An Energy-aware Survey on Mobile-Phone Chargers

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1. Introduction

Upon GeSI request, a wide analysis has been made on most of the commercially available mobile phone chargers and some small handheld devices to evaluate the correlation between charger's rated power and their mechanical/electrical characteristics. This survey has been focused both on data from manufacturers and on measurements on electrical and mechanical parameters.

This report is organized in two main sections. The first section "Analysis from public sources" reports the results derived from data available on the public sites of the different mobile terminal and power supply vendors. In this part both mechanical and electrical data have been considered and compared to characterize the current chargers and to find possible significant correlations among the different parameters taking into account energy efficiency aspects, but also some economic considerations. The second section is based on a set of measurements directly acquired on a sub-set of power supplies. Again two types of quantities have been measured: physical characteristics (e.g., weight and volumes) and electrical characteristics. The reported analysis is addressed to characterize the behavior of the tested objects in terms of energy efficiency and correlations among the different aspects, e.g. efficiency, weight and volume versus supplied power. . Those last parameters being directly correlated to the environmental impact of the equipment.

2. Analysis from Public Sources

This report is focused on 8 major manufacturers of mobile phones: Nokia, Apple, Sony-Ericsson, Samsung, Motorola, LG, HTC, Research In Motion (RIM). According to GartnerGartner, "Competitive Landscape: Mobile Devices, Worldwide, 3Q10," Nov. 2010, http://www.gartner.com/DisplayDocument?ref=clientFriendlyUrl&id=1465830., these brands represent today more than 80% of the market share of mobile phones. Table 2-1 reports the market shares of the considered brands, which were estimated from Gartner for the third quarter 2010. In the rest of this document, these shares will be used as weighting factors per brand.

The missing data were collected from other websites (i.e., mainly spare-parts' vendors) and directly from nameplates of real products.

The survey found information on 117 chargers. As outlined in Figure 2-1, LG declares to provide 63 charger models, which is a very large number with respect to the other brands. This number is probably due to the fact that LG website explicitly gives information on the complete set of chargers distributed word-wide (and then with different types of AC power plugs). Other manufactures typically deliver information only to chargers pertinent with the region/country where the Internet query was performed.

Nokia, Sony, Samsung and Motorola provide about 10 charger models each, while Apple, HTC and RIM less than 5 models.

market share [%]	
Nokia	36.7
Apple	2.3
Sony	4.3
Samsung	19.6
Motorola	4.5
LG	10.3
HTC	0.9
Blackberry	2.8
others	18.6

Table 2-1. Market shares in the third quarter 2010 for all the considered brands. Source: Gartner, "Competitive Landscape: Mobile Devices, Worldwide, 3Q10," Nov. 2010, http://www.gartner.com/DisplayDocument?ref=clientFriendlyUrl&id=1465830.

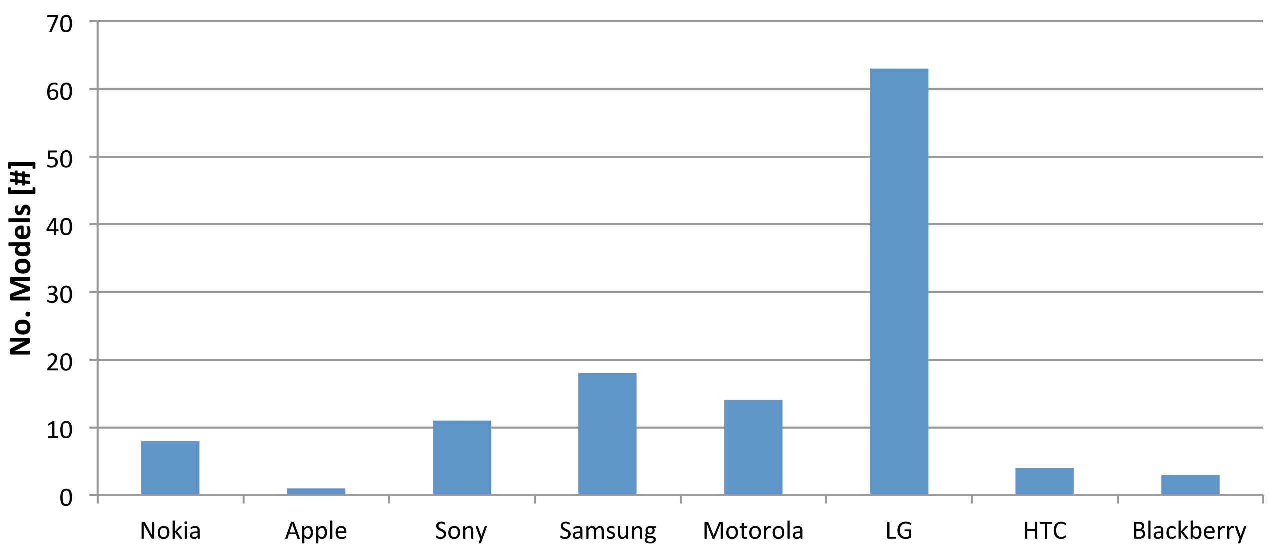


Figure 2-1. Number of charger models per manufacturer.

2.1.Mechanical Features

Figure 2-2 reports the percentage of how many chargers are already compatible with the USB standard. This information was expressed on a per brand basis. Observing this figure, It is evident that the almost totality of charger portfolio from some manufactures, namely Apple, Motorola, HTC and RIM, is already providing USB-based connectivity.

All manufacturers are already producing at least one USB compatible chargers.

About 40% and 50% of chargers from Samsung and Sony-Ericsson, respectively, have USB plugs, while only about 22% and 15% of charger models from Nokia and LG have this feature. Moreover, as far as Nokia is concerned, USB plugs appear to be available only in the most powerful chargers, which probably do not represent the most widespread products.

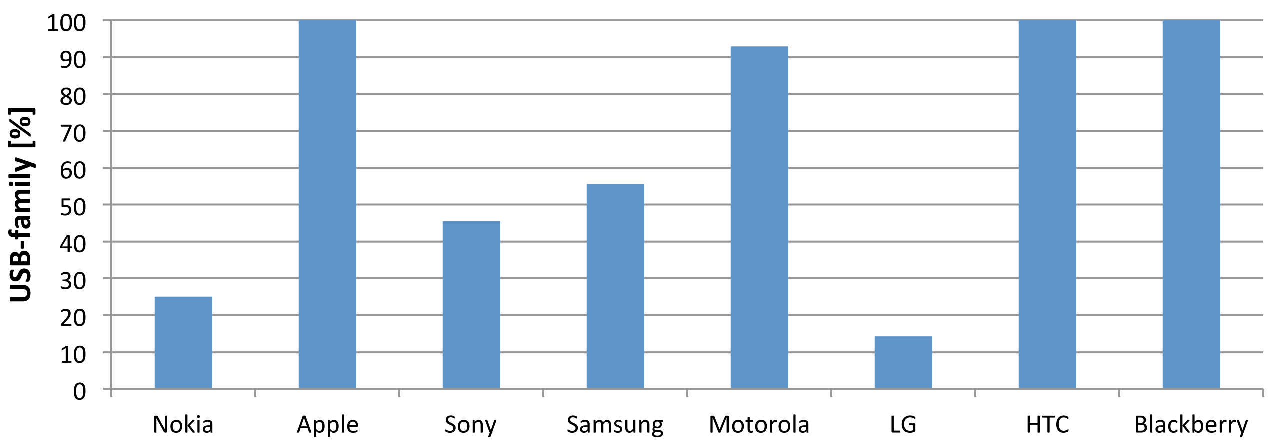


Figure 2-2. Percentage of chargers models per manufacturers, which are compatible with USB plugs.

2.2. Electrical Features

In this section, the electrical features of surveyed chargers are analyzed and discussed. Note that the information here reported comes from the "declared" data (i.e., on product nameplates), and not from real features. In this sense, it is worth noting that the nameplate features sometimes do not correspond to the measured parameters (see section Energy efficiency measurements of this document). In more detail, the most evident differences between nameplate declarations and real behaviors especially arise in the output DC voltage.

As previously sketched, in the current analysis each supplier has been weighted for its market share (see Table 2-1), while chargers from the same brand weight in a uniform way. This last assumption was performed because until now no information on the actual diffusion share of charger models were made available from vendors.

Figure 2-3 shows the distribution of the maximum output current provided from the considered charger set. These results clearly outline how the values of maximum DC current are mainly concentrated between 0.7 A and 0.89 A, while another peak is in the range between 0.5 A and 0.59 A. Chargers with low values of DC current appear to be produced only by Nokia and Sony-Ericsson. On the contrary, a larger number of suppliers provide chargers with an output current equal or higher than 1 A. Moreover, chargers with these highest currents usually appear to be the most recent models in the market.

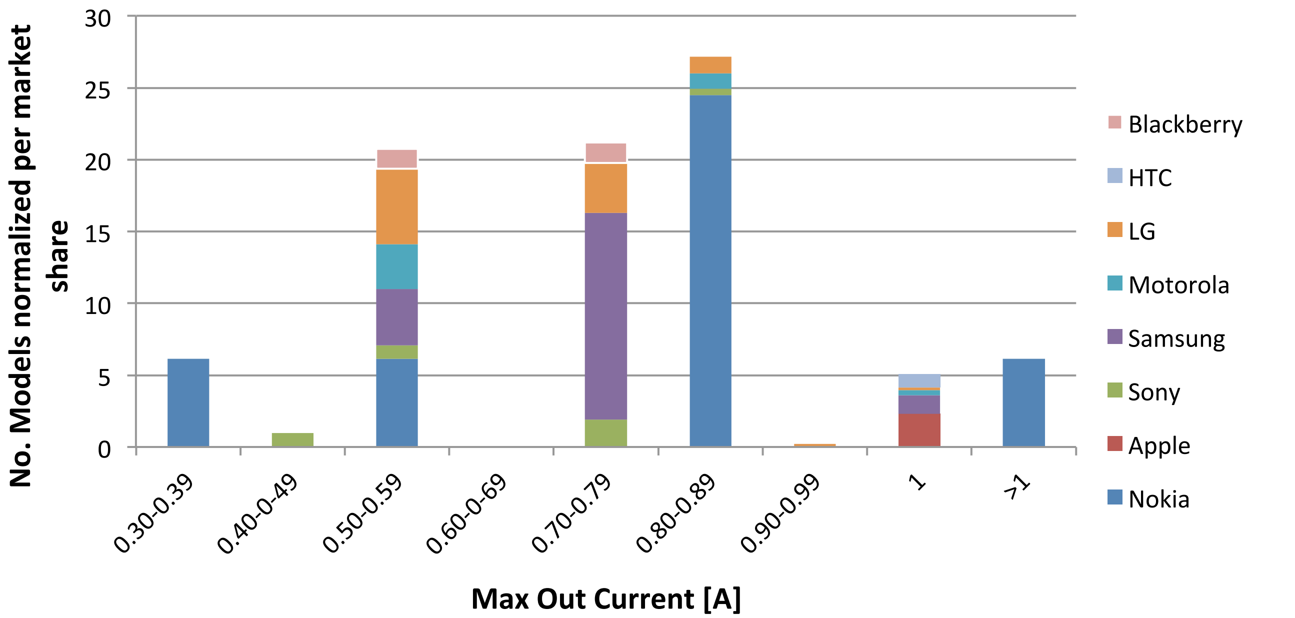


Figure 2-3. Distribution of the maximum DC current provided by chargers. Each brand has been weighted for its market share and each charger model inside the same brand uniformly.

By knowing the Nokia market share and the fact that its lowest current charger (i.e., AC-3) has the widest use (waiting for official data from manufacturers, AC-3 is supposed to represent 2/3 of Nokia chargers), Figure 2-4 attempts to better represent the reality on the market shares of chargers.

