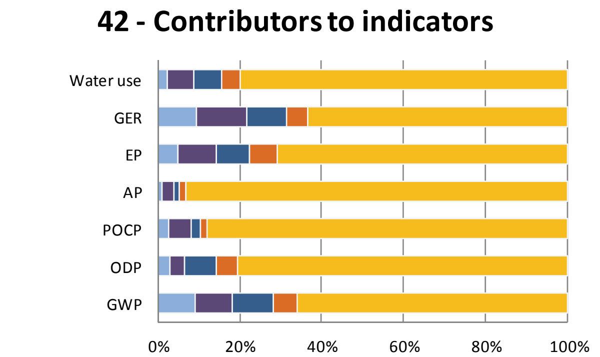
5.3 Contributors to High power PSU

Figure 5.9 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 53 PSUs.



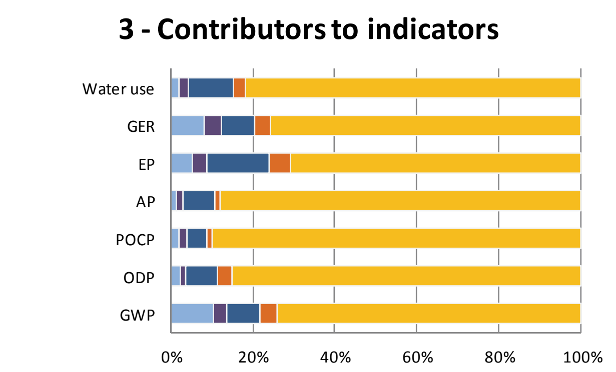
	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	11%	4%	4%	1%	6%	11%	3%
Cables	9%	3%	6%	3%	9%	12%	6%
Other parts	9%	8%	2%	1%	8%	8%	7%
Transformers	6%	5%	2%	2%	7%	5%	5%
PCB&components	66%	80%	86%	92%	69%	64%	79%

Figure 5.10 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 42 PSUs.



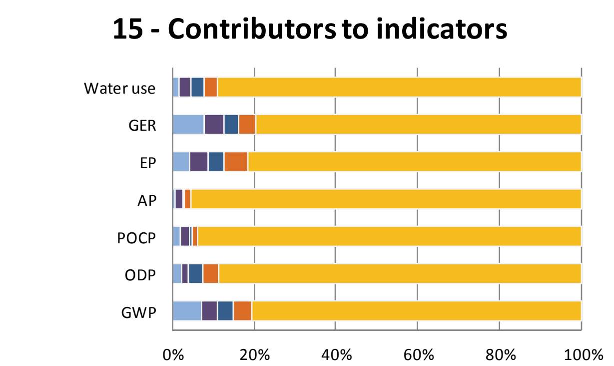
	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	9%	3%	3%	1%	5%	9%	2%
Cables	9%	4%	5%	3%	9%	12%	6%
Other parts	10%	8%	2%	1%	8%	10%	7%
Transformers	6%	5%	2%	2%	7%	5%	5%
PCB&components	66%	81%	88%	93%	71%	63%	80%

Figure 5.11 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 3 PSUs.



	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	10%	2%	2%	1%	5%	8%	2%
Cables	3%	1%	2%	2%	4%	4%	2%
Other parts	8%	8%	5%	8%	15%	8%	11%
Transformers	4%	3%	1%	1%	5%	4%	3%
PCB&components	74%	85%	90%	88%	71%	76%	82%

Figure 5.12 – Share-out of GWP, ODP, POCP, AP, EP, GER, Water use among the reported main components of the 15 PSUs.



