



**GeSI**  
GLOBAL e-SUSTAINABILITY  
INITIATIVE

# An Energy-aware Survey on ICT Device Power Supplies

***Flavio CUCCHIETTI***



GeSI  
GLOBAL e-SUSTAINABILITY  
INITIATIVE



DIST -  
University  
of Genoa

## Analysis developed by DIST - TNT Lab

**Prof. Raffaele Bolla**

Dr. Roberto Bruschi

Dr. Luca D'Agostino

***Presented at the ITU-T Study Group5 - April 2012 meeting***

- The **Department of Communications, Computer and Systems Science (DIST)** is one of the largest departments of the **University of Genoa** and it is active in all aspects of Information Technology.
- **Prof. R. Bolla leads the Telecommunication Networks and Telematics (TNT) Lab.** which is active on the **“technologies for the Future Internet”** with a specific focus on **Green Networking**
  - **“low Energy CONsumption NETworks - ECONET”** (Prof. R. Bolla is the Coordinator of the entire project), FP7 Integrated Project .
  - **“Towards real Energy-efficient Network Design- TREND”** (Prof. R. Bolla is the PI of the Genoa RU), FP7 Network of Excellence.
  - **FINE2** Future InterNet Energy Efficiency (Italy-USA project with the University of South Florida and Portland State University)

# Outline

- General data
  - Sources
  - Categories definition
- Measurements
  - Connectors
  - Name plate output voltage
  - Mechanical Features:
    - Weights and Volumes
    - Estimation on use of resources and e-waste
  - Electrical Features
    - No load measurements
    - Energy efficiency
    - Analytical analysis
    - Out voltage
    - Mass balance and environmental considerations
- Conclusions

# Source of Data

- Energy Star web-site
  - “External Power Supplies AC-DC Product List; December 16, 2010”
- Manufacturers websites (HP, DELL, IBM, Delta, LITE-ON, ... )
- Conference proceedings, market studies and standardization documents
- **Most data have been acquired through direct analysis on a wide set of more than 300 power supplies. Among these, over 200 have been analyzed with respect to their electrical characteristics.**
  - The considered equipment are: single output AC/DC adapters, rated above the USB specifications (e.g., 5 V and 1,5 A).
  - The devices herein analyzed, together with the set of chargers which were analyzed in the 2011 GeSI report (<http://www.gesi.org/LinkClick.aspx?fileticket=Hl2q6rLE6sl%3D&tabid=60>), provide a complete overview on the external power supply market.

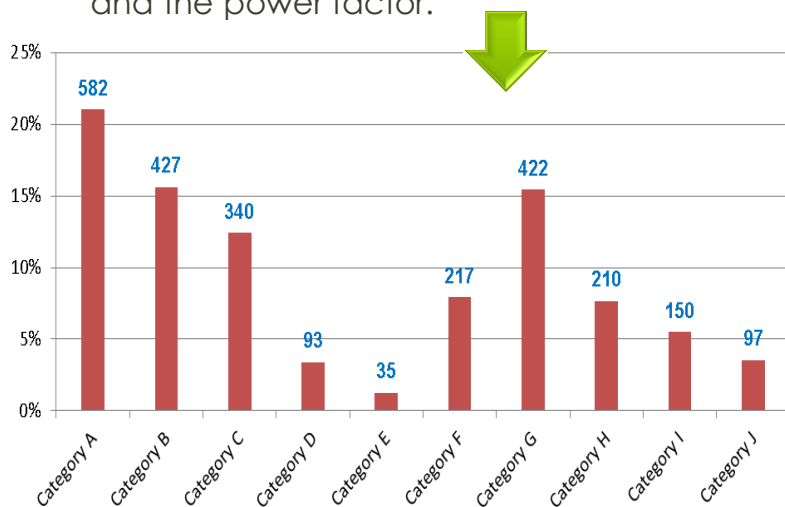
# Categories

- The equipments analyzed have been subdivided into a set of categories (V, A and W).
  - The categories have been aligned with the categories that are being discussed within standardization bodies (ITU-T, ETSI, etc)
  - 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.
- 
- **Category A:** Voltage < 12 V, Current: any, Power: any;
  - **Category B:** Voltage = 12V, Current  $\leq$  1 A, Power: any;
  - **Category C:** Voltage = 12V, 1 A < Current  $\leq$  2 A, Power: any;
  - **Category D:** Voltage = 12V, 2 A < Current  $\leq$  3.5 A, Power: any;
  - **Category E:** Voltage = 12V, 3.5 A < Current  $\leq$  5 A, Power: any;
  - **Category F:** 12 V < Voltage < 18V, Current: any, Power: any;
  - **Category G:** Voltage  $\geq$  18V, Current: any, Power  $\leq$  45W;
  - **Category H:** Voltage  $\geq$  18V, Current: any, 45W < Power  $\leq$  70 W;
  - **Category I:** Voltage  $\geq$  18V, Current: any, 70W < Power  $\leq$  95W;
  - **Category J:** Voltage  $\geq$  18V, Current: any, 95W < Power  $\leq$  120 W;

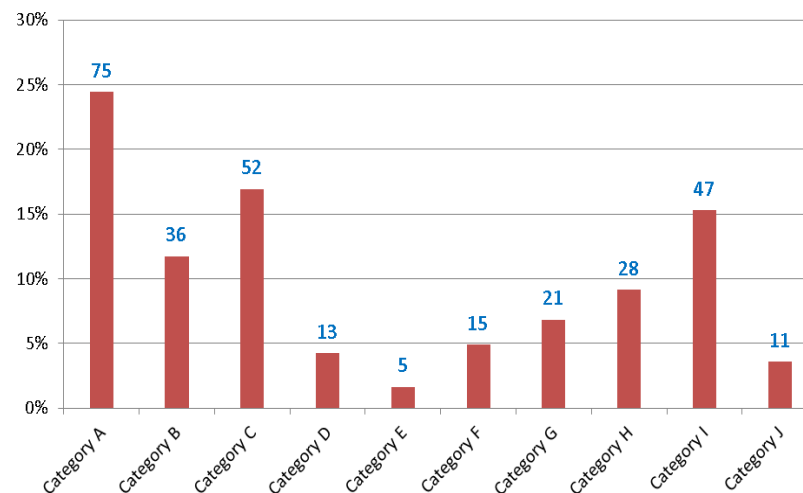
# Categories Impact

## Energy star data

- The impact of the categories with respect to the equipments available in the market, has been evaluated against the most recent power supply data list which was released by the Energy Star Program (ESP) and contains over 2743 models.
- The parameter considered were: the name plate electrical characteristics, the no-load efficiency, the average active efficiency and the power factor.



