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Abstract. In the present study, we investigated the technical qualities of power consumption meters. A selection of nine meters available at general electric and discounts stores was selected for an evaluation along with two more expensive products and one prototype meter. The majority of the affordable devices fell into the price range of 10-20 Euros. In the test, variable load combinations were used to asses the meters in reference to a known, calibrated power quality measurement device. The loads included small and reactive loads estimated to be difficult for the meters. The accuracy of the measured devices was very variable, some meters qualifying with small resistive loads, the majority of meters with high resistive loads. The found inaccuracies were predominantly negative. The devices underestimated the consumption and some devices had more than 25% error. In this report we document these measurements and reveal the relative qualities of the tested products, highlighting two products.

Keywords: power consumption meters, electrict power meter, accuracy, usability

1. Introduction

In 2009 the European Commission has just recently released a new climate and energy package (European Parliament, 2008). This act has been discussed in length in several media, along with other anti-climate change maneuvers. Together these timely debates draw the attention of European citizens into energy issues. When ecological awareness comes coupled with the increasing trend in electricity prices in Northern-Europe, an incentive may arise for consumers to think more carefully about their electricity consumption. Recent study shows economical incentives are the primary reason why people take action (see, Liikkanen, 2009). One of these actions is to seek out information about how much electricity is consumed by different household appliances. This can be achieved using electric power meters. People may be interested to find out do they possess a defective device, or be interested just to learn about the energy consumption of their electrical devices. These needs can be satisfied using end-use electric power meters which have become affordable and widely available in Northern-Europe, Finland by end of the year 2008. However, the availability of inexpensive meters does not yet guarantee a benefit for the consumer if the cheap price is a consequence of poor design and mediocre technical quality.

There are several reasons to suspect that the technical quality may be compromised. Our first concern is the dynamic range requirement to correctly measure and represent all loads of interest. The second issue is the behavior of the inexpensive meters when loaded with non-linear, non-resistive loads. Particularly the reactive power component (Harrison, 1996) is suspected to impair the accuracy of the measurements conducted with affordable measurement devices. Reactive power represents the power component that is out-of-phase from the mains voltage. With the increasing number of fluorescent lamps, including so called energy-saving bulbs (compact fluorescent lamps, or CFLs), the number of reactive load inducing measurement targets in households has increased.

Small loads are technically more challenging than big loads, because we assume that the power meters are normally designed for a typical maximum fuse load of 16 amperes. To perform adequately also with small loads, the devices should have a considerable measurement range. Even though the contribution of small loads to the total energy consumption may negligible, there also several reasons to take small loads seriously. The increasing number of electric devices with standby states can create a considerable waste of electricity globally. Because of this, the Commission of the European Communities is endorsing the 1-watt initiative as one part of recent ecodesign requirements for new electronic devices (EBPG, 2007). We interpret this specification so that a properly functioning power meter should be able to handle loads from 1W, or 1/230 A, up to the maximum typical fuse load of 16A. This corresponds to a dynamic range of 1:3680, which in practice calls for 16-bit resolution from digital circuits.

For the interests of benchmarking and evaluating the options available for Finnish consumer, we decided to test a variety of power meters. In this paper we report our efforts in testing how a selection of these devices performs in different measurement conditions. For the test, we have chosen loads that resemble typical devices found in Finnish households, including the aforementioned loads that are potentially challenging for the meters. After presenting the power meter range, test methodology and results, we conclude that some affordable devices provide value for the money, but the quality is very variable. Surprisingly, even a 10 euro device can accurately measure both small loads and devices with low power factor, high reactive power component.

2. Tested Devices

Eight affordable devices easily available for consumers in Finland, Greater-Helsinki region, were acquired for the test. The units were bought anonymously from retail shops to avoid any bias. In addition, one inexpensive meter (Technoline) was obtained from a co-operating utility where it had been circulated among their customers. It can be purchased, for instance, from Amazon.de or in Finland from Paratronic Oy. We include also two more expensive devices to evaluate if there are noticeable differences between price categories, although these meters (Plogg and Christ-Elektronik) are not commonly available or of interest to consumers. An experimental research sensor prototype was also included for benchmarking purposes. All measured devices were new, except Technoline and Christ-Elektronik. The selection of power consumption meters involved in this study is found in Table 1 below:

Table 1. The technical specifications of the tested devices. Columns from left to right sorted by ascending price.