	GWP	ODP	POCP	AP	EP	GER	Water use
Plastic case	7%	2%	2%	1%	4%	8%	2%
Cables	4%	2%	2%	2%	4%	5%	3%
Other parts	4%	3%	1%	1%	4%	4%	3%
Transformers	5%	4%	1%	1%	6%	4%	3%
PCB&components	81%	88%	94%	95%	82%	80%	89%

5.4 LCIA referred to the maximum output power

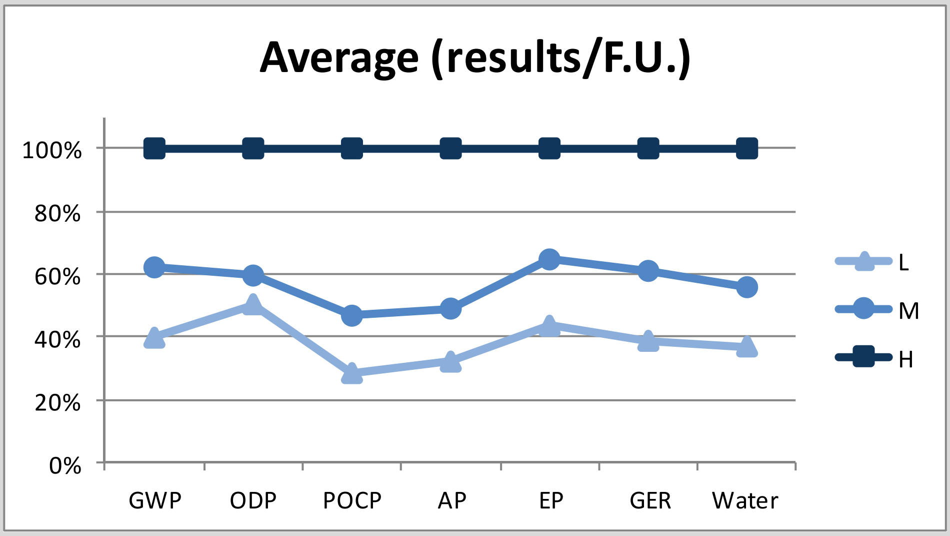
In this section, the goal is to express and to assess the environmental and energy behavior according to the output power supplied by the PSUs.

The environmental and energy results reported in Table 4.1 are referred to the functional unit (1 PSU): the hereafter presented analysis is performed when those results are re-organized according to the maximum output Power. **Therefore, the final results have been normalized and refer to 1 W (output power), instead of to the functional unit of 1 PSU.**

5.4.1 Environmental results according to power generation

In order to appreciate the deviation among the impact categories presented in Table 4.1, the average value among the various products (the single value meant to typify a list of values) was *firstly* calculated for each impact category. As presented in Figure 5.13, the greater figure of average value was chosen as 100% and the other figures were represented accordingly. For the impact categories, the High power PSUs are performing the greater figures of impact category per Functional Unit (F.U.); therefore, High power PSU figures represent 100% of the average value and the other PSUs are represented accordingly.

Figure 5.13 – Average value for each impact categories, according to the functional unit (1 PSU)



Once the average values were calculated for the impact categories, *then* the average values were calculated according to the maximum output power. In Table 5.1, Table 5.2 and Table 5.3 the environmental and energy PSU performance is organized according to the three different levels of rated output power (Low, Medium, High) supplied to the equipment.

Table 5.1 - Low power PSU environmental and energy results according to output power.

Impact Category		19	302	31	301
GWP	kg CO2 eq/W	0,26	0,21	0,21	0,17
ODP	kg CFC-11 eq/W	1,3E-08	1,3E-08	2,4E-08	0,00
POCP	kg C2H4/W	0,0004	0,0006	0,0007	0,00
AP	kg SO2 eq/W	0,0017	0,0056	0,0060	0,00
EP	kg PO4--- eq/W	0,0002	0,0001	0,0001	0,00
GER	MJ/W	5,08	4,18	3,94	3,36
Water	kg/W	2,16	2,41	2,77	1,77

Table 5.2 - Medium power PSU environmental and energy results according to output power.