## Considered devices



**A:** < 12 V  
**B:** 12V,  $\leq 1$  A  
**C:** 12V,  $1$  A < I  $\leq 2$  A  
**D:** 12V,  $2$  A < I  $\leq 3.5$  A  
**E:** 12V,  $3.5$  A < I  $\leq 5$  A  
**F:** >12V  $\div$  18V  
**G:**  $\geq 18$ V, Power  $\leq 45$ W;  
**H:**  $\geq 18$ V,  $45$ W  $\div$  70 W;  
**I:**  $\geq 18$ V,  $70$ W  $\div$  95W;  
**J:**  $\geq 18$ V,  $95$ W  $\div$  120 W;

- The same impact analysis has been realized on the considered devices
- Categories **D**, **E** and **J** are near or below the 5% in both graphs

# Energy efficiency measurements

- Measurement campaign has been performed on **300 devices** for the mechanical and name plate characteristics, and on **200 devices** for the electrical ones.
  - **The devices were selected in order to represent the most recent and widespread models** ranging from power supplies for small home appliances, modems, STBs, networking equipment up to displays and laptops.
  - Note that for some devices, different replicas have been analyzed to verify their performance repeatability and to compare among compatible different versions.
- The following aspects have been analyzed:
  - **Mechanical characteristics: weight and volumes;**
  - **Electrical features:**
    - No load,
    - Efficiency vs. load
    - Power factor vs. load
    - Voltage vs. load
  - **Correlation between mechanical and electrical characteristics**
  - **Mass Balance and environmental characteristics**

# Analyzed equipment & nameplate data

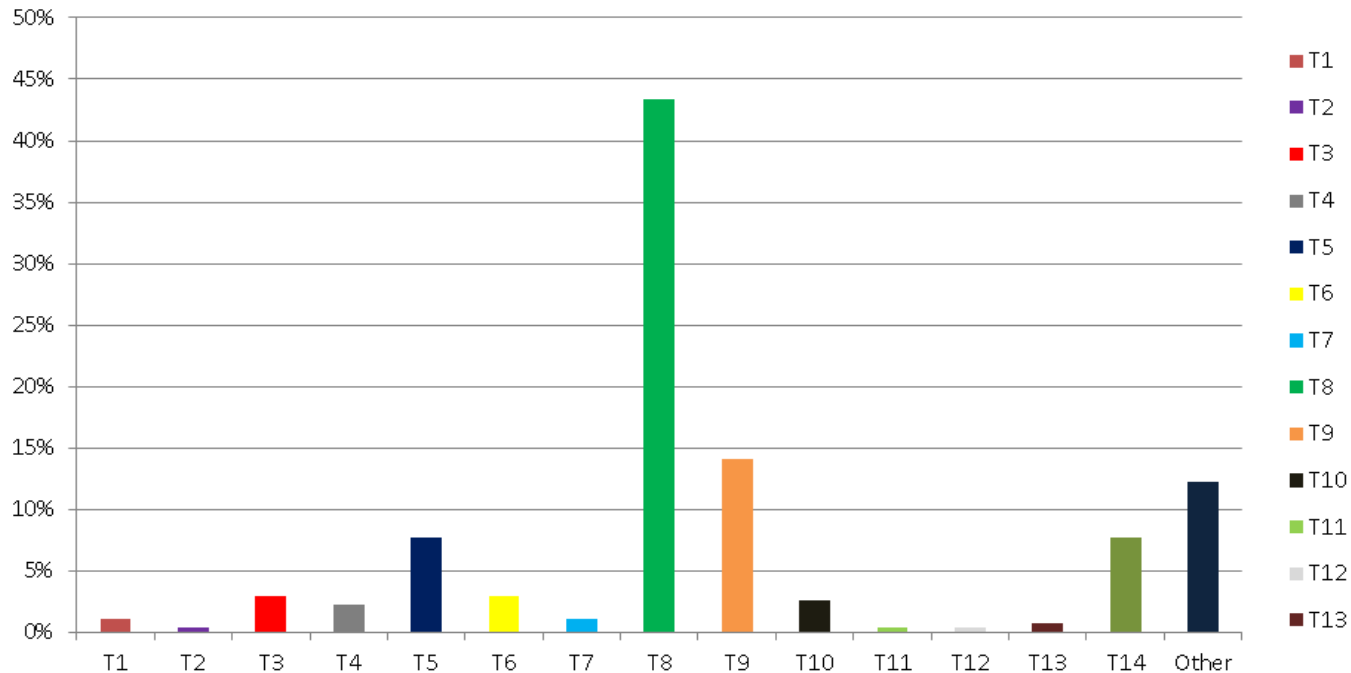
N.	Output voltage [V]	Output current [A]	Rated output power [W]	Safety class	Energy star class	Weight without cable (g)	Weight with cable (g)	Volume (cm <sup>3</sup> )	Connector's type	Made in	Detachable main cable (connector)	mW/cm <sup>3</sup>	mW/g
207	12	2	24	2	V	145	-	287	I	CHINA	NO	84	166
251	12	2	24	2	V	155	-	276	H	CHINA	NO	87	155
252	12	2	24	2	V	155	-	276	H	CHINA	NO	87	155
321	12	2	24	2	-	179	-	131	H	CHINA	NO	183	134
317	12	2.1	25.2	2	-	157	-	156	H	ITALIA	NO	162	161
41	12	2.5	30	2	-	248	-	205	I	CHINA	C7-C8	147	121
42	12	2.5	30	2	IV	163	240	134	H	CHINA	C7-C8	225	184
48	12	2.5	30	2	IV	223	-	390	I	CHINA	NO	77	135
187	12	2.5	30	2	IV	200	298	166	C	CHINA	C7-C8	181	150
148	12	3	36	2	-	290	377	222	H	CHINA	C7-C8	162	124
178	12	3	36	2	-	214	-	133	I	CHINA	C7-C8	270	168
185	12	3	36	2	V	158	212	79	E	CHINA	C7-C8	454	228
206	12	3	36	2	-	162	267	78	E	CHINA	C7-C8	463	222
357	12	3	36	2	IV	151	200	76	E	CHINA	C7-C8	476	238
15	12	3.3	39.6	1	-	312	-	266	H	THAILAND	C13-C14	149	127
121	12	3.3	39.6	1	-	309	-	257	H	THAILAND	C13-C14	154	128
147	12	3.3	39.6	1	-	309	-	257	H	THAILAND	C13-C14	154	128
141	12	3.7	44.4	2	-	338	440	372	Proprietary	CHINA	NO	119	131
142	12	3.7	44.4	2	-	338	440	372	Proprietary	CHINA	NO	119	131
24	12	3.75	45	1	-	309	-	291	I	CHINA	C13-C14	155	146
87	12	4.2	50	1	-	325	-	330	H	-	NO	152	154
123	12	4.16	50	1	-	253	-	219	I	CHINA	C13-C14	229	198
140	12	14.2	170.4	2	-	840	979	1246	Proprietary	CHINA	C17-C18	137	203
153	13	0.625	8.1	2	-	543	-	445	F	CHINA	NO	18	15
96	15	-	5.4	2	V	62	-	78	Proprietary	CHINA	NO	69	87
301	15	0.5	7.5	2	-	83	-	88	H	CHINA	NO	86	90
11	15	0.8	12	2	-	132	-	126	H	CHINA	NO	95	91
37	15	0.8	12	2	V	100	-	153	H	CHINA	NO	79	120
62	15	0.8	12	2	-	138	-	227	H	CHINA	NO	53	87
9	15	1	15	2	-	453	-	387	H	-	NO	39	33
49	15	2	18	2	IV	124	-	219	H	CHINA	NO	82	145
51	15	1.2	18	2	-	149	-	277	H	CHINA	NO	65	121