Basic information											
Dealer	LIDL	Clas Ohlson	Techno-line	Hong Kong	Verkko-kauppa	Clas Ohlson	Motonet	Velleman	Onninen	Plogg	Christ Elektronik
Model	PM333	EMT707CTL	Cost control	FHT-9999	FHT-9999	PM300	PM300	NETBSEM2	REV TS-JD	Blu v2.0	CLM200
Retail price in €*	13	14	14	13	20	20	20	20	40	~110	~180
Ratings											
Max. current [A]	10	16	16	16	16	16	16	16	10	16	16
Minimum [VA]	1.15	5	-	5	5	0.46	0.46	4.6	0	-	5
Features											
Voltage	-	X	-	-	-	X	X	X	X	X	-
Current	X	X	-	-	-	X	X	X	X	X	-
Maximum current	X	-	-	-	-	X	X	X	-	?	-
kWh consumption	X	X	X	X	X	X	X	X	X	X	X
Tariff settings	1	1	1	2	2	1	1	2	1	2	-
Timer / clock	-	-	-	X	X	X	X	X	X	?	-
Overload warning	X	-	-	-	-	X	X	-	-	-	-
Power factor	X	X	-	-	-	-	-	X	-	-	-
Frequency in Hz	X	X	-	-	-	-	-	X	-	X	-
Power supply for the meter	2 x LR44 Battery	Internal battery	1 x LR44 Battery	Internal battery	Internal battery	2x LR44 battery	2x LR44 battery	3x LR44	Internal battery	-	-
Other features										RMS, reactive, angle	External display
	X = feature available			- = feature not present							
Tested features											
Startup dealy	0	0	0	>15s.	>15s.	0	0	0	0	**	0
Off-line functionality***	X	-	X	-	-	X	X	X	-	-	-
Display viewing angle	Narrow	Narrow	Wide	Medium	Medium	Wide	Wide	Medium	Narrow	-	Wide

* = price in Euro as of early 2009, rounded up to the closest euro
** = not measured (Bluetooth connection)
*** = indicates whether the device can be operated without mains current

By looking at the product and their specifications, it becomes obvious that there are fewer producers than brand names. Identical products are being sold under different labels. This shows in our selection of devices which includes two appliances with a model name FHT-9999 and two with the name PM300. This is quite typical of brand discount stores. It is probable that other identical products with different or identical model names exist in the market. Photographs of the devices are presented in the Summaries section and may help to identify clones.

3. Method

3.1. Test environment

Tests were carried out in the power quality laboratory in Department of Electrical Engineering of the Helsinki University of Technology TKK (Espoo, Finland). The laboratory's electricity is routed through a filter for high frequency noise and the laboratory is also shielded from electric fields.

During the tests, power was supplied by Schaffner Profline 2100 EMC test system. This generator can produce up to 5 kVA per phase and voltage between 0-300 V with frequencies of 16-500 Hz. During tests voltage was set to 230 V (50 Hz), corresponding to the nominal network voltage. This power supply ensured that different test sets utilized constant input voltage, independent of network voltage and free from other power instability issues.

To evaluate the performance of the meters, a reference device was utilized. Reference measurements were taken with TOPAS 1000 power quality analyzer. TOPAS 1000 is an 8 channel computer-operated power quality measurement device. It has a 16 bit precision and its channels are electrically isolated. TOPAS is meant for measuring three-phase systems and since all channels are separate from each other, there is no galvanic connection between measurement connections. This means that all measurements are independent and can sample different voltages and currents.

3.2. Loads

For the measurement, electrical loads were necessary to determine the accuracy of the meters. Six different types of loads covering a wide spectrum of nominal ratings (from 1 to 600 W) and behavior (in terms of power factor and capacitive or conductive load) were chosen for the test. These were divided into small (less than 20 W nominal) and regular (> 20 W) loads. Two of the loads were small, four regular, they are listed in Table 2..

Table 2. Summary of the utilized loads.