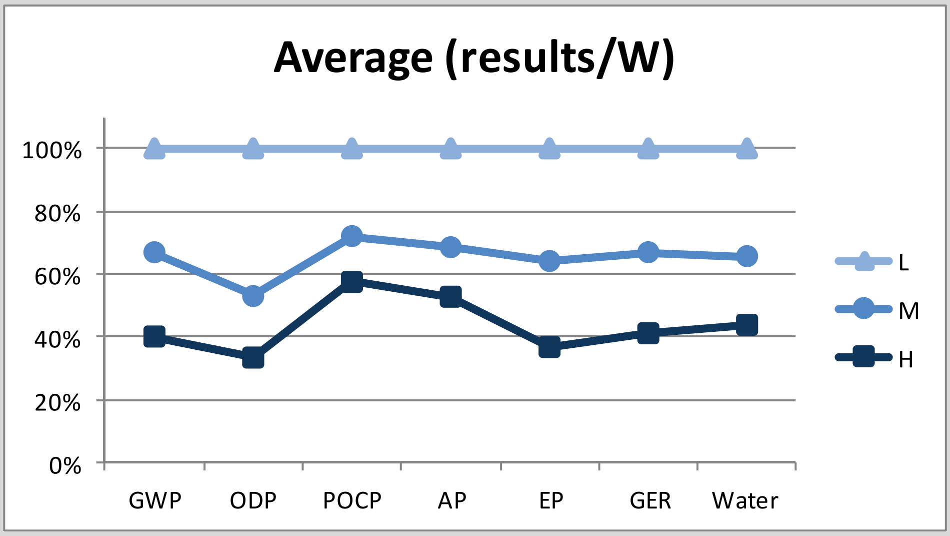
Impact Category		63	70	60	52
GWP	kg CO2 eq/W	0,12	0,19	0,13	0,12
ODP	kg CFC-11 eq/W	7,7E-09	9,6E-09	8,4E-09	8,1E-09
POCP	kg C2H4/W	0,0005	0,0002	0,0004	0,0003
AP	kg SO2 eq/W	0,0044	0,0013	0,0031	0,0024
EP	kg PO4--- eq/W	0,0001	0,0001	0,0001	0,0001
GER	MJ/W	2,51	3,59	2,66	2,34
Water	kg/W	1,56	1,59	1,52	1,32

Table 5.3 - High power PSU environmental and energy results according to output power.

Impact Category		42	53	15	3
GWP	kg CO2 eq/W	0,07	0,09	0,11	0,06
ODP	kg CFC-11 eq/W	4,6E-09	5,6E-09	7,0E-09	4,1E-09
POCP	kg C2H4/W	0,0002	0,0003	0,0004	0,0002
AP	kg SO2 eq/W	0,0021	0,0021	0,0029	0,0015
EP	kg PO4--- eq/W	0,0000	0,0000	0,0001	0,0000
GER	MJ/W	1,49	1,92	2,21	1,20
Water	kg/W	0,84	1,03	1,37	0,76

In order to appreciate the deviation with respect to the output power, the average value among the various products was calculated according to the figures presented in these Tables. As presented in Figure 5.14, the greater average value of three different levels of rated output power supplied to the equipment was chosen as 100% and the other figures were represented accordingly. For the three different levels of rated output power supplied to the equipment, the Low PSUs are performing the greater figures of impact category according to power generation. Therefore Low PSU figures represent 100% of the average value per output power (W) and the other levels of rated output power are represented accordingly.