Snapshot of a sub-set of equipment and parameters acquired



# DC connectors

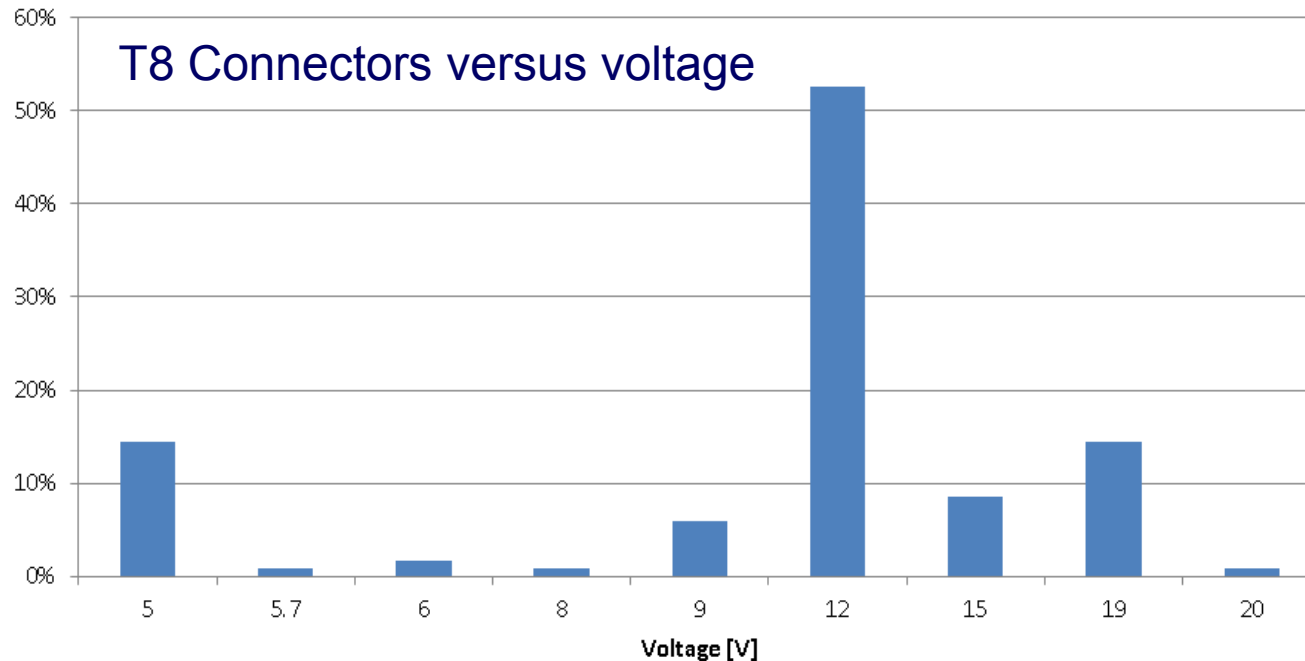
- Used connector percentage versus connector types.



- The five most used connectors represent the 86 % of the total
- Nearly all connectors are barrel type
- It looks that a kind of de facto standardization is taking place
- There is a problem of equipment with the same connectors and different voltage/current that create risks of mis-operation of equipment and damage

# DC connectors

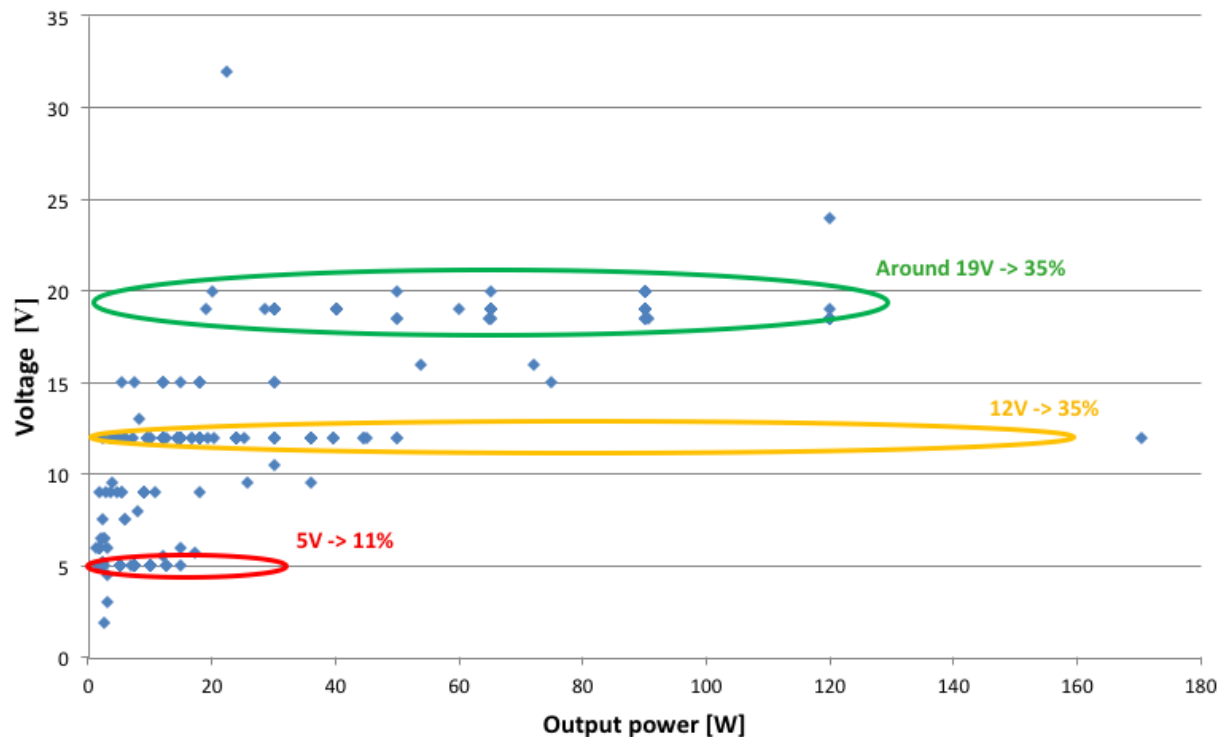
- Used connector percentage versus connector types.



- The five most used connectors represent the 86 % of the total.
- Nearly all connectors are barrel type.
- It looks that a kind of de facto standardization is taking place.
- There is a problem of equipment with the same connectors and different voltage/current that create risks of mis-operation of equipment and damage.**