#	Load description
1.	15W compact fluerescent lamp
2.	Battery eliminator 1W@5V load
3.	2x36W fluerescent tubes
4.	CRT display + PC (Non-PFC), web browser, instantaneous power
5.	200W dimmed incandescent bulbs (460 W nominal)
6.	600W resistor

The small loads we used were a charger and a compact fluorescent lamp. Battery eliminator with 1 W load is a normal small voltage transformer with resistive load (24 Ω) connected to it. This corresponds to a typical very small load, such as charging a mobile device. Compact fluorescent lamp (CFL) also has a low nominal power (15 W)and a very difficult current waveform.

In the category of regular loads, 2x36 W fluorescent tubes have choke to limit current flow, which makes their load bit inductive. Even more challenging target was an older, non-power factor corrected computer (non-PFC ATX PC, AMD 1 GHz Duron). In the tests, a webpage was opened on full screen, simulating web surfing, and screensaver and power saving modes were disabled . Therefore this computer did not have major difference in consumption between different computational loads. Parallel to the PC, we connected a 19" CRT monitor to test meters capability to measure switching power supply load. This older computer also had high power consumption, and the combined nominal power of the setup was 170 W. This computer setup was used to perform the electricity consumption measurement.

Incandescent lamps dimmed to operate at 200 watts (nominal 440 W) were used to test meters capability to measure clipped current. The dimmer holds current from flowing until the amplitude of voltage reaches the level set by the switch. Current flows again until the next zero crossing of current occurs. This causes current to have sudden changes and harmonics. The final load was 600 W resistor which resembles an electrical heating radiator or a hot plate. With this kind of load, current is in phase with voltage which should make it the easiest possible target to measure. This test also reveals how accurately meters can handle higher currents.

3.3.Procedure

During the measurement, all meters were plugged one meter after another so that they all measured the same phase (see Figure 1 for an illustration). Although the phase remains constant, this produces some error since meters do not measure their self consumption and meters' power is taken mostly with direct capacitive coupling to phase voltage. This capacitive coupling also creates some error when measuring small inductive loads as meters' capacitive connection cancels some of the inductive current on load. Almost all meters measure current with shunt resistor which means that on higher loads the voltage drop over each meter will affect meters after it. These errors were considered negligible as the reference measurements taken from directly before the meter stack and after the meters, just before the load. Reference measurement itself did not affect measured signals.

Figure 1. Meter stack containing 9 of the measured devices (illustration).

The tests began with pilot tests which employed a subset of meters, a wider selection of loads (including the six documented here) and were used to check the procedure. The power meter from Onninen broke down by the end of the pilot test. Meters internal 10 A fuse blew in a maximum load test and changing the fuse did not fix the meter. The results regarding Onninen reported here are based on comparing Onninen's pilot measurements to parallel PloggBlu measurements.

The actual measurements were done in two sets. The first set consisted of 7 meters. It included Christ-Elektronik CLM 200, Clas Ohlson PM300, LIDL PM333, Verkkokauppa.com FHT-9999, Hong-Kong FHT-9999, Motonet PM300 and BeAware prototype. The second set included Clas Ohlson EMT707CTL, Technoline Cost Control and Velleman NETBSEM2. The first batch was tested during 4^{th} -6^{th} of February and the second set 1^{st}-2^{nd} of April 2009.

TOPAS 1000 reference measurement device was connected to measure current and voltage on two separate connection points between load and supply. This was made so that measurements for different meters would be comparable since all meters in a set were connected in series. TOPAS was set to continuously measure RMS values with integration time of 10 seconds and instantaneous measurements were updated every 15 seconds. All measurements were also recorded on TOPAS' hard drive for further analysis and cumulative energy measurement.

After the measurements, we calculated a unique reference value for each meter based on its relative position in the stack. The reference value was calculated by assuming a linear function between the measurement points, that is, assuming an equal voltage loss and power consumption per meter. It should be noted the power consumption of the meters was generally below one watt, expect when the rechargeable battery-driven meters were charging.

Cumulative energy consumption measurements were done by leaving on the computer and when enough time had passed, the PC was shut down and the energy measurements were taken from meters. Measurement time for first set was 16.5 hours and 22 hours for the second set. Some of the measured loads where instable because they warmed up and their consumption changed for a short period after turning them on. Where needed measurements where taken after load current had become stable. This was required on computer and on both fluorescent lamps. If the readings were still drifting, typically between two adjacent numbers, then the highest reading appearing within a 5 second window was selected. All loads on each meter were measured once.