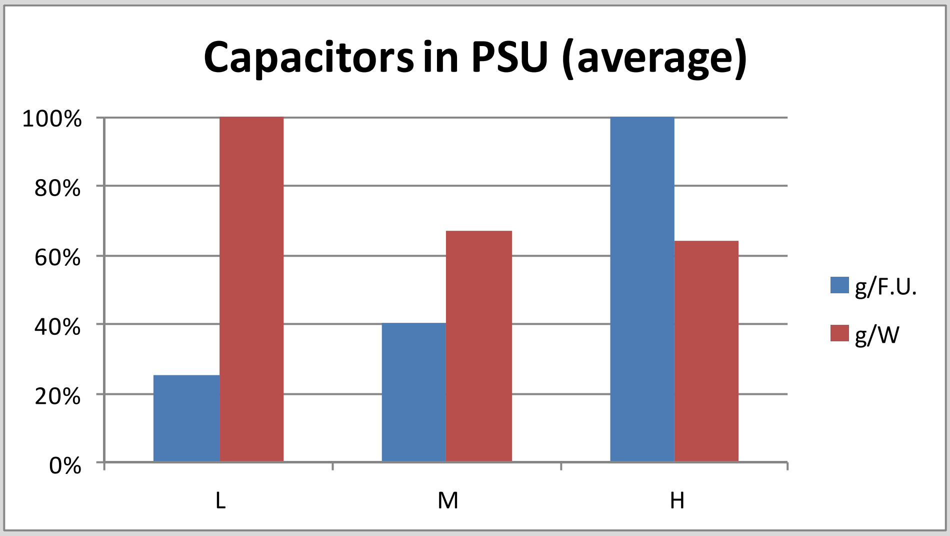
Figure 5.14 – Average value for each impact categories, according to output power (1 W)



In Figure 5.13 and Figure 5.14, it is possible to appreciate a trend line among the average environmental results, both for the results that refer to the functional unit (1 PSU) in which the maximum values are identified with the High Power group, and for the results that refer to the output power, in which the maximum figures are related to the Low Power group.

It is important to highlight the behavior of two environmental indicators, not completely in line with the others: POCP and AP. This is mainly due to the presence of capacitors, which provide the main contributors for these two indicators and, in the following graph, it is possible to see the average values of the "mass of capacitors" that refer to the functional unit and the output power.

Figure 5.15 - Presence of capacitors in PSU, referred to the average functional unit and to the average output power, for Low, Medium and High Power PSU.



5.4.2 Common Power Supply with ETSI specification

Telecom was in charge of a specific study concerning the environmental and energy assessment, fully implementing the Life Cycle Assessment methodology, of a common power supply (identified with device code 44) performing the ETSI specifications.

The considered 44 PSU was a TYPE 2 subcategory b, weighting 92 g, with a nameplate Output Voltage equal to 12 V and a nameplate Output Current equal to 2 A; the rated Output Power was equal to 24 W.

Table 5.4 - 44 PSU component characteristics.

Component	unit	44
Case virgin ABS + Recycled ABS	g	32,00
Cable	g	26,00
Plug & Connectors	g	4,00
PCB	g	5,00
Transformer	g	13,00
Capacitors	g	4,00
Inductors	g	4,00
Other Electronic Components	g	4,00
Total	**g**	**92,00**

In Table 5.5, it is possible to appreciate the environmental and energy result according to the functional unit (Results/F.U.) and according to power generation (Results/W).

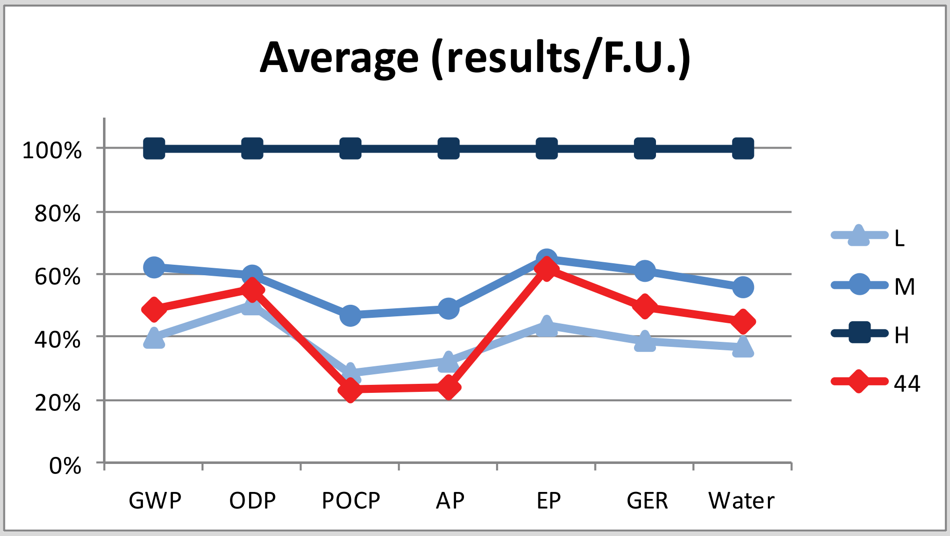
Table 5.5 - Type 2 subcategory b, 24W, 44 PSU environmental and energy result according to the functional unit and according to power generation.