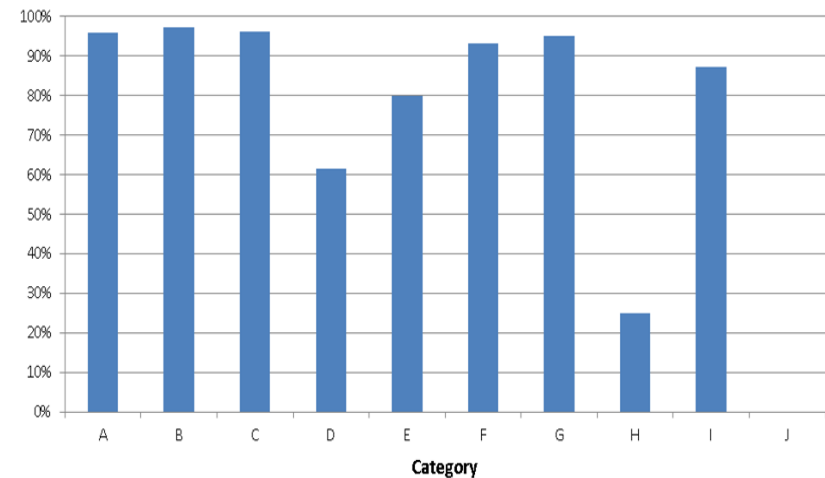
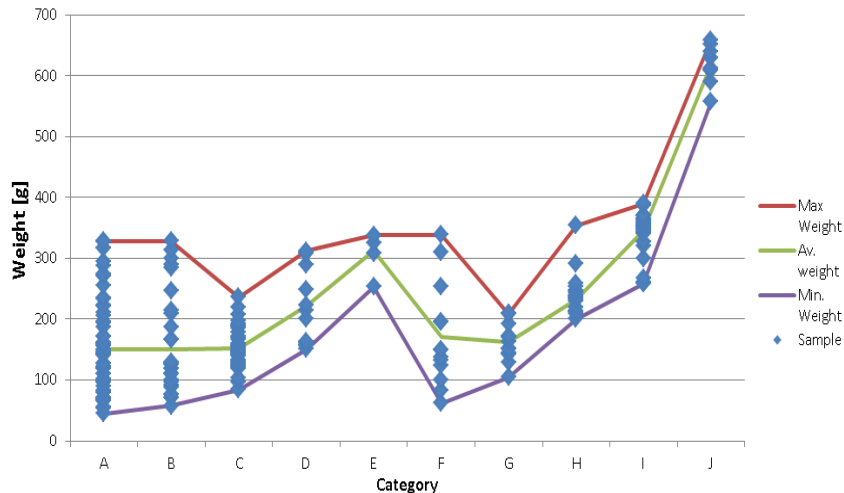
# Name Plate Output Voltage

- 81% of the devices are in the 5, 12 or 19 voltage ranges.



# Weights of the adapters

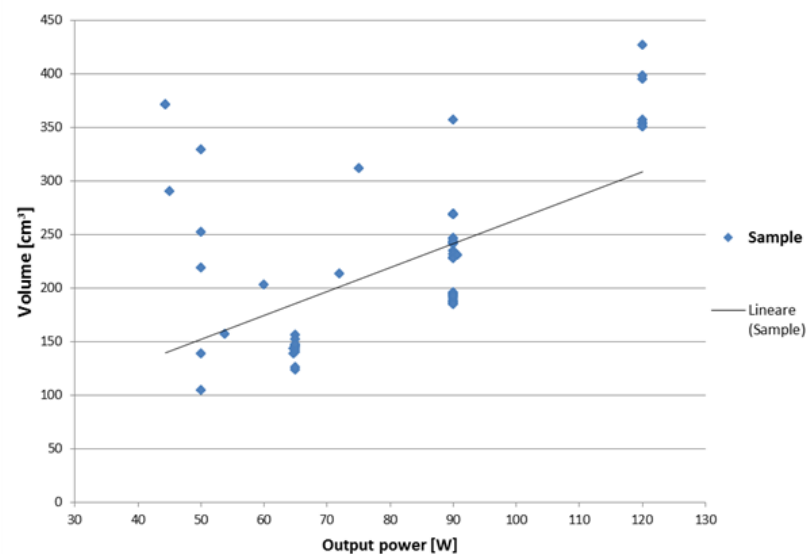
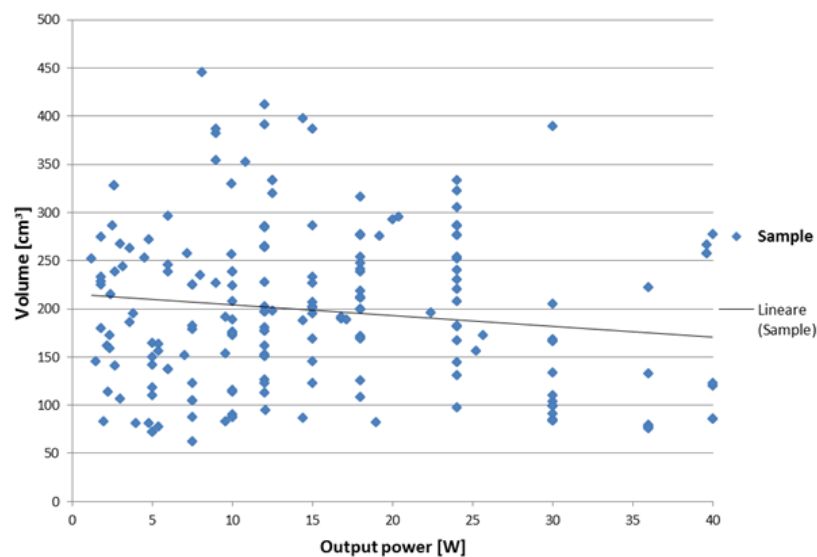
A: < 12 V  
 B: 12V, ≤ 1 A  
 C: 12V, 1 A < I ≤ 2 A  
 D: 12V, 2 A < I ≤ 3.5 A  
 E: 12V, 3.5 A < I ≤ 5 A  
 F: >12V ÷ 18V  
 G: ≥ 18V, Power ≤ 45W;  
 H: ≥ 18V, 45W ÷ 70 W;  
 I: ≥ 18V, 70W ÷ 95W;  
 J: ≥ 18V, 95W ÷ 120 W;



- Weights of the adapters without their mains cable, versus categories. For each category, **maximum, minimum and average weights** have been highlighted
- This graph shows the percentage of power supplies **that weigh more than 120% of the best in their category**
- There are large differences among equivalent devices: **lots of unnecessary use of resources and e-waste**
- Some categories show **even more than 300%** difference among best and worst devices.
- Most the current devices look not optimized at all in this respect
  - There is great potential to reduce resource utilization and E-Waste.**

# Volumes

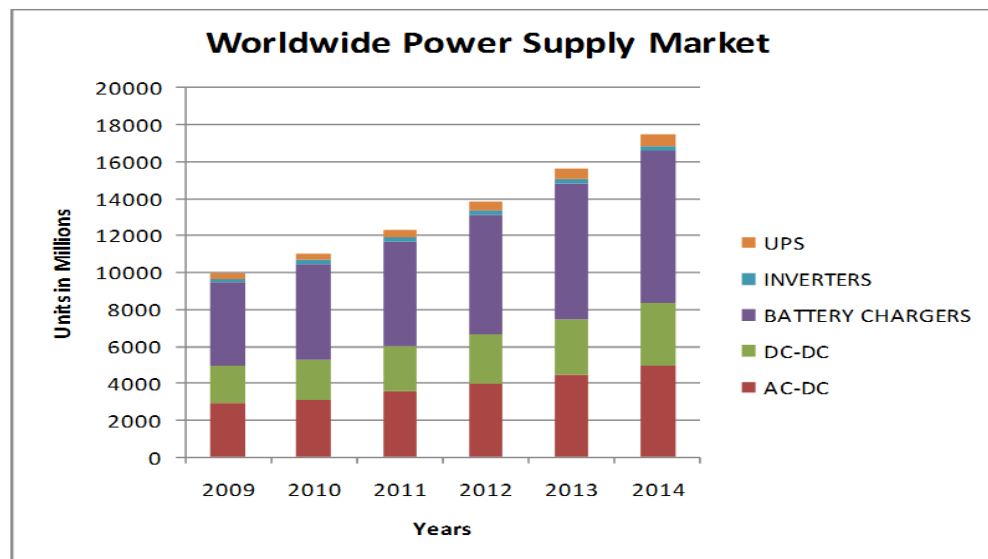
- Volumes of the adapters against their declared power. A linear trend line has been included in the graph



- Up to fifty watts, the volumes are spread along large range of values and do not seem correlated to the output power.