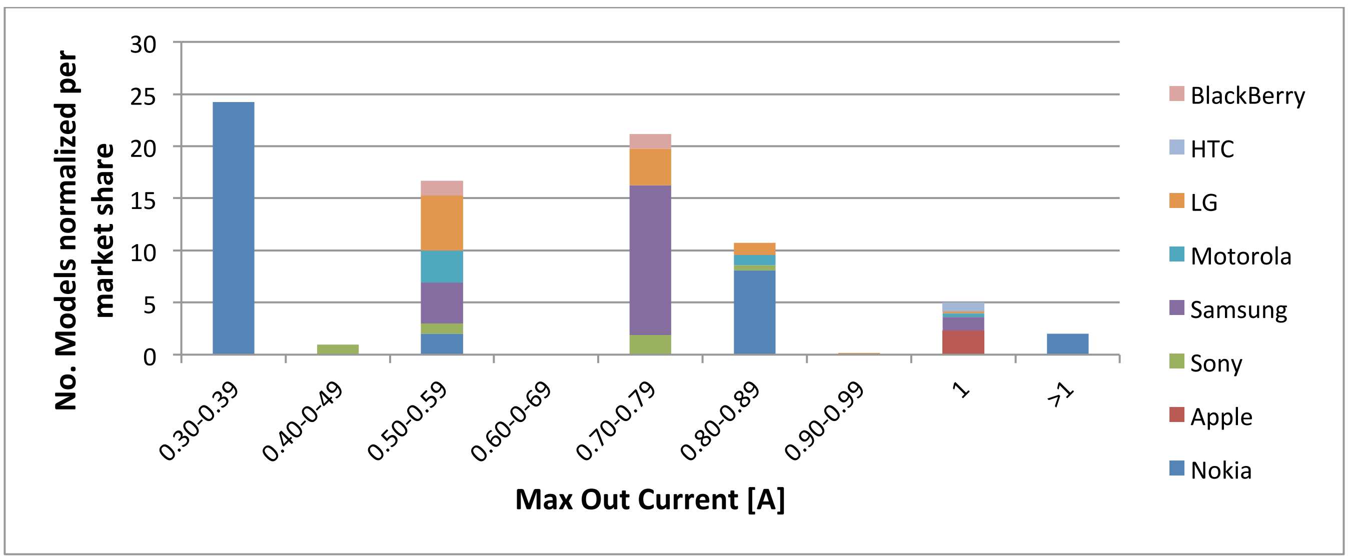


Figure 2-4. Distribution of the maximum DC current provided by chargers with different weights with respect to Figure 2-3. Each brand is still weighted its market share and each charger model inside the same brand uniformly except for Nokia. Nokia AC-3 has been associated to a weight equal to 66%, while other Nokia chargers uniformly divide the remaining 33%.

As far as the output voltage is concerned, the current survey on public sources outlined that 98% of considered chargers declare 5 ± 0.5 V.

2.3.A short look on compatible chargers

Compatible chargers from various vendors The SBS web site, http://www.sbs-power.it. The CellularLine website, http://www.cellularline.com/. exhibit similar electrical features independently from official brands. For instance, the almost complete portfolio of chargers from SBS and CellularLine is characterized by an output current of about 700 mA, and an output voltage of 5 V.

The only difference among all chargers in a same portfolio appears to be the form-factor of the DC connector so to adapt to the various phones.

2.4.Chargers for small-handheld devices

This survey considers also the electrical features of a number of chargers of small-handheld devices (different from mobile phones). The aim here is to provide some additional data in view of a broader application of a universal charger.

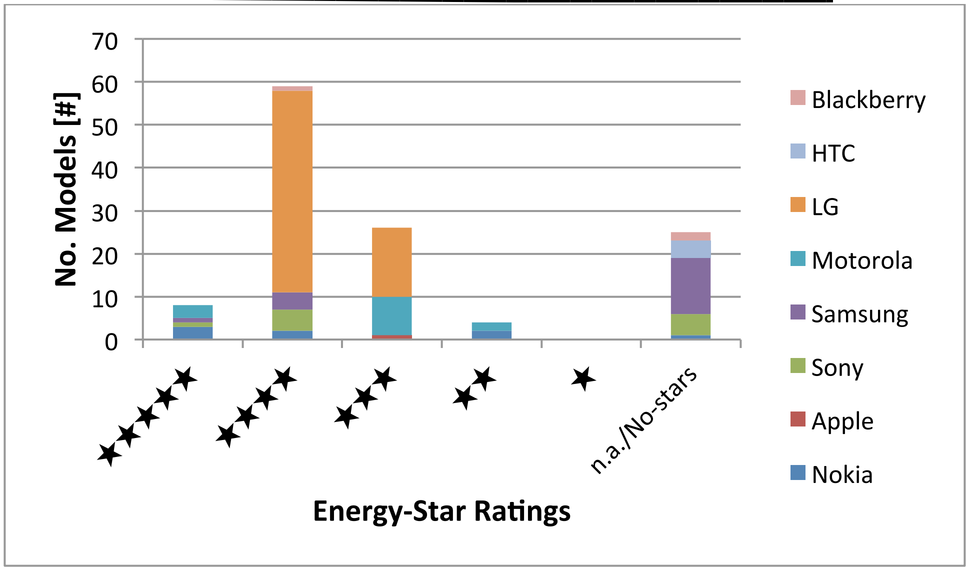
Some small-handled game consoles have energy requirements very similar to mobile phones. For instance, the charger of the Nintendo DS console has a maximum DC current equal to 0.55A, while the Sony Playstation PSP requires much more powerful power supply (i.e., 2 A).

Also GPS navigators have similar energy requirements. For example TomTom chargers provides DC voltage at 5 V and maximum DC current at 1 A.

2.5.Energy-efficiency

In this section, data and information regarding the energy efficiency of chargers are surveyed. In more detail, Figure 2-5 reports how many chargers of which brands received a certain star rating according to the IPP Project on "the Efficiency of a Mobile Device Charger" Nokia, mobile phone chargers: http://www.nokia.com/environment/devices-and-services/energy-effiency/charger-energy-rating. This project is a voluntary agreement committing electronics manufacturers to develop chargers with low no-load power consumption. This means that when the charger is not charging a device, but is still plugged in, it consumes a minimal amount of energy.

Figure 2-5 outlines that a considerable share of chargers did not receive any ratings on low power consumption. The reasons for these rating lacking may be multiple: on one hand some brands do not publish any information regarding the rating of their product; on the other hand, some brands did not extend this rating scheme to their full set of products or to the less recent charger models.



Energy Efficiency Rating for Mobile Device Charger (By Voluntary Agreement EU and Industry IPP Project)	
Rating	No-load Power consumption
★★★★★	≤ 0.03W
★★★★	>0.03W to 0.15W
★★★	>0.15W to 0.25W
★★	>0.25W to 0.35W
★	>0.35W to 0.5W
-	>0.5W

Figure 2-5. Star ratings according to the IPP project for the analyzed set of chargers. Each brand has been weighted for its market share and each charger model inside the same brand uniformly.

2.6.Economic aspects

In order to provide some feedbacks on the correlation between the power and the cost of chargers, the prices of 28 charger models were collected from an on line re-seller My Trendy Phone website, http://www.mytrendyphone.com. and shown in Figure 2-6. These prices refer to replacement and spare parts, and then are characterize by low volumes and high logistic costs for distribution. Despite the impact of the logistic costs, it is reasonable to assume that these costs contribute to the final price of chargers in an almost uniform way. So that, if any evident dependency of manufacturing costs from the charger power exists, it is reasonably expected to be maintained in the final cost in reseller websites despite of the overhead from logistic costs.

The obtained results in Figure 2-6 outlined that low current chargers (<0,45 A) have slightly lower costs. This is probably also correlated to the selling volumes. Above 0,5A the mean cost seems to have little dependence on output current. Another indication in this sense comes from the official Nokia on-line shop, where the chargers with the higher output current and better energy efficiency appear to have even lower costs (Figure 2-7).

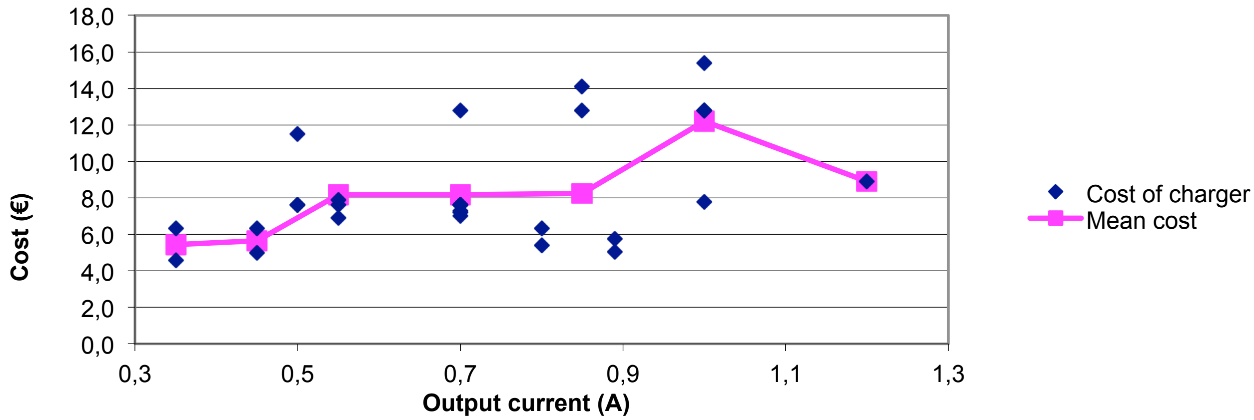


Figure 2-6. Costs and average trends of the considered chargers. Source: My trendy Phone My Trendy Phone website, http://www.mytrendyphone.com..

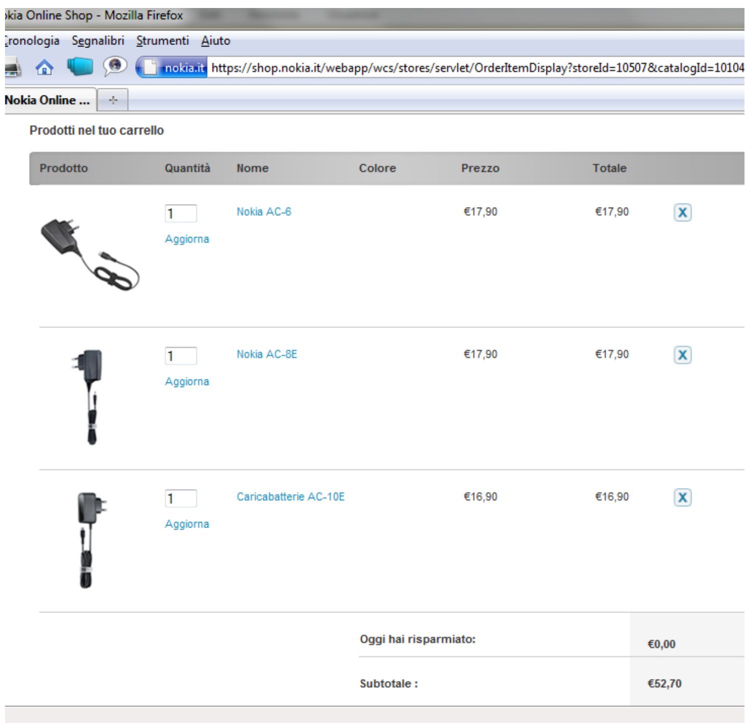


Figure 2-7. Costs of the AC-6 (0.55 A, 4 stars), AC-8 (0.89 A, 5 stars), and AC-10 (1.2 A, 5 stars) on the official Nokia website.

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3. Energy efficiency measurements

This section introduces the results obtained with a measurement campaign performed on 52 chargers from official brands and compatible part suppliers. The chargers were selected in order to represent the most recent and widespread models from the mobile phone brands. The nameplate features of the analyzed chargers are reported in Table 3-1. In order to complete, the survey and the analysis on current chargers, some additional old models of chargers (see Table 3-2), not any more shipped together with mobile phones, were included in order to take some historical trends into account. Note that for some chargers, different replicas have been analyzed (chargers no. 5, 35, and 36, no. 10 and 25, as well as 49 and 50 with reference to Table 3-1).