Impact category	Unit	Results/F.U.	Results/W
GWP	kg CO2 eq	1,54	0,064
ODP	kg CFC-11 eq	1,1E-07	4,6E-09
POCP	kg C2H4	0,0024	0,00010
AP	kg SO2 eq	0,0193	0,00081
EP	kg PO4--- eq	0,0011	0,00004
GER	MJ	31,6	1,32
Water	kg	16,96	0,71

5.4.3 Power generation: a possible comparison

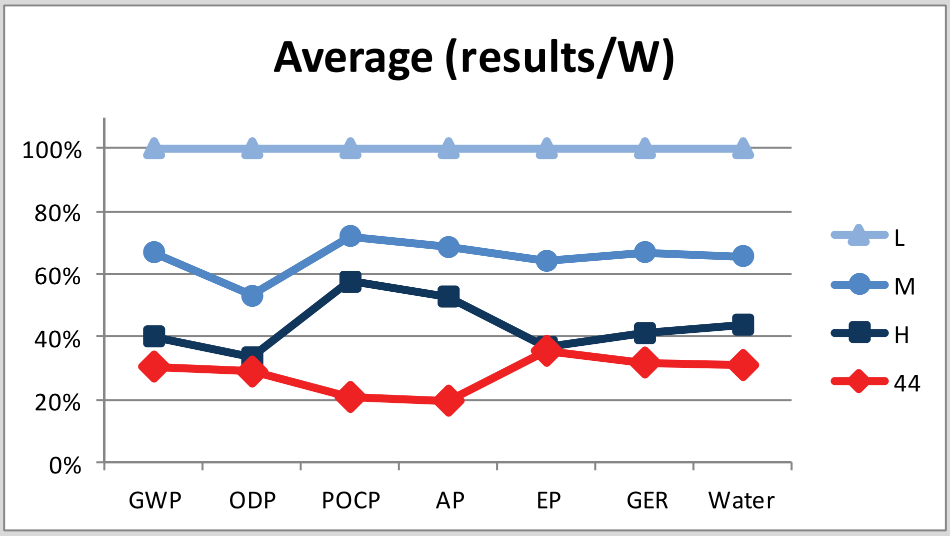
Eventually, the information gathered in Figure 5.13 and in Table 5.5 was organized together as presented in Figure 5.16.

Figure 5.16 - Average value for Low, Medium, High and 44 PSU impact categories, according to the functional unit.



The information gathered in Figure 5.14 and in Table 5.5 was organized together as presented in Figure 5.17.

Figure 5.17 - Average value for Low, Medium, High and 44 PSU impact categories, according to power generation.



6 *Preliminary conclusions*

The present study was developed by Politecnico di Torino in order to describe the environmental and energy performance of different PSUs for customer premises equipment, by means of the Life Cycle Thinking approach.

It is important to highlight that the considered PSUs were chosen among an entire population of the products analyzed in the present study in order to provide an overview of the different levels of the rated output power supplied to the equipment (here organized in three levels: Low, Medium and High Power); and within each level of the output power the choice was to select a "sample" composed by a small amount of products with different power outputs. The sample of the considered PSU was chosen according to the possibility of analyzing the influence of different weights, different dimensions and different electronic possibilities according to the apparatus to be powered. The aim was to establish a possible relationship among these characteristics and the environmental and energy performances.

The different power output levels of PSU were analyzed and data coming from the full LCA of a selected common power supply (44 PSUs) were considered for further comparison.