# Estimation on use of resources and e-waste

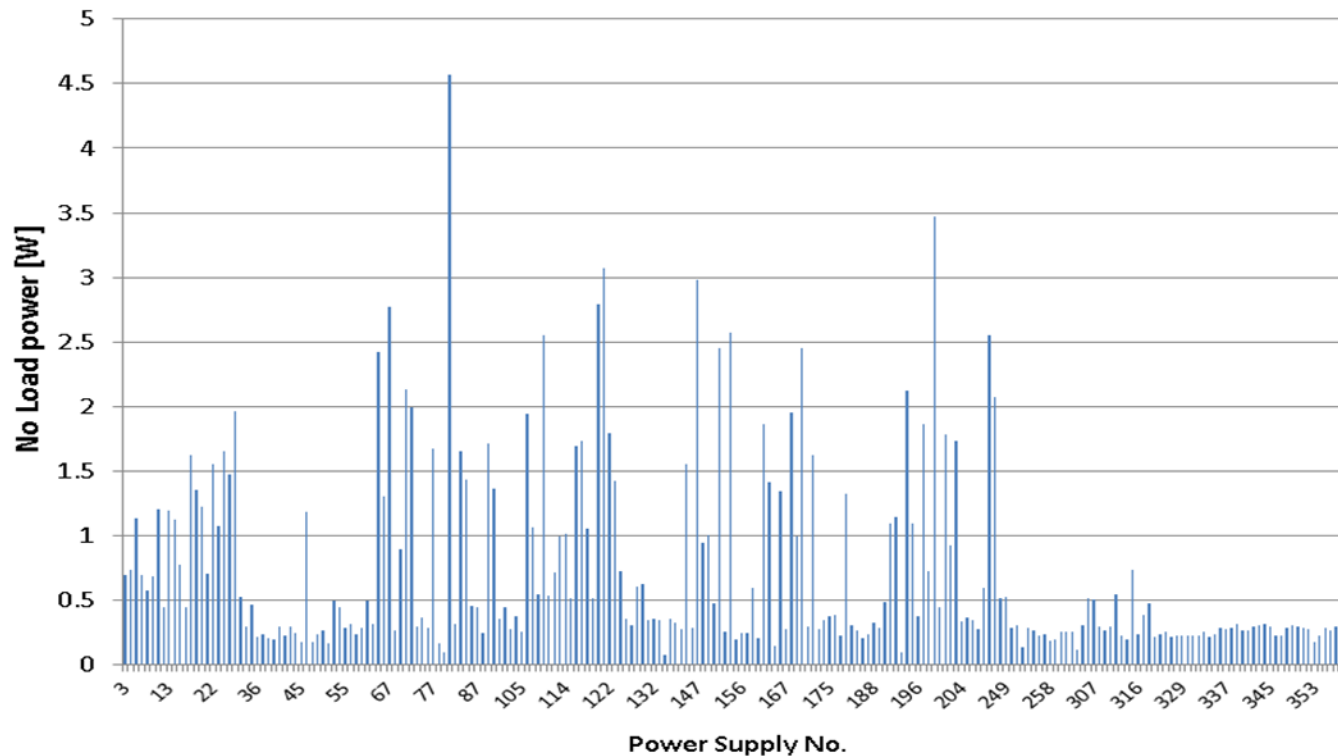
- Many billions of new EPSs every year.
- Amount of material (and e-waste) estimated being about **1 million tons**.
- E-waste can be estimated to be at least half a million tons per year.**



Source: Selantek Power Supply Report 2010

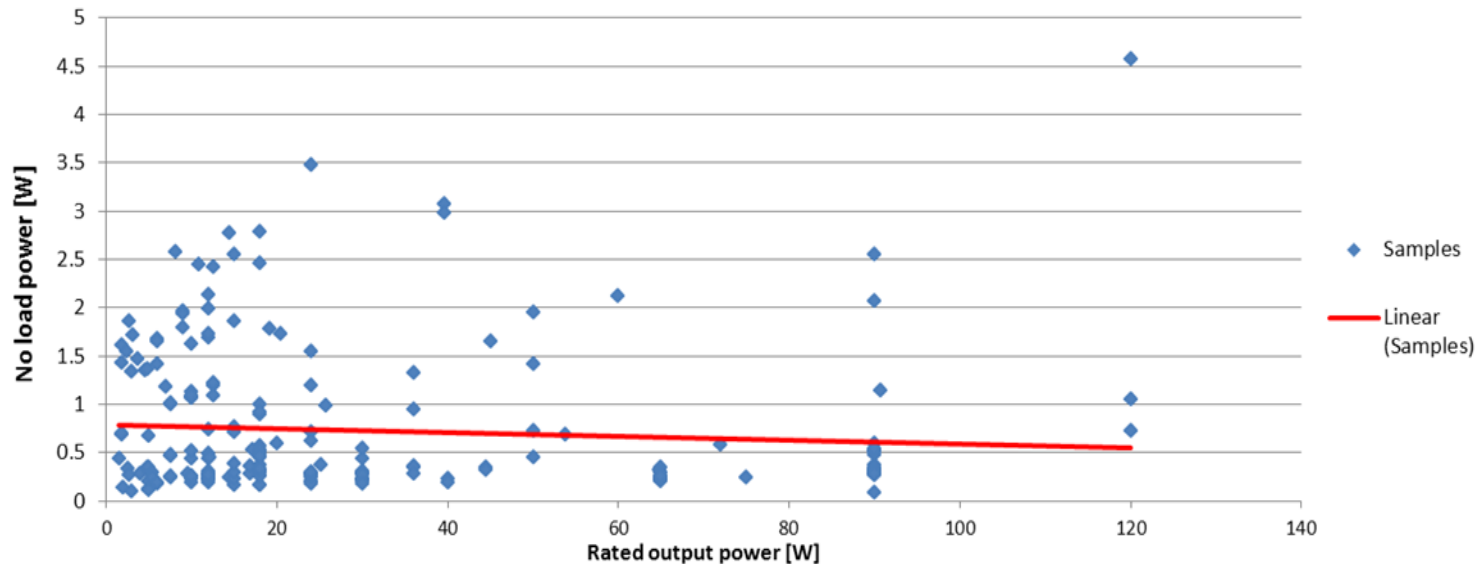
- A **huge quantity of material could be saved**. At least half of it could be expected to be saved if a standardized solution was available.
- Weight is directly linked to environmental impact, so manufacturers should optimize their products, aligning them with the best (lightest) in the corresponding category as **it could reduce the use of resources (and the e-waste) more than 300 thousand tons per year**.

# No Load

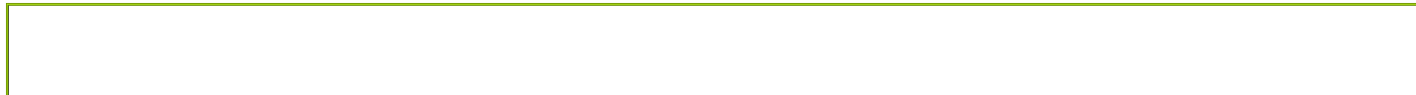


- The range of efficiency is quite wide. Many very good (low) values below 0.1–0.15 W, but very inefficient equipment (even higher than 2W) are frequent too.
- Mobile charger have shown is possible to have even better efficiency (< 30 mW).