3.4. Analysis

The meter accuracy was estimated as an average measurement error of the meter. The accuracy was determined as a relative deviance from the meter-specific reference values. We started by including the type of deviance, above or below reference, but eventually all error scores were calculated as absolute deviances. This meant that we could calculate an average error across all load conditions by simply summing up the absolute error percentages from all measurements.

To help to interpret the data, we further classified the error percentages. Inspired by the idea of tolerance commonly applied in electronics, we transformed the error ranges were into scores, or three categories of error ranges; < 5 %, < 10%, > 10 %. Devices within 5% of the reference reading received score 3 (excellent), within 10% adequate (2 points), over 10% with 1 point (poor), and when no reading could be obtained 0 points (failure) The measurements of the small and regular loads, and consumption were further aggregated as category averages.

In the results section, we have additionally included some findings regarding the usability of the tested products. We consider the display viewing angles and the readability of the meter after it has been detached from the mains current.

4. Results

4.1. Summary about accuracy

Each meter was tested against the six loads as described in 3. The error ranges were derived from the relative deviations of the meter reading and the reading of the reference device. The average errors in absolute figures were also calculated for all devices, and their average was 9.2% (standard deviation = 6.3%). The average errors associated with individual devices are displayed in Figure 2 below:

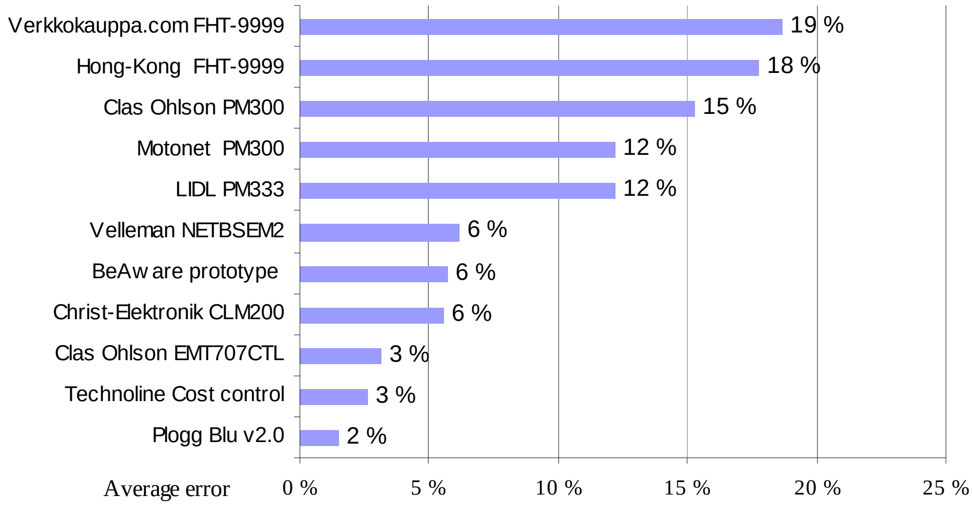

Figure 2. The average errors in each meter in comparison to the reference value. All errors are presented as absolute values deviating from the reference.

We found no relation between the accuracy of the device and its retail price (see Figure 3). This was not surprising in the given price range, because the manufacturing costs for the tested devices are likely very similar. Bit surprising was that the two more expensive devices did not perform significantly better.

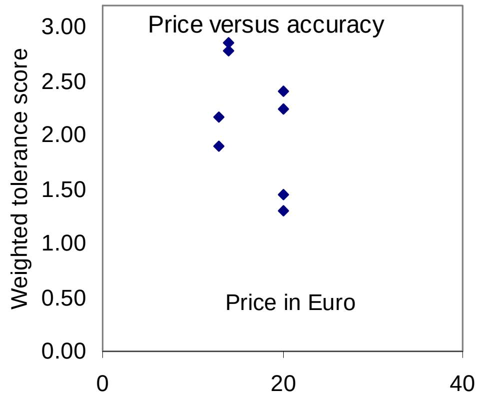

Figure 3. Relation of price and accuracy. The two most expensive meters excluded.

The error range scores are presented as absolute figures, so that the directions of the deviances are not considered. However, the analysis of errors revealed that in the 73.3% of measurements the deviances were negative, i.e. the device underestimated the amount of electric power. If only 10% deviances are considered, this balance remains, 75.0% of devices still underestimate the load. This trend is illustrated in Figure 4.