N°	Brand	Cord Lenght (cm)	Efficiency Level	Output DC Voltage [V]	Output DC Current [mA]	Rated Output Power [W]
41	A	USB-A	IV	5	1000	5
42	A	USB-A	V	5	1000	5
44	B	145	IV	5	660	3.3
5 \ 35 \ 36	C	185	IV	5	500	2.5
65	C	USB-A	V	5	750	3.75
2	R1	165	-	7.5	700	5.25
37	R2	USB-A	-	5	1000	5
26	D	USB-A	-	5	1000	5
16	D	USB-A	-	5	1000	5
47	E	180	-	5.1	700	3.57
29	E	150	V	5.1	700	3.57
30	E	USB-A	-	5.1	700	3.57
32	E	155	-	5.6	400	2.24
31	F	180	-	5.9	375	2.2125
18	F	185	-	5	550	2.75
52	F	185	IV	5	850	4.25
33	F	185	-	6.4	200	1.28
17	F	191	-	5	550	2.75
56	F	190	-	5	550	2.75
27	F	USB-A	-	5.1	850	4.335
19	G	175	V	5	1200	6
12	G	180	V	5	350	1.75
7	G	180	IV	5	890	4.45
22	G	175	V	5	800	4
23	G	165	IV	5	890	4.45
48	G	180	V	5	800	4
46	G	165	V	5	890	4.45
53	D	145	IV	5	1000	5
54	D	145	IV	5	1000	5
1	H	182	IV	5	700	3.5
39	H	147	V	4.75	550	2.6125
6	H	186	IV	5	700	3.5
9	H	183	-	5	700	3.5
10 \ 25	H	203	V	4.75	550	2.6125
24	H	178	IV	5	700	3.5
51	H	149	V	4.75	550	2.6125
21	H	153	V	5	700	3.5
20	H	188	-	5	700	3.5
13	H	184	IV	5	700	3.5

11	H	184	-	4.2	650	2.73
14	H	183	-	4.2	650	2.73
40	H	179	IV	5	700	3.5
28	I	205	-	5.1	450	2.295
45	I	160	-	4.9	450	2.205
43	I	175	IV	4.9	700	3.43
49	I	141	IV	5	700	3.5
50	I	141	IV	5	700	3.5
55	I	151	V	5	550	2.75
15	I	141	-	5	850	4.25

Table 3-1. Nameplate data for the analyzed chargers. R1 and R2 manufactures refer to compatible part suppliers. Manufacturers A-I correspond official brands. For each charger, the energy efficiency rating according to the Energy star, the voltage and maximum current on the DC side are reported.

The rest of this section is organized as follows. Section "Measurement of Mechanical Features" introduces measurements regarding mechanical features of chargers, while section "Measurement of Electrical Features" reports measurements regarding the characterization of electrical parameters and performance. Finally section "Charging Cycles" deals with measurements performed during charging operations with real mobile phones.

N°	**Brand**	**Cord Lenght (cm)**	**Efficiency Level**	**Output DC Voltage [V]**	**Output DC Current [mA]**	**Rated Output Power [W]**
8	F	136	-	5	400	2
34	F	191	-	5.9	375	2.2
3	G	185	-	5	890	4.45
38	F	175	-	4.4	1500	6.6
4	F	185	-	5	850	4.25

Table 3-2. Nameplate data for the additional chargers included in the current surveys. These chargers are old models of original brands, which are no more packaged with mobile phones.

3.1.Measurement of Mechanical Features

3.1.1. Weight measurements

Weight is expected to be the parameter more correlated to the environmental impact of the charger, particularly as the charger can represent as much as 30-40% of the amount of material while the telephone represents the 60-70%.

Figure 3-1 and Figure 3-2 report the measured weight of the chargers with and without the cord, respectively.

These results clearly show a slight correlation between the chargers' weight and their rated output power. In more detail, the weights of chargers without the cord appear to be almost constant with respect to the rated power, while, in the presence of the cord, this correlation becomes more evident: the trend lines in Figure 3-1 show that going from 1 W to 6 W, the average weight increases less than 10%. These results suggest that, on one hand, the mass of electronic and plastic parts of the charger do not sensibly change with respect to the output power, on the other hand, more copper is needed in the cords to support higher rated power values. Figure 3-3 confirms these concepts by reporting the trend line of Figure 3-1 and Figure 3-2.

Further measures have been done by disassembling some chargers to weigh separately "plastic" and electronic parts. Figure 3.4 shows that, for almost every charger, the case constitutes more than 50% of the total weight. The trend lines highlight very slight correlations between weight and power for both electronic and plastic components.

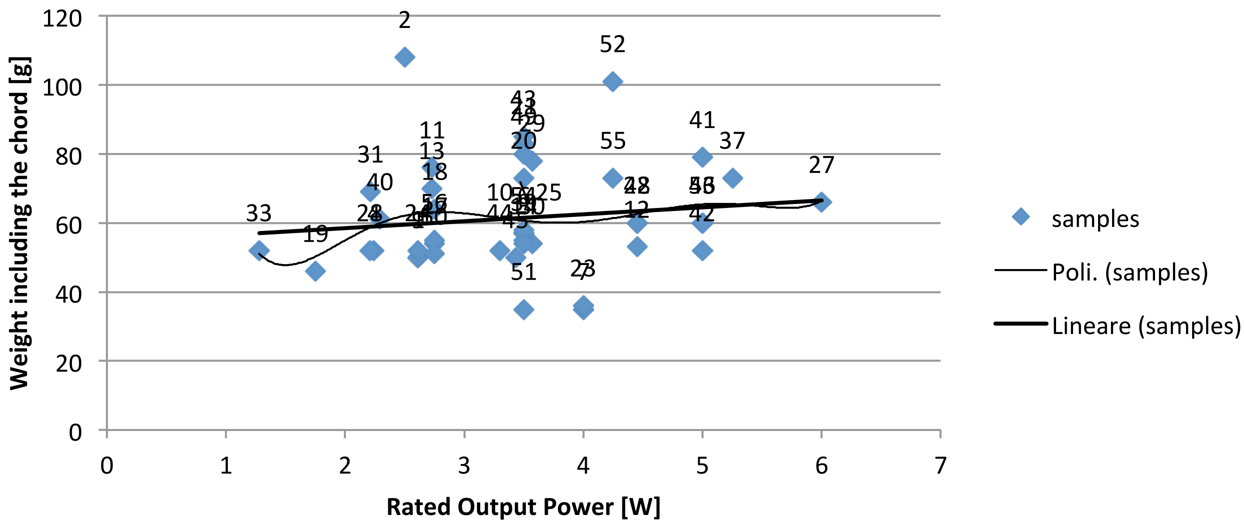

Figure 3-1. Weights of the chargers including their cord (if present) against their declared power. A linear and a polynomial (6th degree) trend lines have been included in the graph.

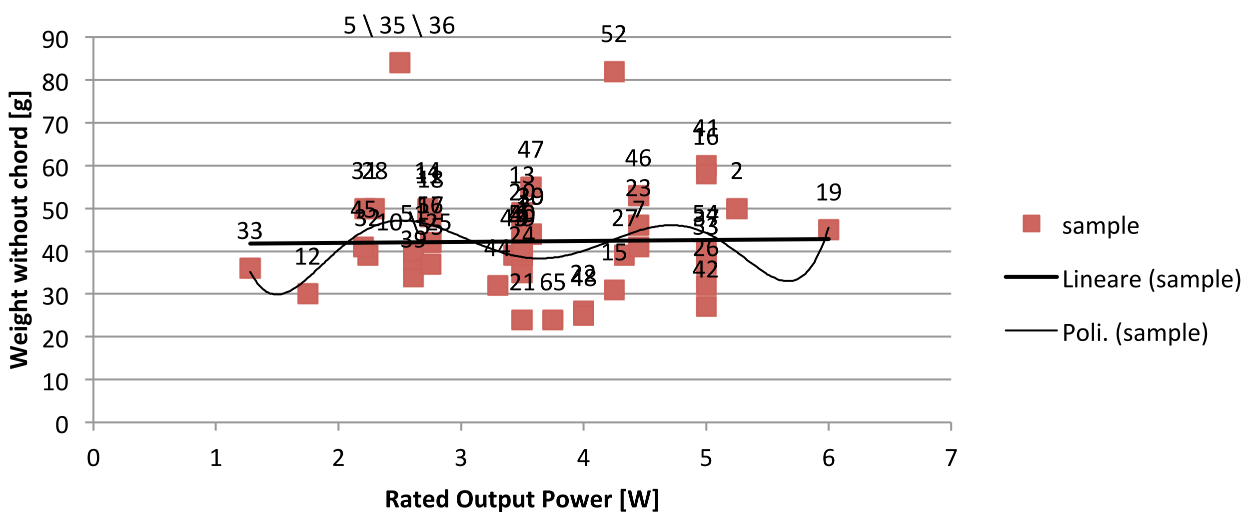

Figure 3-2. Weights of the chargers without their cord against their declared power. A linear and a polynomial (6th degree) trend lines have been included in the graph.

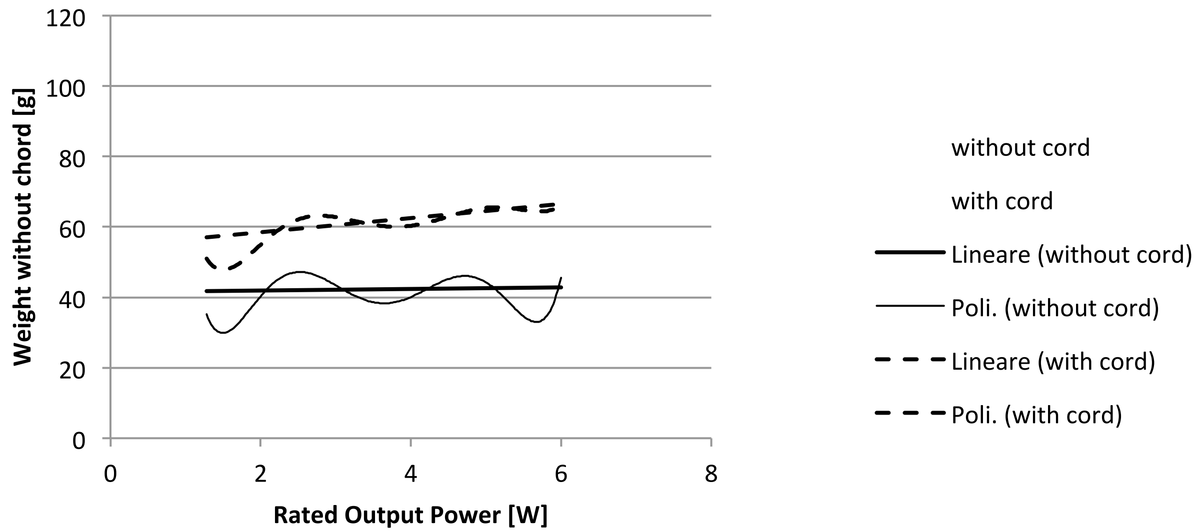

Figure 3-3. Trend lines (both linear and polynomial) as obtained in Figure 3-1 and Figure 3-2.

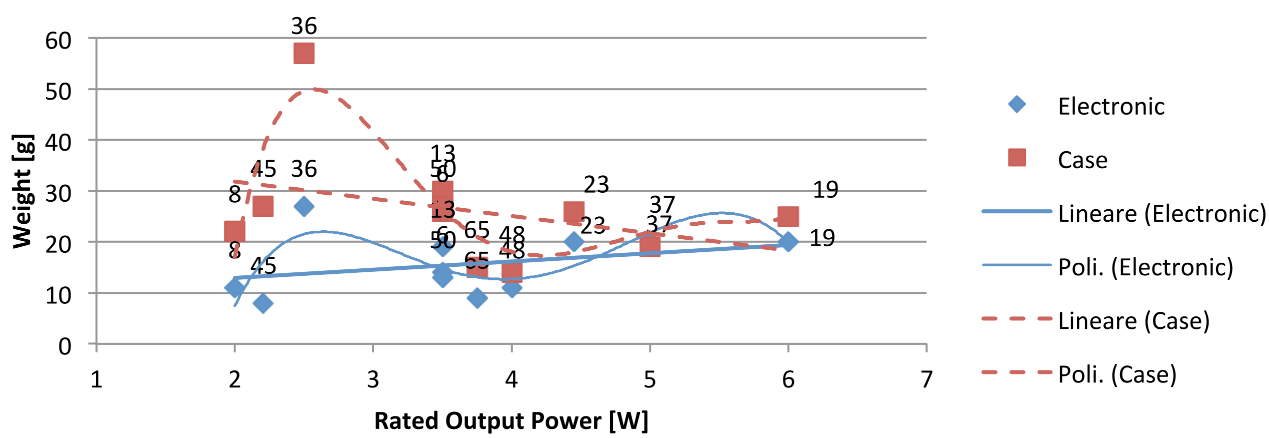

Figure 3-4. Weights of some chargers' cases and electronics, against their declared power. A linear and a polynomial (5th degree) trend lines have been included in the graph.