# No Load vs Rated Output Power

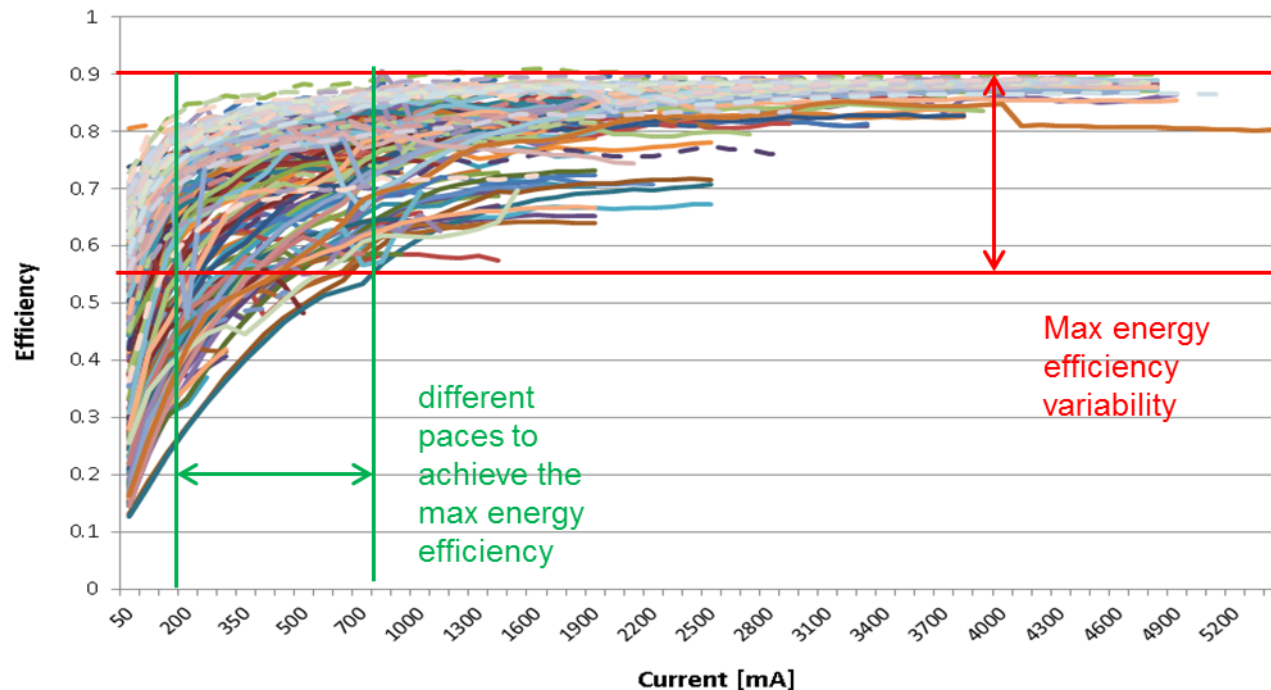


- No correlation between no-load performance and output power.
  - It can be noted how many 90W adapters show very good no load consumptions and one of them is among the best of the tested equipment.
  - On the contrary, high no-load absorptions are present at low/medium power rates.





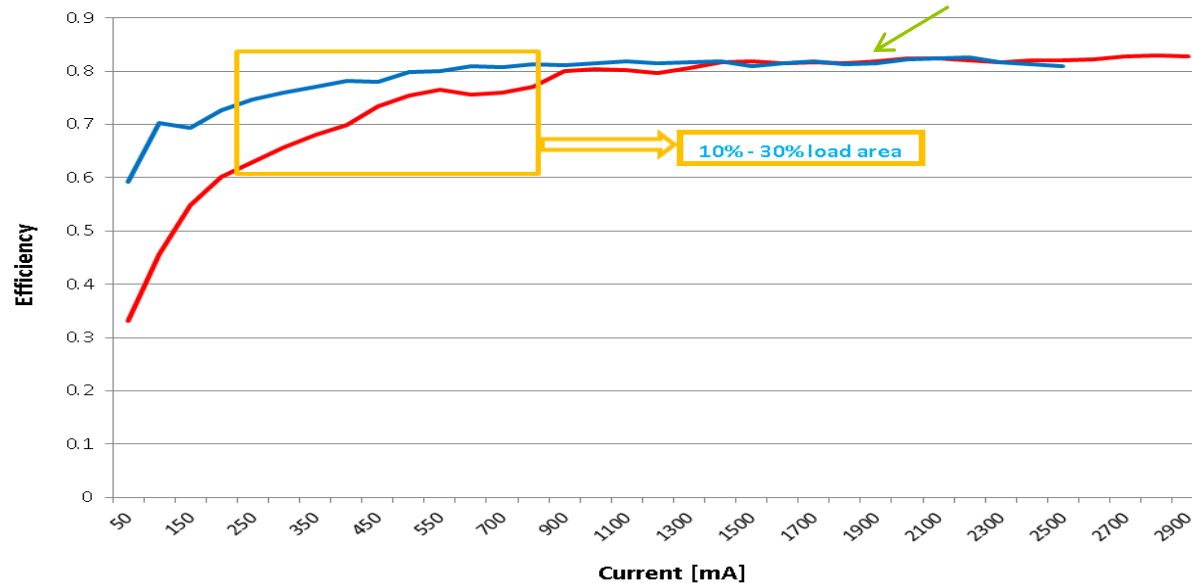
# Energy Efficiency at Variable Loads



- Energy efficiency curves with variable loads for all the analyzed adapters.
- Each power supply has been tested up to its declared maximum value of DC current.

# Comparison among equivalent equipment

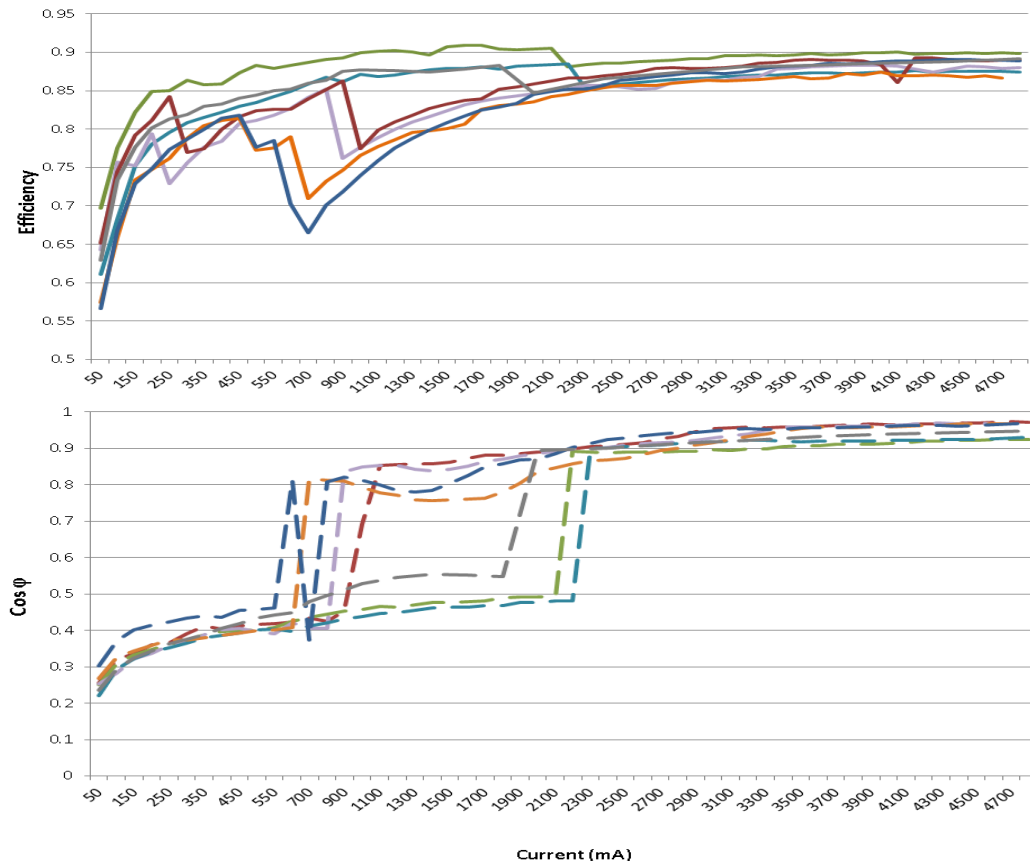
Two EPSs with the same average ES consumption