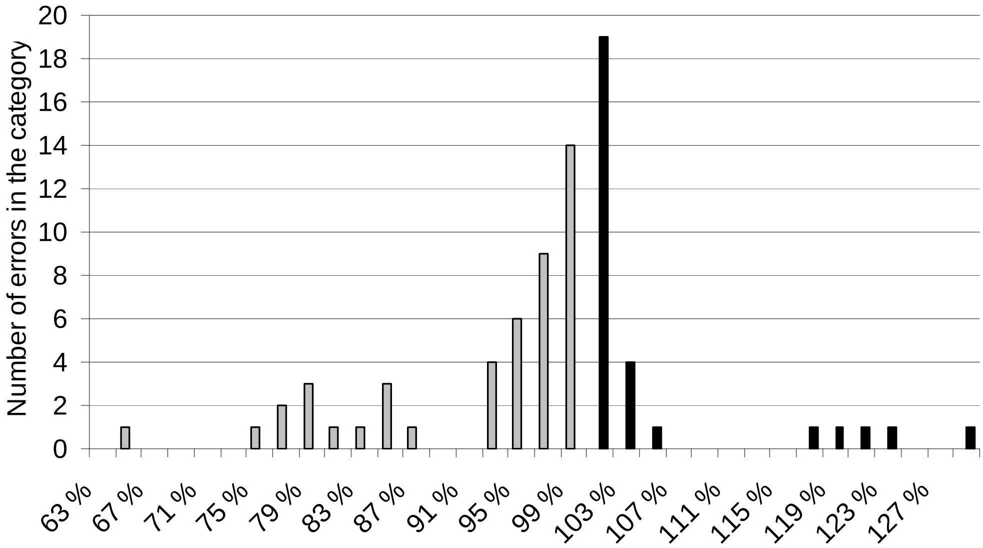

Figure 4. The distribution of errors across all measured devices and all measurements. The measurements have been categorized into 2% categories (X-axis) and the number of deviations in each category is indicated on the Y-axis. 100% represents the correct measurement in comparison to the reference values, categories below 100% are marked in gray, over 100% in black.

Of all tested meters, PloggBlu was clearly the most accurate device with less than 2% average error. The score of expensive Christ-Elektronik was reduced by poor performance with the smallest load. The accuracy scores of Technoline Cost control and Clas Ohlson EMT707CL are very impressive considering their price. The details about the accuracy of each device are given on the next page in Table 3. For the table, we have provided the scores for each load and categorized them into consumption, small instantaneous loads, and regular instantaneous loads. Each category has its own category average figure. On the bottom of table, the scores in each category are summed to a weighted average. The consumption has a relatively big weight, 40% as accurate readings over a long period time are considered viable for many purposes. Both classes of instantaneous power have the same weighting. This may exaggerate the differences in measuring small loads, which seemingly contribute little to the overall consumption, but are nevertheless important for stand-by measurements. The reader is urged to re-calculate the figures according to the desired weighting scheme.

Table 3. Summary of the measurements. Scores stand for error ranges (3 points = <5%, 2 points =<10%, 1 points = >10%, 0 points = no reading)

Measurement	**LIDL** PM333	**Clas Ohlson** EMT707CTL	**Techno-line** Cost control	**Hong-Kong** FHT-9999	**Verkko-kauppa** FHT-9999	**Clas Ohlson** PM300	**Motonet** PM300	**Velleman** NETBSEM2	**Plogg** Blu v2.0	**Christ Elektro-nic** CLM200	**BeAware proto**
Average error	12.2 %	3.2 %	2.6 %	17.8 %	18.7 %	15.3 %	12.2 %	6.2 %	1.5 %	5.6 %	5.7 %
Consumption											
1. Computer, Non-PFC	1	3	3	3	3	1	1	3	3	3	3
Instantaneous power, < 20 W load											
2. 15W CFL	3	3	3	1	1	1	1	1	3	3	1
3. 1W Battery elimin.	3	2	2	0	0	1	1	1	3	1	3
Category average	3	2.5	2.5	0.5	0.5	1	1	1	3	2	2
Instantaneous power, > 20 W load											
4. 70W fluerescent tub.	3	3	3	3	3	3	3	3	3	3	3
5. 170W PC, Non-PFC	1	3	3	3	3	1	1	3	3	3	3
6. 200W dimmed bulbs	1	2	3	2	3	1	3	3	2	2	3
7. 600W resistor	3	3	3	3	3	3	3	3	3	3	3
Category average	2	2.75	3	2.75	3	2	2.5	3	2.75	2.75	3
Weighted scores											
Consumption 40.0 %	0.40	1.20	1.20	1.20	1.20	0.40	0.40	1.20	1.20	1.20	1.20
Instant. power, < 20 W 30.0 %	0.90	0.75	0.75	0.15	0.15	0.30	0.30	0.30	0.90	0.60	0.60
Instant. power, > 20 W 30.0 %	0.60	0.83	0.90	0.83	0.90	0.60	0.75	0.90	0.83	0.83	0.90
Total score	1.90	2.78	2.85	2.18	2.25	1.30	1.45	2.40	2.93	2.63	2.70