The following conclusions have to be taken into consideration within this specific context of the present study and cannot be used in general terms.

The following preliminary conclusions can be drawn:

- Environmental and energy impacts do not depend only on weight characteristics; the behavior is dependent on the different design choices, especially for electronics, and is at any rate different depending on the single impact category analyzed;
- Environmental and energy impacts do not depend only on output power; in some cases, high power PSU has very similar impacts in comparison to medium power PSUs. The same also applies to the comparison between the medium power and low power category; this demonstrates the importance of adopting accurate design choices (especially for electronics, but also for the plastics) to minimize the environmental burdens associated with the manufacturing phase of the single product;

- According to Figure 5.13, it is possible to appreciate an increasing trend of impact for each PSU group among the impact categories considered (higher impacts for High Power PSU); anyway, in Figure 5.14, this trend becomes reversed, if the maximum output power is taken as a reference for the normalization of the environmental results (lower impacts for the maximum output power of High Power PSU);
- In Chapter 5, the LCA interpretation of the environmental results is provided: most of the impacts are due to electronics in all cases; a detailed analysis of the energy efficiency during the use phase should be done in order to understand if the use of advanced electronic components is balanced by a higher efficiency when applied to the final CPE;
- Within the same impact category, it is always possible to identify one example of PSU coupling good use-performance as well as good environmental and energy performances. Depending on the single impact categories, the best in class for the single category can improve the performances of the worst one of a mean percentage around 25-30%, up to 50% in some specific cases. Again, this demonstrates the importance of adopting design rules optimizing the environmental aspects.

A more detailed analysis of the general up-described framework should be necessary in order to assess how environmental impacts depend on the design of electronics as well as on the design of the object (in terms of the material selected).

7 References

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- Energy Efficiency and Ecodesign requirements for a common power supply for home gateway, home networking equipment and end devices (HGI)
- EPD Supporting Annex B
- ISO 14025:2006
- ISO 14040:2006
- ISO 14044:2006
- www.ecoinvent.ch
- www.environdec.com

8 Acronyms & Symbols

- AP: Acidification Potential
- CED: Cumulative Energy Demand
- EP: Eutrophication Potential
- EPD: Environmental Product Declaration
- ETSI: European Telecommunications Standards Institute
- F.U.: Functional Unit
- GCV: Gross Calorific Value
- GER: Gross Energy Requirement
- GHG: Greenhouse Gases

- GWP: Global Warming Potential
- HGI: Home Gateway Initiative
- LCI: Life Cycle Inventory
- LCIA: Life Cycle Impact Assessment
- ODP: Ozone Depletion Potential
- POCP: Photochemical Ozone Creation Potential
- PSU: Power Supply Unit

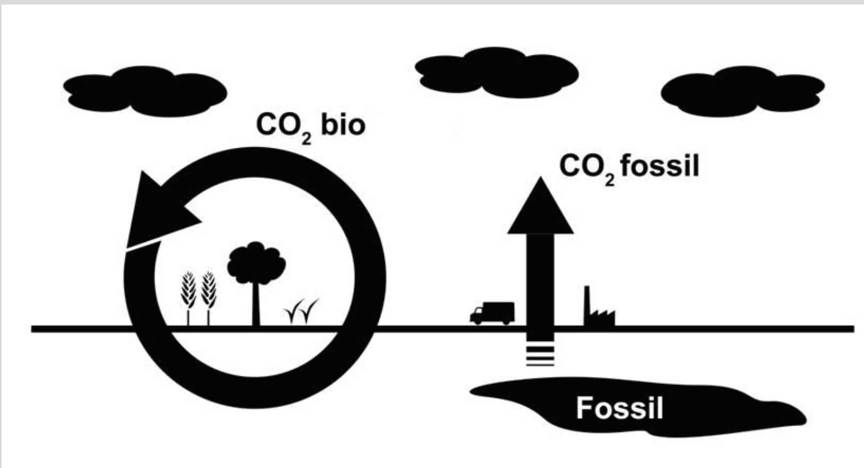
9 *Appendix: Environmental Indicators*

9.1 Environmental indicators

The impact categories are calculated by means of the following indicators, in which conversion and characterization factors used for converting LCI data into resource use and potential environmental impacts come from the EPD Regulation Supporting Annex B (www.environdec.com):