Remarks – *Graphs 3-2 and 3-3 show a high dispersion on weights of chargers having the same ratings. As weight can be directly linked to the environmental impact, it would be advisable to urge manufacturers to take care on this issue and optimize their products aligning to what other already achieved.*

3.1.2 Volume measurements

Similarly to the previous section, Figure 3-5 shows the volumes measured for the set of analyzed chargers according to their rated output power. The obtained results outline how the collected volume measures are not so much correlated with the charger power. The trend lines are almost flat, and various samples are very distant from them both at low and high values of output power. In some cases, chargers with output power between 3.5 and 5 W appear to have smaller form-factors than the ones working at 1-3 W.

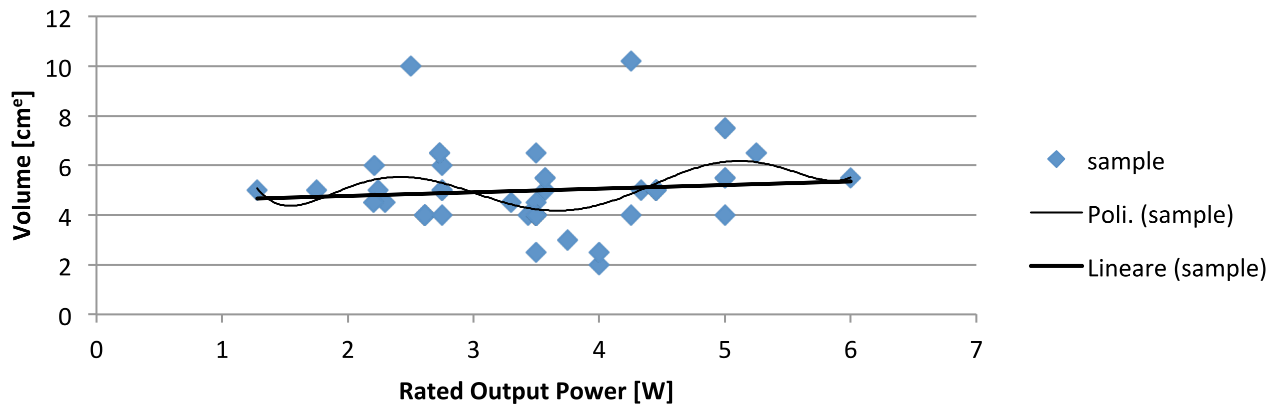

Figure 3-5. Volumes measured from the chargers without their cord against their declared power. A linear and a polynomial (6th degree) trend lines have been included in the graph.

3.2. Measurement of Electrical Features

This section introduces measurement results obtained for estimating the "electrical" performance of chargers. In more detail, subsection 3.2.1 introduces some measures on no-load power, while sub-section 3.2.2 focuses on the energy efficiency and the behavior of chargers in the presence of DC loads.

3.2.1 No load measurements

Figure 3-6 shows both the measured active power provided by chargers in no-load conditions, and, where available, the maximum no-load consumption allowed by the declared IPP star rating of the charger. Except some chargers (more than 10% of analyzed chargers with declared star rating), as one can expect, measured values are generally lower than star-rating thresholds.

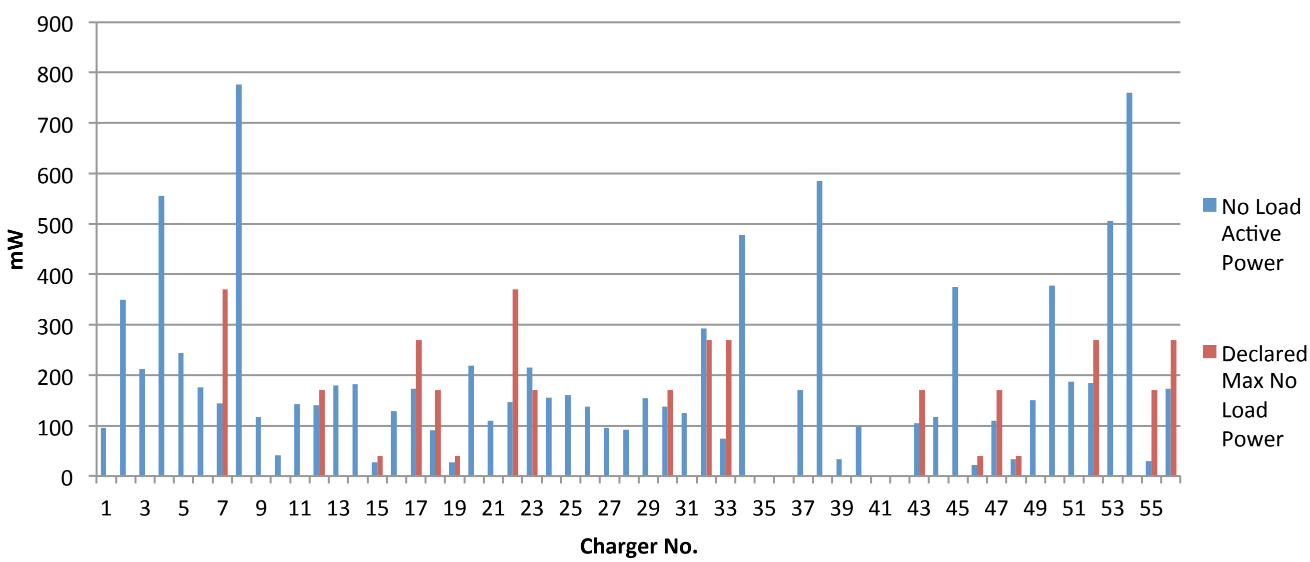

Figure 3-6. No load measurements (in terms of active power) and declared IPP star rating values of the chargers.

Remarks – *Some chargers have shown a no-load consumption higher than what declared by the manufacturer while other samples of the same chargers have shown values within the declared limits. This could be linked to problems in the quality check process*.

Moreover, Figure 3-66 clearly highlights that, except many chargers with no declaration on IPP star rating exhibit no-load absorptions, which can be mapped to star-rating schemes. The largest part of these chargers may be mapped in the IPP categories with 2, 3 or 4 stars.

Figure 3-77 tries to underline the possible correlation between no-load energy efficiency and rated output power. Despite the slight increase of the trend lines, it can be noted how a charger with an output power of 6 W shows one of the minimum values of energy absorption. On the contrary, high no-load absorptions are present at low and medium power rates. Starting from these assumptions, it is reasonable to conclude that no-load efficiency is mainly independent from output power, but mostly depend only on the design and internal components' quality of the chargers.

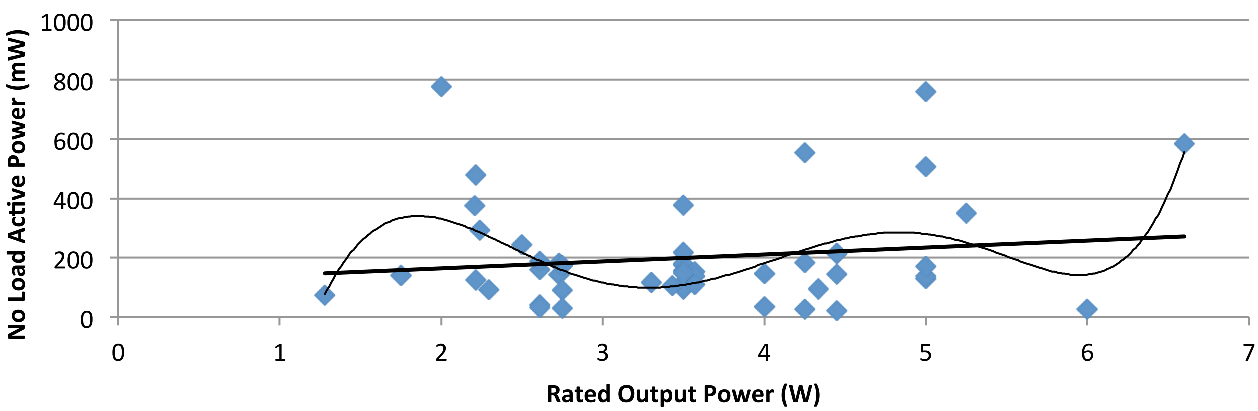

Figure 3-7. Measured values of active power during no-load periods with respect to rated output power of the charger.

3.2.2 Electrical measurements with variable loads

Figure 3-88 reports the energy-efficiency characteristic curves of the analyzed charges. The energy efficiency curve is defined in each point as the ratio between the power provided on the DC side and the active power absorbed by the charger on the AC side. The tests were performed for each charger up to its declared maximum current in 10 mA steps.

All the energy efficiency curves have similar shapes: they rapidly increase and then flatten around a certain value, which represents the maximum efficiency level achievable by the charger. Some chargers are characterized by sensibly irregular slopes in the efficiency curves, and this behavior probably depends on internal circuitry design aiming at optimizing also the no-load behavior.

Despite the similarity on the shapes of such curves, Figure 3-88 clearly shows that analyzed chargers have highly heterogeneous values of maximum energy efficiency, and different paces to achieve these values. Moreover, as highlighted in **Errore. L'origine riferimento non è stata trovata.**9, replicas of the same chargers may have much different behavior in their characteristic curves.

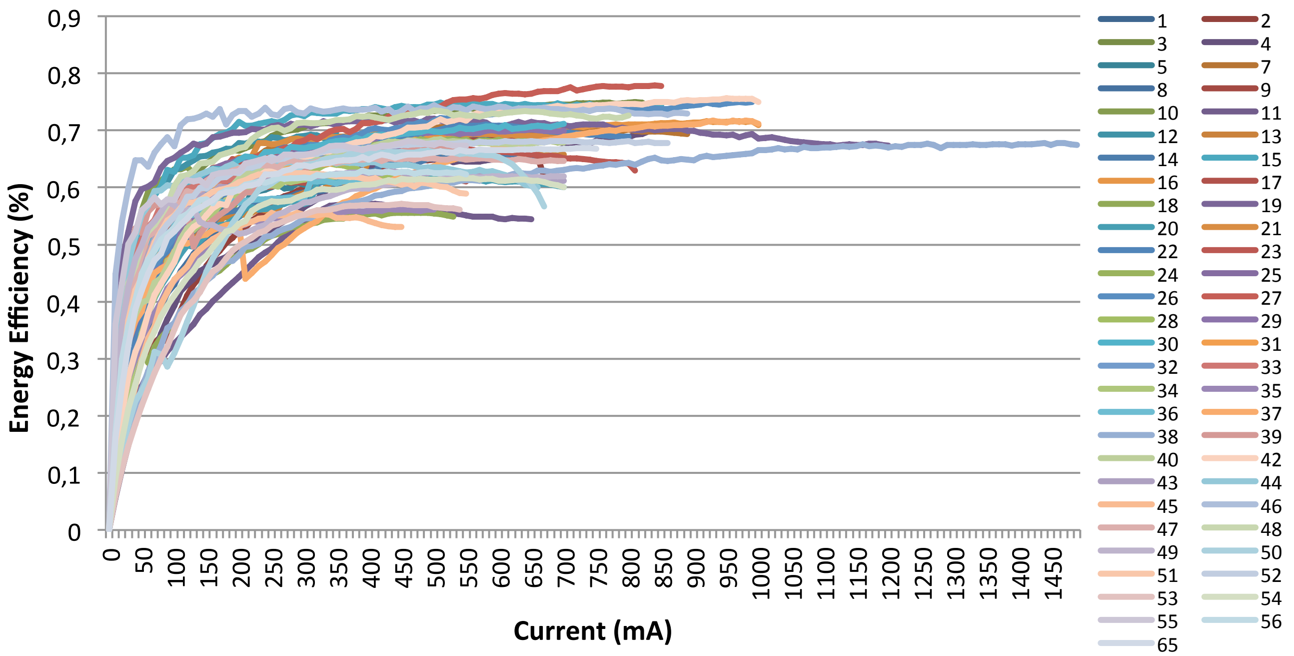

Figure 3-8. Energy efficiency curves with variable loads for all the analyzed chargers. Each charger has been tested up to its declared maximum value of DC current.