Measurement data and for different measurements of individual devices are available by request from the authors.

4.2. Usability

In this evaluation we did not conduct any full-scale usability evaluation. This was because the primary interest was in determining the technical quality of the appliances and because the functions provided by the devices differ considerably. However, some observations were made. The fact that the majority of devices contain a similar number of control buttons implies that the devices with a greater number of functions may be more difficult to operate. While our observations during the tests confirmed this, we did not encounter any major usability issues with the interfaces. All meters provided a straightforward access to the most important consumption and power figures in a straight-forward manner. However, two concerns came up in the inspection.

The **LCD display viewing angles** were an issue, because sometimes the meters very difficult to read. Even though we operated the devices in a quite flexible and open laboratory setting, we had repeated difficulties in reading some of the devices. These observations are presented in the lowermost part "Tested features" of Table 1. The devices with viewing angles evaluated as "narrow" were only readable when viewed directly. "Medium" score indicates a wider, but still constrained viewing angle and "wide" displays are the only ones that can be read from various angles.

Viewing angles are an important property because all inexpensive devices have the display fixed the body of the meter. As the user has no other way to extract the electricity consumption data this means that the readability of the display determines the usefulness of the device. While battery-powered devices (5 of all tested) can provide consumption figures without power input, reading instantaneous power always requires the device to be plugged in. In many homes, electric plugs for many basic appliances, such as fridge, dish washer, freezer etc., can be in difficult to access locations. If the meter is not readable from a wide range it maybe impossible to use in these environments. This applies to all affordable units that are more or less of the same volume. The display issue can be circumvented if the display is an external device, as in Christ-Elektronik CLM-200, or if the data can be transferred wirelessly from the meter to a receiver device. PloggBlu v2 utilizes the latter option by allowing the user to receive the consumption information via Bluetooth connection. The maximum current function available in some of meters (see Table 1) may also circumvent this problem partially.

We also noted that some of the battery-powered devices may take a considerable amount of time to power on. This is a consequence of their structure; these meters charge their battery from the mains when connected. If they are stored normally, then they will loose the charge and will have to re-charge themselves before they can be operated. This may render the device useless if the battery dies completely.

5. Conclusion and Summaries

In summary, the range of power consumption meters available for end users is wide. By selecting the right device, a consumer can acquire an accurate meter affordably. However, with inexpensive devices, there are usually drawbacks. In the tested devices, the biggest problem was usually the embedded display, which may seriously hinder their usage across physical locations of a household. In future, we expect to see very different, much more flexible solutions for addressing the needs of measuring electricity consumption at home.

In this paper we have reported an evaluation of nine consumer electric power meters. This work was motivated by the recent introduction of this product typology to the consumer market. This indicates that there is demand for this kind of energy information (Liikkanen, 2009). Power consumption meters are a quite simple way of trying to empower consumers. The present availability of cheap devices and borrowing services makes it easy for consumers to adapt an active role in their electricity consumption. However, do the present meters provide adequately accurate data in order to lead to right direction?

In the present study we investigated the accuracy of nine affordable power meters using three different types of measures in a laboratory. We inspected the meters for instantaneous power reading with both small and regular loads. The loads were chosen to be representative of types of devices users might commonly own and be interested to measure. Additionally we investigated the accuracy of consumption measurement by letting the meters run continuously over 16 hours while a desktop computer was idling. Generally, the devices performed best in measuring large, instantaneous loads and had the most difficulties with small loads. We had expected the small loads to be problematic because many of the tested devices were not even specified to handle small loads properly (see Table 1 for minimum VA). This partially explains the present results. The response to the reactive power was surprisingly good and only three devices had notable problems in calculating the effective power out of the total consumption.