- Even if the Energy Star calculation of the average energy efficiencies (mean of the efficiencies at 25%, 50%, 75% and 100% of the rated load) gives very similar results, the differences in the efficiency behavior are often clearly noticeable.
- The gap in the range up to the 20-30% of the maximum load can be 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.

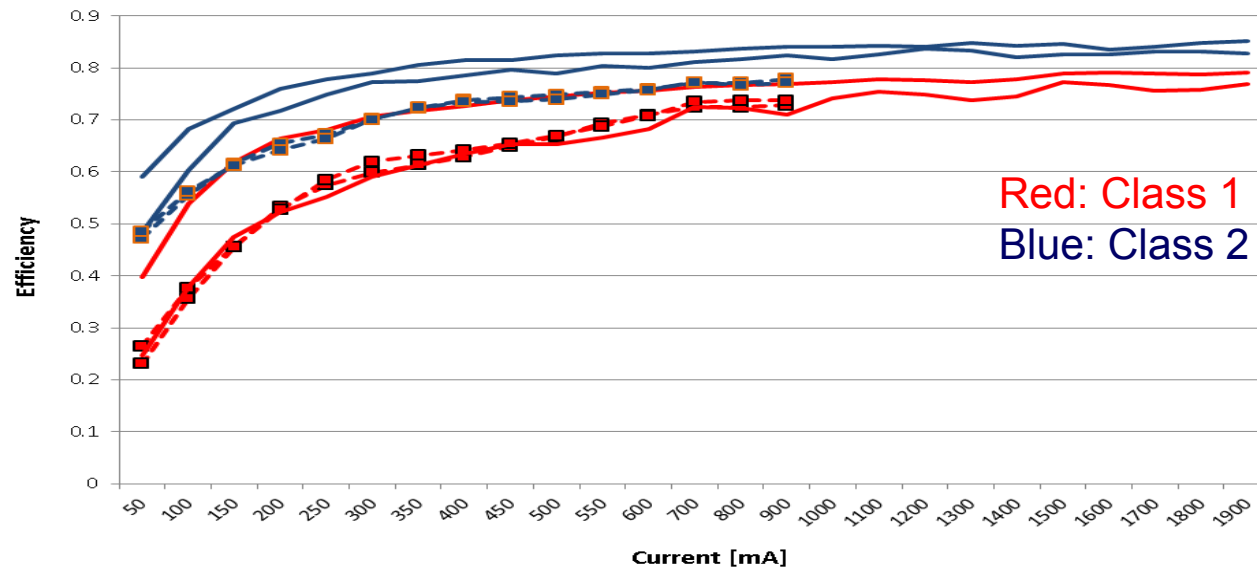
# Power factor vs. load and efficiency

- Regulation require power factor correction for higher power EPSs (>75-100W). The power factor is verified in full load condition.
- Almost every EPS with a high power factor (more than 0.8) has a much poorer power factor when operating at lower power.
- Efficiency and Cos  $\phi$  have been coupled to show the correlation between them
- Increased power factor comes at a cost of reduced efficiency (3-10%)



- 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 the electrical network with good power factor.
- Power Factor Correction shows to reduce the EPS's efficiency. The cost (less efficiency) / benefit (higher power factor) should be evaluated.**

# Correlation between safety class and efficiency



- The vast majority of the equipment analyzed belongs to safety class 2.
- Safety Class 2 EPSs have shown better efficiency.

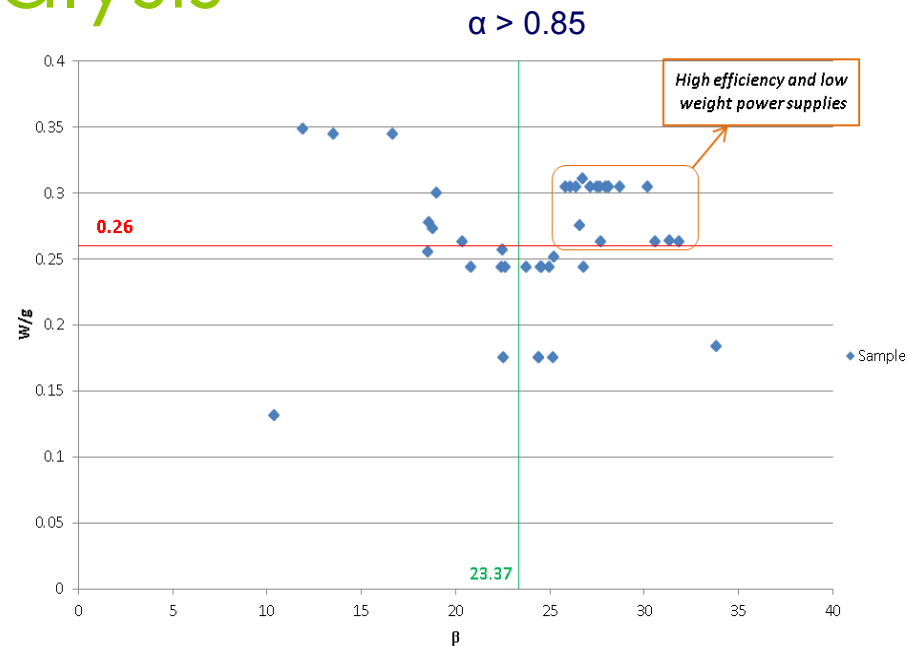
**Considering the: savings of material, increased efficiency, better compatibility of the class 2 mains connectors (2 pins) and increased safety for clients, it might be advisable the complete switch-over to this kind of solution/connectors/cables.**