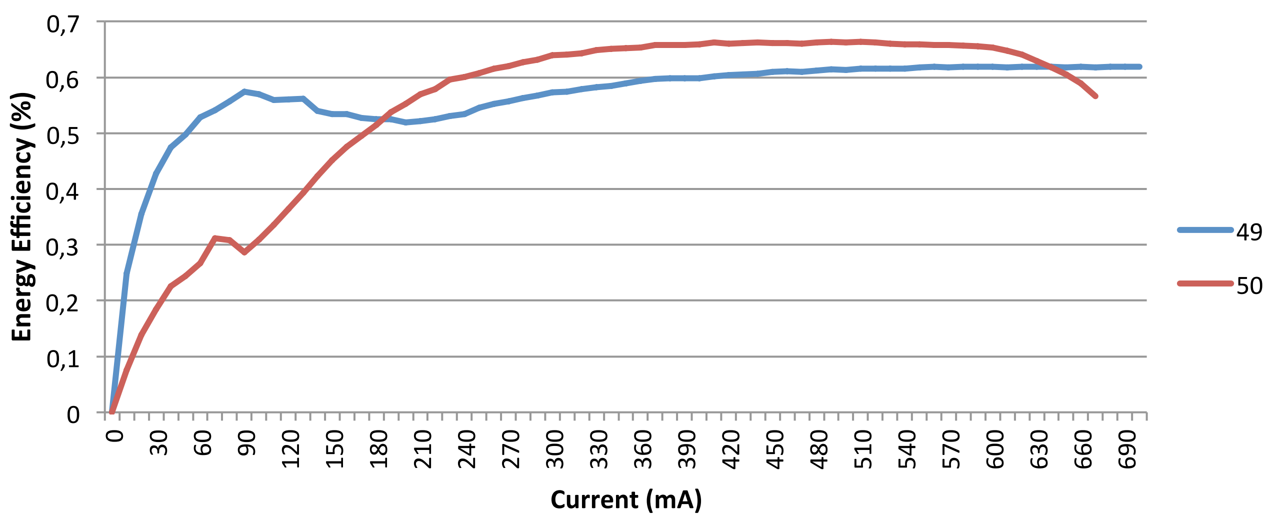

Figure 3-9. Energy efficiency curves for the charger 49 and 50, which are replicas of the same charger model.

Remarks – *Different replicas of same model of charger have shown significantly different efficiency behaviors – probably they are produced by different charger manufacturers (OEM) who use different circuitry*.

Figure 3-10 highlights the particular behavior of some chargers at low current level. To better understand the reasons behind this manner, some additional measurements have been made by using an oscilloscope and a spectrum analyzer. These measures identify a change of switching frequency with the increase of the output current. Figure 3-11 shows the switching frequency of the three charges measured in three different working points (in term of output current): before the efficiency decrease (point A), soon after the efficiency decrease (point B) and finally in the second regular part of the curve (point C, see Figure-3-10).

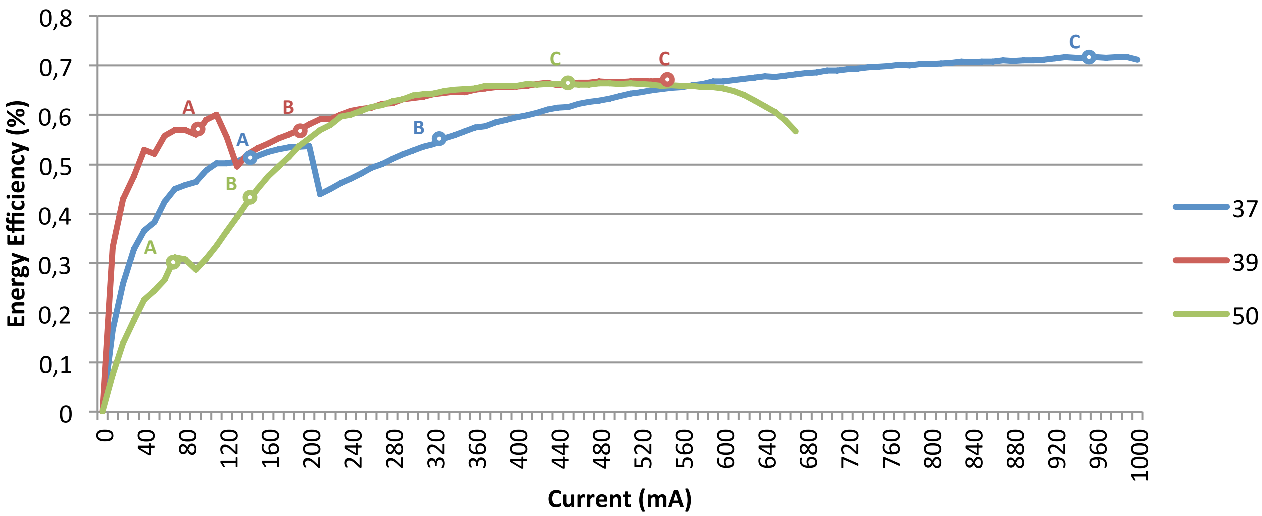

Figure 3-10. Energy efficiency curves for the charger 37, 39 and 50, that show sudden changes in energy efficiency at low current level.

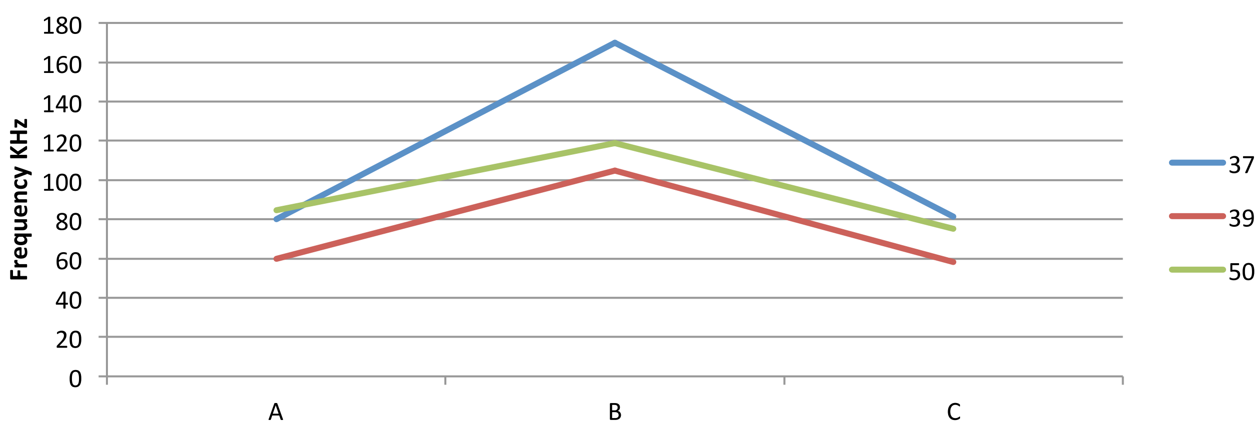

Figure 3-11. Frequency changes observed, taking into account the points shown in Figure 3-10.

Before the quick decrease of the efficiency level we noticed that chargers were working at a certain (lower) frequency, but they operate in an intermittent way (by moving periodically from active to not active and vice versa). Right after that efficiency dip, they switch to a higher working frequency and that irregular behavior disappears. By incrementing the current value, the working frequency decreases again.

Remarks – In all probability this particular behavior is implemented to respect low load efficiency requirements.

In order to synthetically describe the energy-aware performance of chargers, it was decided to fit the collected samples of characteristic curves in Figure 3-8 with the following function:

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

Where i represent the value of the provided DC current, while α and β are the fitting parameters. In more detail, α obviously represent the maximum efficiency achievable by the charger, 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 α level – 3% for i>350 mA, β values must be greater than 10,02. However, greater β values indicate that the charger may be effectively used (with good efficiency levels) also with mobile phones with lower energy requirements. The α parameter is obviously one of the most important meters of the energy efficiency of chargers.

Table 3-3 reports the α and β parameters, and related standard error, obtained by fitting the characteristic curves of each charger in Figure 3-8 with the model above introduced. Standard errors clearly give useful feedbacks on the goodness of the fitting it-self, but also on the regularity of the curve slopes. It is worth noting that good maximum efficiency levels (i.e., α>0,70) are achieved only by chargers with good performance at 350 mA (β>10,02).

Figure 3-12 and Figure 3-13 show the values of α and β fitting parameters against the rated output power of chargers. These results highlight the lack of correlation among these two parameters and the rated output power: the trend lines are almost flat and different samples are heavily distributed in the graphs. Also in such a case, it is reasonable to conclude that energy efficiency parameters mostly depend on the quality of the design and of the internal components of chargers, and not from output power.

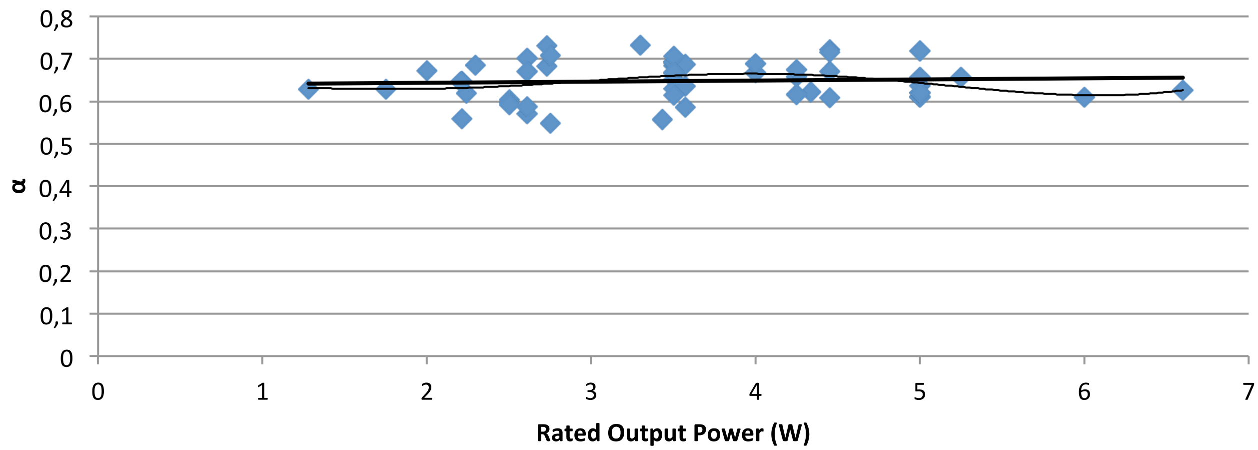

Figure 3-12. Values from the α parameter as in Table 3-3. A linear and a polynomial (6th degree) trend lines are also reported.

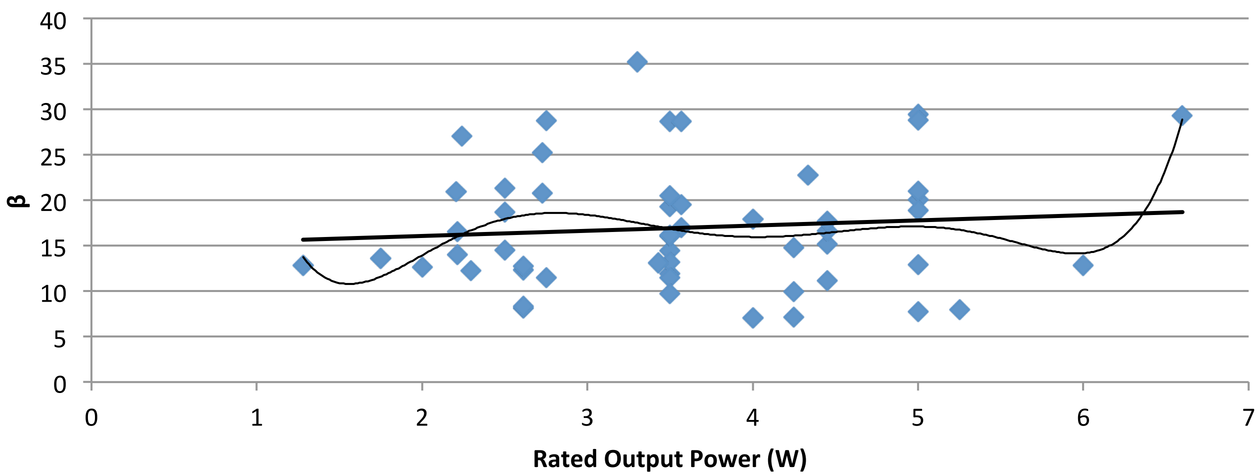

Figure 3-13. Values from the β parameter as in Table 3-3. A linear and a polynomial (6th degree) trend lines are also reported.