- **GWP**, Global Warming Potential for the time horizon 100 years, is an impact category that groups greenhouse gases (GHG) and calculates their total impact in terms of kg CO_2 equivalent, according to the *IPCC (Intergovernmental Panel on Climatic Change)* reference document, *Climate Change 2007*; the indicator has been split into:
  - ◊ GWP_{100} Fossil: the contribution of GHG air emission derived by fossil fuel combustion and process;
  - ◊ GWP Bio (+): the contribution of GHG air emission derived by biofuel/biomass combustion and process;
  - ◊ GWP Bio (−): the contribution (credit) of organic carbon embodied in biomass (see **Figure** 9.1), excluding packaging;

Figure 9.1 - Differences between GWP Bio and GWP Fossil. Carbon storage may arise during the life-cycle of a product when biogenic carbon forms part or all of a product or when atmospheric carbon is taken up by a product over its life cycle



According to the GHG Protocol Initiative, Product Life Cycle Accounting and Reporting Standard (2010), carbon storage should not be included as a carbon credit in the GHG inventory; however, the carbon storage potential of a product should be reported separately, as identified in the reporting requirements.

- **OPD,** Ozone Depletion Potential, that calculates the degradation and depletion of the ozone layer in the stratosphere for the time horizon 20 years, in terms of trichlorofluoromethane, or CFC-11 equivalent, in accordance with the reference document *Solomon & Albritton, 1992, in Nordic Guidelines on Life-Cycle Assessment, Nord 1995:20, Nordic council of Ministers, Copenhagen*;
- **AP**, Acidification Potential, in terms of kg SO_2 equivalent (ref. *CML, 1999; Huijbregts, 1999; average Europe total, A&B*);
- **EP**, Eutrophication Potential, in kg PO_4^{3-} equivalent (*ref. CML, 1999; Heijungs et al. 1992*); Eutrophication includes all impacts due to excessive levels of macronutrients in the environment caused by emissions of nutrients to air, water and soil;
- **POCP**, Photochemical Ozone Creation Potential, that calculates the possibility of creating ground-level ozone; it is expressed in kg C_2H_4 equivalent in accordance with the documents *POCP (Jenkin & Hayman, 1999; Derwent et al. 1998; high NOx); baseline (CML, 1999)*;
- **GER**, Gross Energy Requirement, that calculates the total energy consumption of the process; the energy requirement has been split into Renewable resources, Feedstock and Non-Renewable energy consumption; values of resources with energy content expressed in MJ/functional unit making use of the Gross Calorific Values, according to *OECD, IEA, Eurostat "Energy Statistics Manual" 2004*;
- **Water Use,** which calculates the total water consumption of the entire life cycle, in kg.

The environmental analysis of a subset of the power supplies considered for the study has been performed. It has been started from a mass balance quantifying the amount of plastic materials and electronics used to manufacture the various devices. A number of power supplies have been considered having in mind to distinguish three main categories depending on the nameplate output power they can provide. In addition, different technologies have been considered within the single category (switching or linear PS) to evaluate the different environmental burdens associated to them and verify if there is a proportional relationship between the total weight and the associated environmental impact (obviously, excluding any environmental consideration related to the energy efficiency of the single technology). Starting from the mass balance, a Life Cycle Assessment analysis has been elaborated, thanks to a devoted database enabling the association between the uses of a specific material/electronic part with its intrinsic environmental impact. The final results are presented and they refer to a number of impact assessment indexes, as indicated by ISO 14040 standard series. A summary of the main results obtained during this part of the study, carried out in cooperation with Politecnico di Torino, is presented.

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