The accuracy readings we have presented do not reveal the total technical quality of the devices. We did not make tests of re-test reliability, prolonged endurance, or power quality tolerance. However, the fact that we witnessed the break down of one of the devices (Onninen REV TS-JD) during our normal test procedure, implies that the manufacturing quality of the appliances may match their price tag. About the more expensive devices, such as Christ-Elektronik CLM 200, we know that the utility which borrowed us the device has been circulating the meter for several years among its customers. The specific device we tested has likely been used by tens if not hundreds of customers before the test, implying a strong record for robustness. Even though we measured only a single device from each brand, some hints of this manufacturing tolerance can be seen in the slightly different accuracy ratings for devices that look identical and probably also host the same electronic design (although this was not ascertained).

Our present results show that the technical quality of inexpensive power meters is variable. If a consumer makes an uninformed guess in buying a meter, the acquired meter may provide readings with an average error of almost 20% and even in critical use cases, such as measuring long-term consumption. Of course, even this poor resolution maybe adequate for some purposes, but generally it unconceivable that someone would like to pay for 20% extra on their electricity bill by mistake. However, with the help of the present results, a consumer can find an affordable device that provides surprisingly accurate data. Two of the tested meters with a street price less than 15 euro performed with less than 5% error under various conditions. On the other hand, a step away from the inexpensive consumer products category to 50-250 euro adds only little to meters' accuracy but does increase their usefulness and flexibility.

Beyond the accuracy, the tested products have a few potential usability issues. The biggest concern for their practicality comes from their built-in displays. Some models include LCD displays that are readable only from a very constrained angle. This severely limits their usefulness in places where the space is scarce; close to the floor, ceiling, walls, or where ever power outlets are commonly located in. Although extensions cords may help to circumvent this problem, the viewing angles are a major problem. In the more expensive Plogg and Christ-Elektronik this is not an issue by because the display unit is not fixed to the body of meter. Another issue encountered in two of the meters was the internal battery. The dis- and re-charging of the battery slows down the operation, which is annoying for the operation and maybe fatal in a longer term.

Looking to the future of power meters, it is hardly necessary to make the meters any more accurate (on average). However, the data extraction and interpretation will need more attention. Future smart home systems, such as those envisioned by the BeAware project (see acknowledgements), should produce the power measurements in a new kind of way that simplifies the measurements and facilitates making the right inferences from the readings (Liikkanen, 2009). Usability will be a major concern as new features, such as social networking and mobile access become introduced.

5.1.Individual devices

Lidl PM333

13 € Accuracy: **1.9 / 3**

Average error: **12.2 %**

The cheapest unit included in the test performed well with small loads. Despite the fact that it can display power factor, it did not do well with reactive loads. Consumption and bigger load measurements were also inaccurate. The device has lots of functions but its usage is severely restricted by the reduced viewing angles of the display.

Clas Ohlson EMT707C TL

14 € Accuracy: **2.8 / 3**

Average error: **3.2 %**

The new model branded by Clas Ohlson manufactured by EverFlourish was a very positive surprise. It performed very well across conditions, handling all loads properly. It has a good selection of features, but suffers considerably from the poorly readable display.

Technoline Cost control

Best value for the money

Appr. **14 €** Accuracy: **2.9 / 3**

Average error: **2.6** %

Technoline had the second best accuracy of all devices we tested. Given the price, this is was quite surprising. The device also embeds an excellent display. On the downside, this device has only the basic functions, instantaneous power, consumption, and cost. However, these will likely suffice for most customers. Cost control is currently not available in Finland.

Hong Kong FHT-9999

13 € Accuracy: **2.2 / 3**

Average error: **17.8 %**

This meter is equipped with an internal battery which allows it to be operated even when disconnected from the mains. However, the capacity of the battery seems pretty poor as we witnessed long startup delays when the device was re-connected. The device has the basic functions and provides average accuracy. Even though the reactive loads are handled quite well, small loads are not. This performance can not be justified by the price, so the verdict is unsatisfactory.