Charger no.	α	stderr α	β	stderr β
1	0.684602	0.00357863	11.924	0.307208
2	0.656684	0.00458872	8.00054	0.212191
3	0.72226	0.0034234	15.1337	0.408562
4	0.657915	0.00492403	7.16029	0.188275
5	0.604602	0.00389064	18.6623	0.684082
7	0.693757	0.00273256	14.4736	0.316202
8	0.608851	0.00362932	11.1574	0.236672
9	0.672188	0.0036323	12.6582	0.34982
10	0.651835	0.00681982	28.6766	2.30134
11	0.570976	0.00524742	8.12155	0.286231
12	0.6828	0.0060187	25.2088	1.27321
13	0.627986	0.00556128	13.6102	0.644259
14	0.62984	0.00443811	13.1873	0.487281
15	0.73125	0.00386151	20.8062	0.752062
16	0.675614	0.00417672	14.8413	0.516568
17	0.609681	0.00286047	20.0642	0.590509
18	0.548121	0.00653566	11.4703	0.596595
19	0.707836	0.00396184	28.7358	1.3167
20	0.609551	0.00299879	12.833	0.32561
21	0.689759	0.00257289	16.0441	0.352809
22	0.693559	0.00348543	11.5093	0.278832
23	0.667372	0.00243019	17.8946	0.409303
24	0.669981	0.00310688	16.634	0.464438
25	0.665791	0.00295224	19.3134	0.525491
26	0.702033	0.00436321	12.3561	0.386943
27	0.718712	0.00648807	12.9158	0.603704
28	0.622363	0.00463935	22.7441	1.02164
29	0.685841	0.00367561	12.2458	0.328858
30	0.686656	0.00331629	16.9843	0.499914
31	0.63616	0.0047244	19.5342	0.723467
32	0.648272	0.00602185	16.5926	0.71559
33	0.618463	0.0125976	27.0464	2.29155
34	0.627713	0.00435427	12.8129	0.336466
35	0.559344	0.00257186	14.0002	0.307703
36	0.597134	0.003769	21.3348	0.829613
37	0.592651	0.00905447	14.5434	1.23596
38	0.61155	0.00284131	7.75172	0.133746
39	0.627249	0.00729096	29.3117	2.64513
40	0.670019	0.00388658	12.7961	0.382142
42	0.706407	0.00409322	9.71914	0.243603
43	0.621244	0.00252519	20.9921	0.586999
44	0.637493	0.00326611	29.473	1.25335
45	0.557369	0.00425293	13.1334	0.430497
46	0.732967	0.00459997	35.2561	2.02345
47	0.645724	0.00277599	20.9443	0.618625
48	0.715788	0.00396981	17.72	0.613824
49 / 50	0.585337	0.00513514	28.6513	2.05442
51	0.614522	0.00310675	20.5323	0.659842
52	0.668492	0.00279617	16.1129	0.398317
53	0.587567	0.00340376	8.35335	0.17235
54	0.616378	0.00185237	9.96647	0.131702
55	0.656379	0.00514445	28.7888	1.73444
56	0.620756	0.00301792	18.8885	0.556245

Table 3-3. Results of the interpolation of energy-efficiency curves with respect to the fitting model. The values of the α and β parameters are reported with the estimated standard error from the fitting process. Most efficient chargers (i.e., values of β>10.02 and of α>0.70) have been highlighted.

Finally, Figure 3-14 reports the DC voltage provided by the analyzed set of chargers according to the output current. In such a case, we can underline how different chargers that declare nameplate DC voltages equal to about 5 V, in the reality provide much higher voltage values (almost twice the declared values), and never provide 5 V. Moreover, in some cases, the voltage levels sensibly decrease according to the output current.

Another interesting aspect consists on the fact that 24 of the analyzed chargers have USB interfaces, but only 16 of them are compliant with the voltage specification of this standard. As it can be seen in Figure 3-15, 3 of them even exceed in an evident way the maximum voltage allowed by the USB specification.

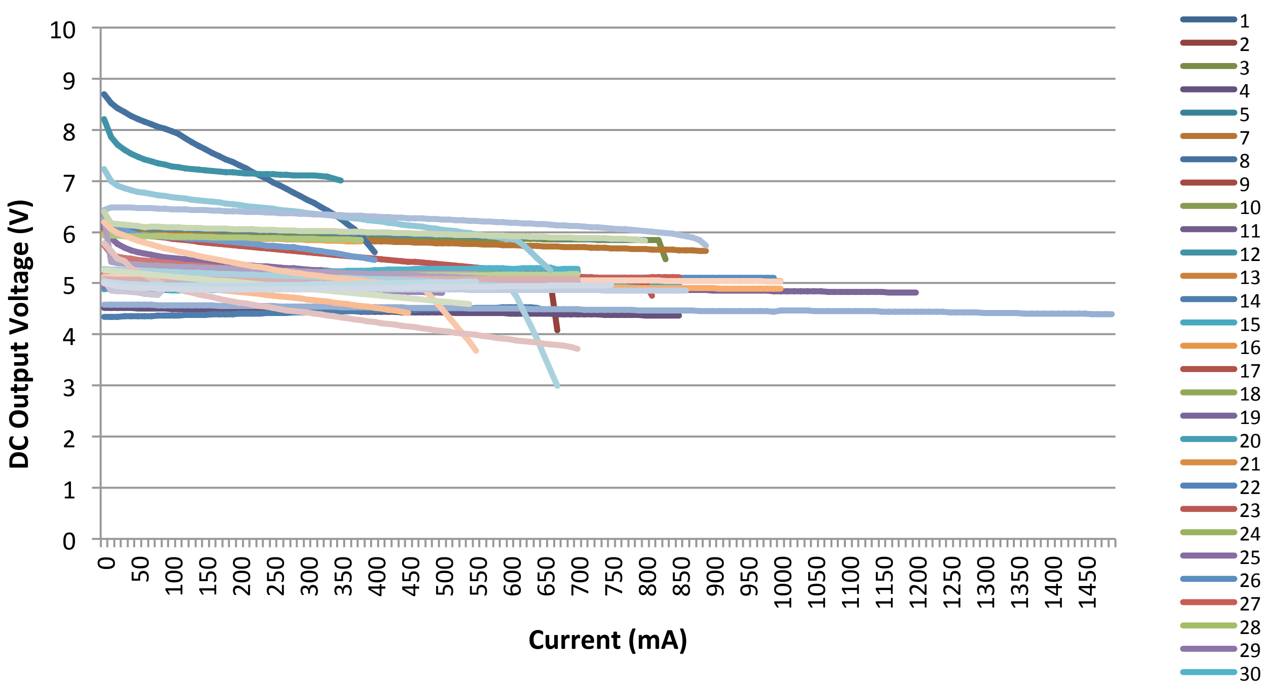

Figure 3-14. DC Voltage measurements according to a variable load in terms of provided output current.

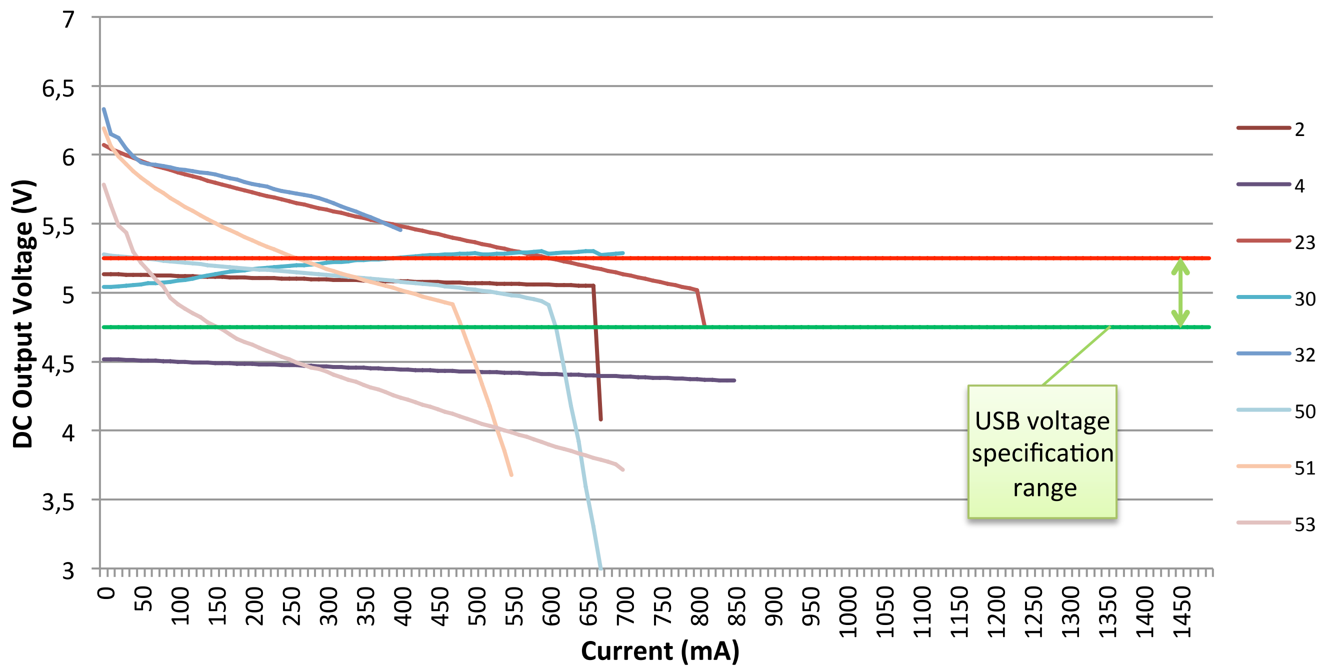

Figure 3-15. USB chargers' DC Voltage measurements according to a variable load in terms of provided output current. The USB voltage specification range is highlighted.

Remarks – *Many chargers have shown an output voltage quite far from what declared by producers and reported in their nameplate. This, further than creating confusion among users, could create them troubles in case they would use them to power other products. In general, the ratings declared in the nameplate are expected to be accurate, and represent the real features of the power supply. One charger in particular terminated into a microUSB connector has shown an output voltage far beyond the USB limits. It could damage USB devices.*

3.3. Charging Cycles

This section introduces some preliminary tests, which were performed to analyze charging process with real mobile phones. To this purpose, all the chargers introduced in section 3 have been connected to 6 different models of mobile phones from various brands. The set of selected mobile phones consist of a mix of high and low-end devices.

Table 3-4 shows the results of some test carried out to analyze the compatibility between chargers and mobile phones. These results outline that chargers with not stabilized voltage are often incompatible with mobile phone packaged with power supply with stabilized voltage, and vice versa.