# 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:

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

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

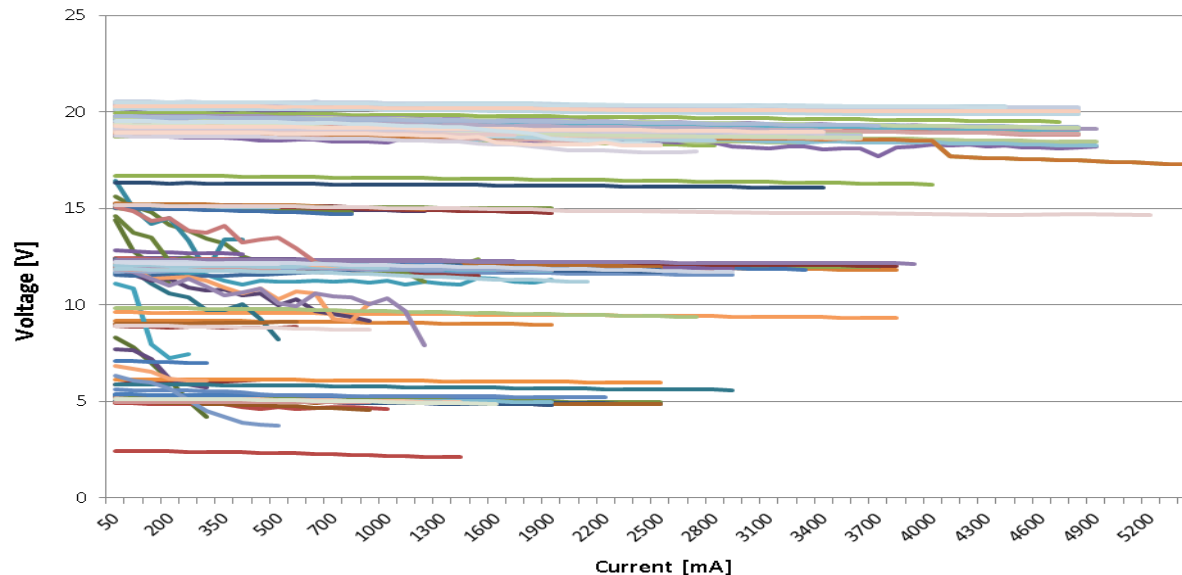


- For example, for having an efficiency correspondent to the 97% of a level for  $I > 150$  mA,  $\beta$  values must be greater than 23.37.
- The analytical analysis with alpha and beta parameters indicates that **only the 24% of the power supplies reach its efficiency target value** at low output current. 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.**

**A good compromise between weight and efficiency can be reached. This suggests again the opportunity of design improvements for large part of the current devices.**

# Output voltage

DC voltage measurement at variable output load



- A subset of the analyzed adapters shows, low loads voltages much higher than what declared.

**This could create troubles for the connected devices, especially when the voltage value is far higher than the declared. In general, the ratings declared in the nameplate are expected to be accurate, and represent the real features of the power supply.**

# Mass balance and environmental considerations

## Global Warming Potential

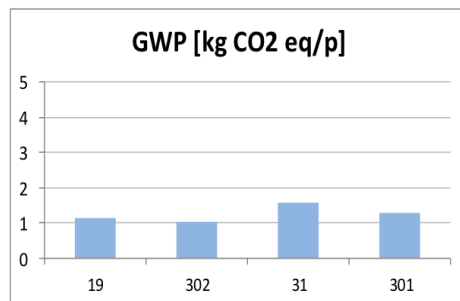


Figure 1: Low Power PSU GWP results

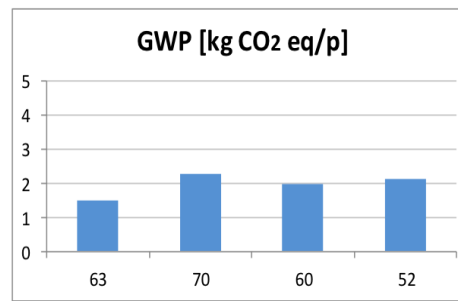


Figure 2: Medium Power PSU GWP results.

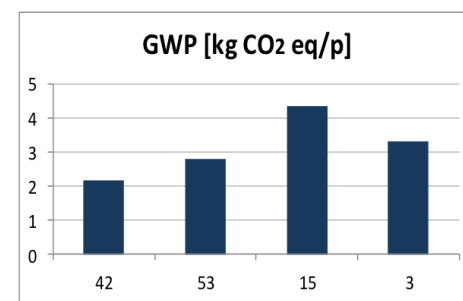


Figure 3: High Power PSU GWP results.

- Environmental and energy impacts do not depend only on weight characteristics;
- Environmental and energetic impacts do not depend only on output power
- 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.



GeSI  
GLOBAL e-SUSTAINABILITY  
INITIATIVE



DIST -  
University  
of Genoa

# Conclusions

- A wide analysis has been performed on a large set (>300) of commercially available external power supplies to assist the standardization activities within ITU-T SG5 (L.1000 phase 2). Mechanical, electrical and environmental characteristics have been evaluated and correlation and statistics have been developed in this regard.
- The main results of this study are:
  - **Categories** – to better analyze and compare the large amount of acquired data the set of adapters have been divided in 10 categories with different electrical characteristics (V, I and W), aligned with the categories that are being discussed within standardization bodies (ITU-T, ETSI, HGI, IEC ...).
    - The results are in **very good agreement with those categories and are gathered around 5, 12 and 19V.**
    - **Only 47% have an ES label.** That label is found very seldom on lower power adapter (< 40W).
      - This point suggests the presence of a serious problem as most EPSs are low power ones.
  - **DC Connectors** – **nearly all connectors are barrel type and the five most used connectors represent 86% of the total.**
    - Problem - The same connector is often used on power supplies with different voltage and current creating risks of mis-operation of equipment and damage.
  - **Weight/volume** – **Up to the 300% of difference among best and worst device: Lots of unnecessary use of resources and e-waste.** Below 50W, no correlation between weights and volume with respect to the rated power. Weight is expected to be the parameter more correlated to the environmental impact of the power supplies.
    - 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 of electronics of EPSs is 1 million tons per year and is growing.  
**At least half a million tons per year of it could be expected to be saved if a standardized solution was available.**



# Conclusions

- **No-load consumption** – high variance. **Some adapters have very low no-load consumption while many show quite higher values.** This could be linked to the lack of regulation enforcement. No dependence on the rated output current of power supplies.
- **Energy efficiency – a wide spread of efficiencies has been found.** Many adapters show very good efficiencies but many have very poor behavior. High power adapters show slightly better efficiency (5-10%).
  - **Often, equivalent EPSs show quite different efficiency at lower loads.** 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. 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.
  - **Many adapters having high power factor when at full load, actually show poor power factor at lower loads.** 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 the electrical network with good power factor
- **Power factor** - As the **measurements have shown negative correlation between the efficiency and power factor**, it should be evaluated which is the most important in order to obtain the best overall effect.
- **Safety class** - **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 the complete switch over to this kind of solution/connectors/cables.
- **Output Voltage** - **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. In general, the ratings declared in the nameplate are expected to be accurate, and represent the real features of the power supply.

# Conclusions

In general, there seems to be **little (if any) correlation among different rated power and the mechanical/electrical characteristics of chargers.**

The analysis highlights a **high variance between the best/lighter/smaller and the worst/heavier/bigger.**

**There is definitely a golden opportunity for improvement !**





GeSI  
GLOBAL e-SUSTAINABILITY  
INITIATIVE



DIST -  
University  
of Genoa

Any questions?

Thank you  
for your attention

[flavio.cucchietti@telecomitalia.it](mailto:flavio.cucchietti@telecomitalia.it)

The full report is available at:

<http://www.itu.int/ITU-T/climatechange/report-ict-device.html>

<http://www.gesi.org/ReportsPublications/tabid/60/Default.aspx>