<table>
<tr><th>Verkkokauppa.com FHT-9999</th><th>Velleman NETBSE M2</th></tr>
<tr><td>

20 € Accuracy: **2.3 / 3**

Average error: **18.7 %**

FHT-9999 sold by Verkkokauppa.com is identical to the Hong Kong power meter. The measurement accuracy is slightly better but all arguments of Hong Kong apply here. On the positive side, both FHT-9999s have adequate displays and are the only affordable units to provide two tariff settings. The higher price of Verkkokauppa.com FHT-9999 in contrast to Hong Kong is by no means legitimate.

</td><td>

20 € Accuracy: **2.4 / 3**

Average error: **6.2 %**

Velleman includes the best package of functions. It can display all typical figures, but also power factor, network frequency, and the maximum load. The device was very accurate on all regular loads. The errors for reactive loads and consumption were excellent. However, the meter is inaccurate with small loads restricting its usefulness. In overall, the range of functions in this battery-powered device makes it interesting product for many use cases.

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<tr><th>Clas Ohlson PM300</th><th>Motonet PM300</th></tr>
<tr><td>

20 € Accuracy: **1.3 / 3**

Average error: **15.3 %**

The PM300 is equipped with one of the best displays. Because the device is battery-powered, it can also be configured anywhere. However, the major problem of the meter is that it provides very inaccurate results. In particular small loads and reactive power cause major underestimation of the electric power. The consumption measurements were very bad as well.

</td><td>

20 € Accuracy: **1.5 / 3**

Average error: **12.2 %**

This PM300 is identical to the Clas Ohlson PM300 model except for the white housing. This model includes an audible overload setting for instantaneous power. The accuracy of this unit was surprisingly bit better than the Clas Ohlson, but only on one of the seven measurements. This model could only be recommended for big, completely resistive loads.

</td></tr>
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Onninen REV-TS-JD

40 € Accuracy: **1.5* / 3**

Average error: **- %**

The Onninen meter has more buttons than any other device, even though the number of functions is typical. The test unit broke down before in a maximum load test and thus we could not fully test the unit along the other devices. The accuracy score given here is derived from initial tests and covers only instantaneous power with loads comparable to 3, 4, 5, and 6. The average error for bigger loads was excellent, only 1.5%. However, a small computer standby load (5-10W) was not registered at all. Thus the value for money appears questionable.

PloggBlu

Most accurate

Appr. **110 €** Accuracy: **2.9 / 3**

Average error: **1.5 %**

Plogg Ltd. produces a range of wireless power meters for temporary and permanent installations. PloggBlu uses Bluetooth communication to transmit consumption information. The manufacturer provides client software capable of logging consumption for a variety of operating systems. The Plogg unit was the most accurate device we tested. It performed flawlessly across conditions and would have received a full score without a single 5.3% deviation from the reference. The wireless connection adds to versatility of the device, but also makes it fully dependent on receiving devices.

Christ-Elektronik CLM 200

Appr. **180 €** Accuracy: **2.6 / 3**

Average error: **5.6 %**

Christ-Elektronik GmbH produces sophisticated meters that are used by several Finnish utilities to help their customers to inspect their appliances. CLM 200 consists of a long cable between the plug and the main unit. Only instantaneous power and consumption functions. Meter is quickly readable and easy to use. The cabling enables measurements in hard to reach locations. The device is very accurate on all but the smallest loads. Given the specified resolution, this is not surprising, but nevertheless limits the applicability of the device.

BeAware Prototype v.1

n/a Accuracy: 2.7 / 3

Average error: **5.7 %**

For the purposes of the BeAware research project, a new power sensor unit was built from a scratch. Although this is not, and will unlikely become, a commercially available unit, it was included here for benchmarking. The unit does not include a display but instead transmits the consumption data wirelessly using a custom radio protocol. In the test, the unit performed very well, only the 15 W CFL load brought up the need for re-calibrating the instrument.

6. Acknowledgements

We thank electricity providers Helsingin Energia and Vattenfall Finland for providing meter for the trials.

This work was carried out as a part of the BeAware project. BeAware is a European research & development effort that concentrates in examining ways to improve energy awareness and reduce electricity consumption in households across Europe. For more information, see http://www.energyawareness.eu/

7. References

Selected electric power-meter manufacturer web sites:

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HELSINKI UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF HELSINKI

This technical report describes the test methodology and provides the results of a comparison of electric power meters available for end-users.

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