Remarks – *Voltage stabilization is a key aspect to be considered in L1000 standard and in the type approval process, since it appears to be the main incompatibility factor among existing power suppliers and mobile terminals.*

Charger N°	Mobile 1	Mobile 2	Mobile 3	Mobile 4	Mobile 5	Mobile 6
44	no	yes	yes	yes	yes	yes
5 \ 35 \ 36	yes	yes	yes	no	yes	yes
2	yes	yes	yes	no	yes	yes
37	yes	no	no	no	yes	yes
26	yes	no	no	no	yes	yes
16	yes	no	no	no	yes	yes
47	yes	yes	yes	no	yes	yes
29	yes	yes	yes	no	yes	yes
30	yes	yes	yes	no	yes	yes
32	no	yes	yes	yes	yes	yes
4	yes	no	no	no	yes	yes
31	yes	yes	yes	yes	yes	yes
8	no	yes	yes	yes	yes	yes
18	yes	yes	yes	no	yes	yes
52	yes	yes	yes	no	yes	yes
33	yes	yes	yes	yes	yes	yes
17	yes	yes	yes	no	yes	yes
56	yes	yes	yes	no	yes	yes
34	yes	yes	yes	yes	yes	yes
38	yes	no	yes	no	yes	yes
27	yes	yes	yes	no	yes	yes
19	yes	no	no	no	yes	yes
12	yes	yes	yes	yes	yes	yes
7	no	yes	yes	yes	yes	yes
22	no	yes	no	yes	yes	yes
23	no	yes	yes	yes	yes	yes
3	no	yes	yes	yes	yes	yes
48	no	yes	yes	yes	yes	yes
46	no	yes	yes	yes	yes	yes
53	yes	yes	yes	yes	yes	yes
54	yes	yes	yes	yes	yes	yes
1	yes	yes	yes	no	yes	yes
39	yes	yes	yes	no	yes	yes
9	yes	yes	yes	no	yes	yes
10 \ 25	yes	yes	yes	no	yes	yes
24	yes	yes	yes	yes	yes	yes
51	no	yes	yes	yes	yes	yes
21	yes	yes	yes	yes	yes	yes
20	yes	yes	yes	no	yes	yes
13	yes	yes	yes	no	yes	yes
14	no	no	no	no	yes	yes
40	yes	yes	yes	no	yes	yes
28	no	yes	yes	no	yes	yes
45	yes	yes	yes	no	yes	yes
43	yes	yes	yes	yes	yes	yes
49 / 50	yes	yes	yes	no	yes	yes
55	yes	yes	yes	no	yes	yes
15	yes	yes	yes	no	yes	yes
65	yes	yes	no	no	yes	yes

Table 3-4. Chargers vs Mobile phones compatibility report

Furthermore, current and voltage values during complete charging cycles of some of our mobile phone were measured, by using chargers providing different output current values. Various strategies have been adopted by different brands, as it can be noticed in the following figures. In some cases the mobile phone applies a sort of current level control, by absorbing a fixed level of current, independently of the charger characteristics (Figure 3.22 and 3.24) and when possible (i.e., when the maximum output current of the charger is larger than the requested one). As Figure 3.18 and Figure 3.20 show, other brands' mobiles don't adopt this kind of control.

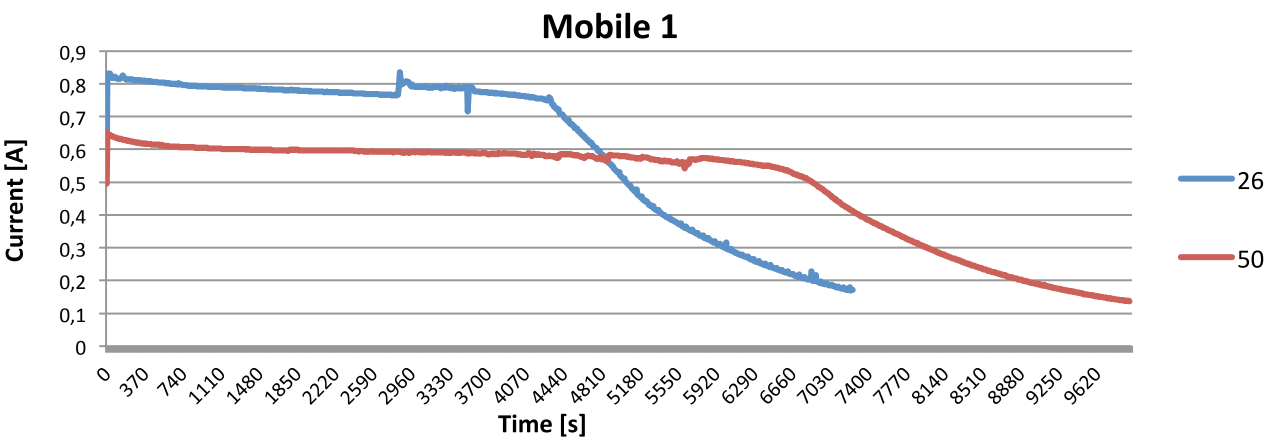

Figure 3-16. DC current measurement representing the complete charging cycle, with different chargers.

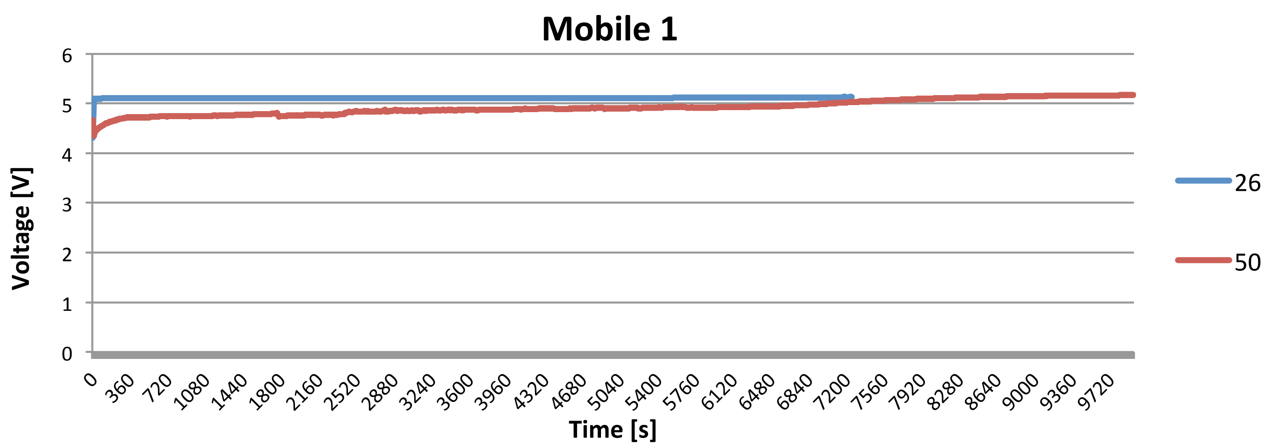

Figure 3-17. DC voltage measurements, representing the complete charging cycle, using different chargers.

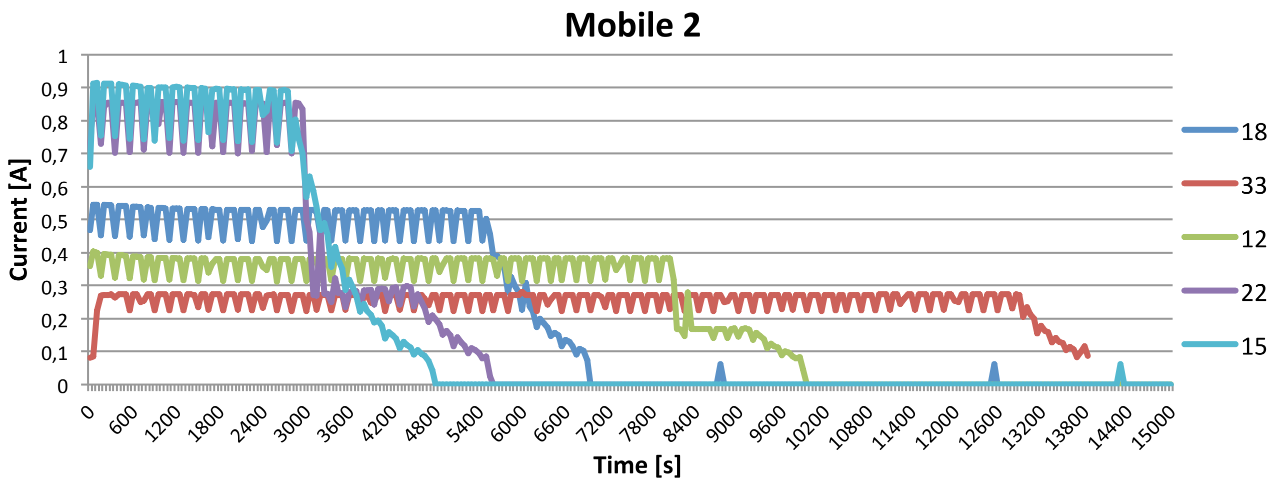

Figure 3-18. DC current measurements, representing complete charging cycles, using different chargers.

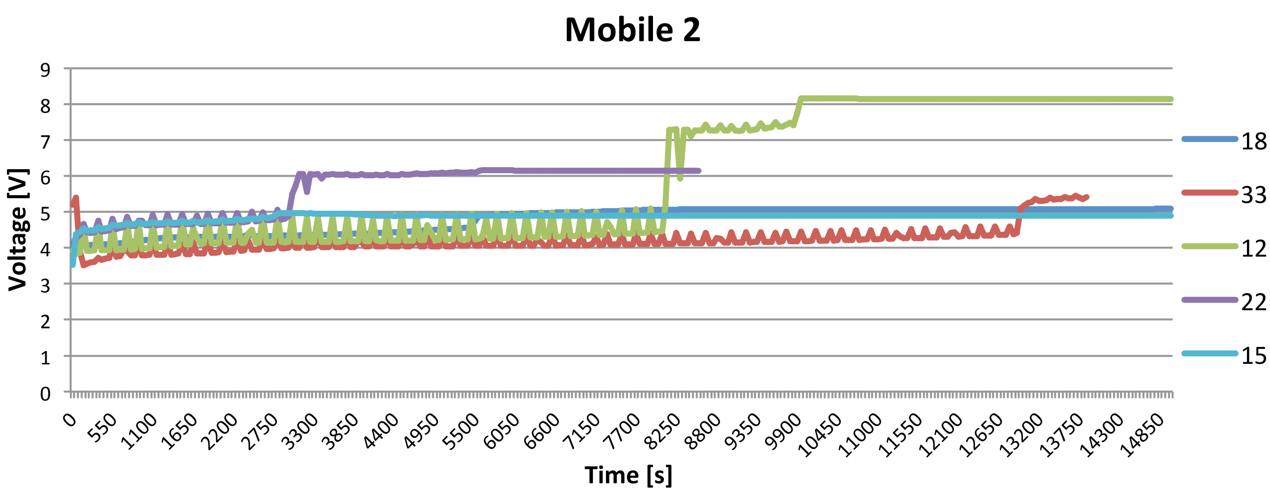

Figure 3-19. DC voltage measurements, representing the complete charging cycle, using different chargers.

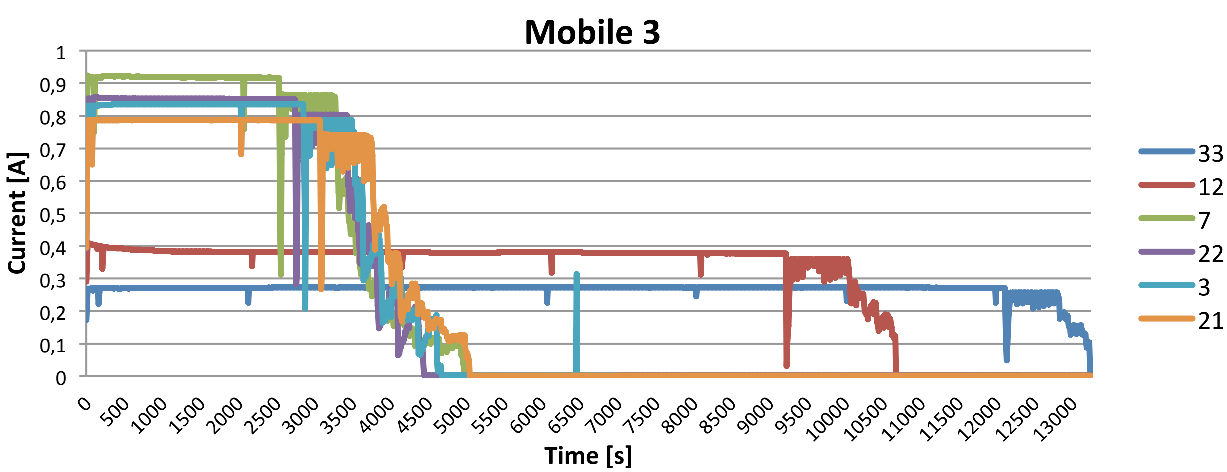

Figure 3-20. DC current measurements, representing the complete charging cycle, using different chargers.

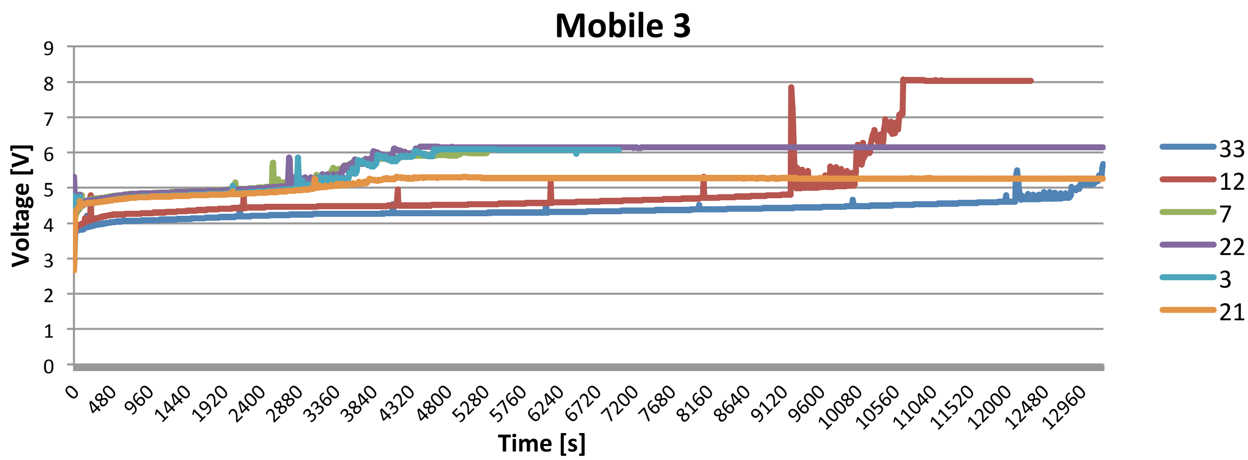

Figure 3-21. DC voltage measurements, representing the complete charging cycle, using different chargers.

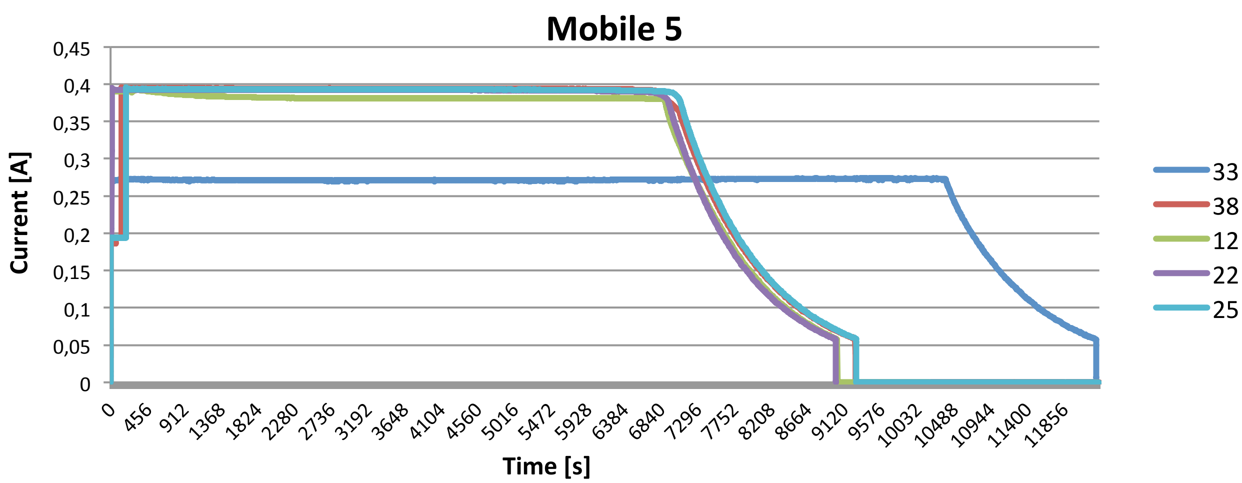

Figure 3-22. DC current measurements, representing the complete charging cycle, using different chargers.

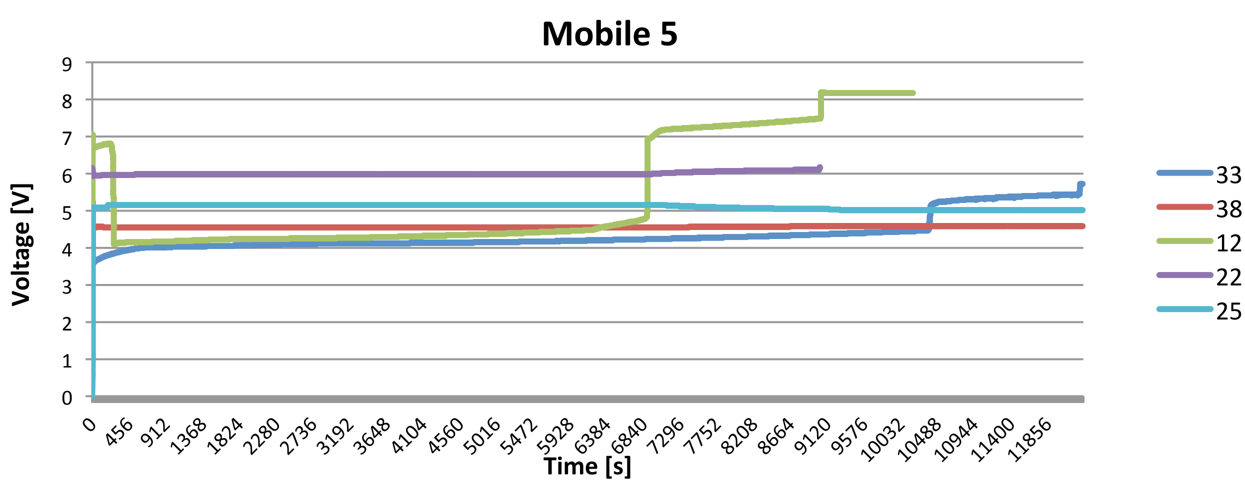

Figure 3-23. DC voltage measurements, representing the complete charging cycle, using different chargers.

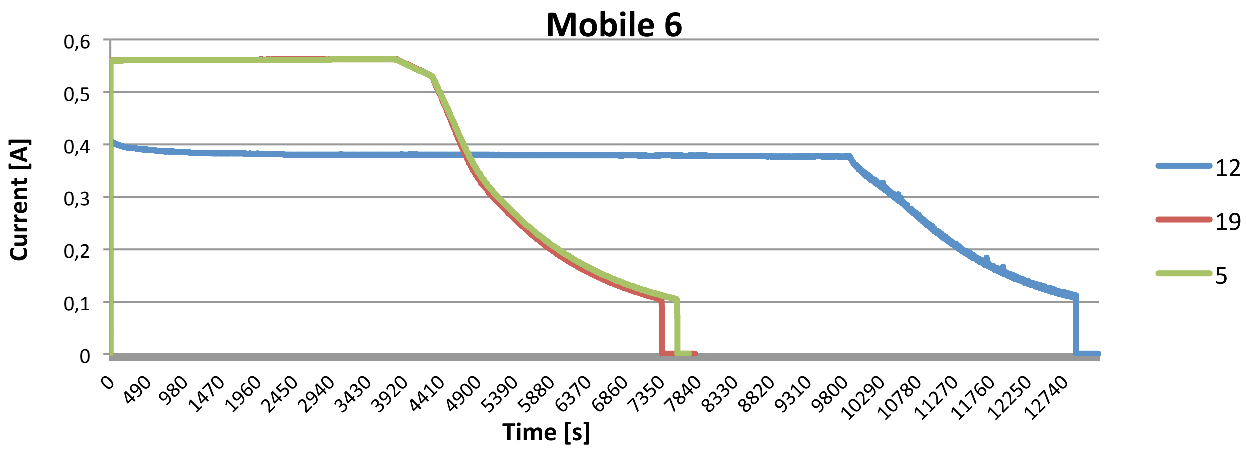

Figure 3-24. DC current measurements, representing the complete charging cycle, using different chargers.

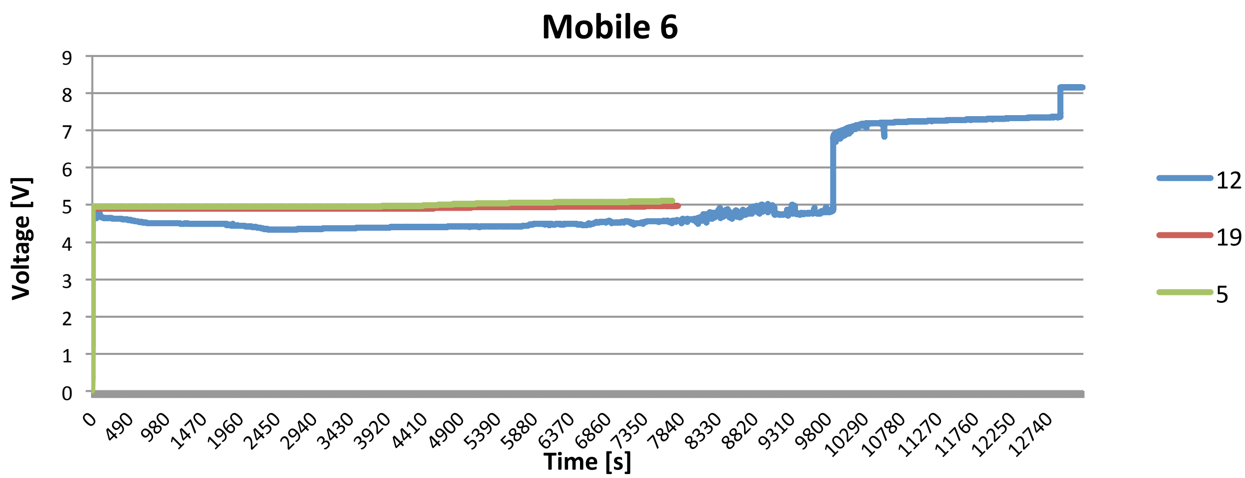

Figure 3-25. DC voltage measurements, representing the complete charging cycle, using different chargers.

Remarks – The lack of a current control mechanism could cause an incorrect charge of the batteries or overload, especially considering that chargers with different nameplate output current often have the same plug.

4. Conclusions

Upon GeSI request, a wide analysis has been made on most of the commercially available mobile phone chargers and some small handheld devices to evaluate the correlation between charger's rated power and their mechanical/electrical characteristics.

This survey has been focused both on data from manufacturers and on measurements on electrical and mechanical parameters.

The main results of this study are:

- Connectors towards the device – Four Vendors are declaring to use USB compatible only connectors and chargers. All Vendors provide at least one USB compatible charger.
- Output current – most recent chargers show ratings beyond 500mA
- Output voltage - On vendors data, 98% of considered chargers are declared within 5 ± 0.5 V
- Costs – low current chargers (<0,45 A) show slightly lower costs. This could be correlated to the higher market volumes of low end phones. Between 0,5 and 0,9A the mean cost seems to have very little dependence on output current
- Weight/volume – the weights of chargers (without the cord) and their volume appears to be almost constant irrespective of the rated power. Weight is expected to be the parameter more correlated to the environmental impact of the charger.
- No-load consumption – high variance. Some chargers have very low no-load consumption while other show quite higher values. No dependence on the rated output current of chargers. Some chargers have shown a no-load consumption far higher than what declared by the manufacturer. This could be linked to problems in the quality check process.
- Energy efficiency – a wide spread of efficiencies has been found. Many chargers show very good efficiencies but many have very poor behavior. Energy efficiency seems to be independent from the charger output power.
- Output voltage measurements - many chargers have shown an output voltage quite far from what declared by producers and reported in their nameplate. Only 14 out of 24 chargers having USB interface have shown full compliance with the USB specifications.
- Voltage stabilization – it is a key aspect to be considered in future specification of the L1000 standard, since it appears to be the main incompatibility factor among existing power suppliers and mobile terminals.
- Current level control: a current regulator inside the mobile terminal should enhance the compatibility among different chargers also by avoiding incorrect charge cycles of the batteries.

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 a high opportunity for improvement.

References

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[9] The CellularLine website, http://www.cellularline.com/.

[10] My Trendy Phone website, http:// www.mytrendyphone.com.