Ecodesign of Energy Related Products Lot 27 – Uninterruptible Power Supplies

Task 3 – Consumer/user behaviour and local infrastructure

Report for European Commission, DG Energy

Ricardo-AEA/R/ED56828
Issue Number 1
Date 01/03/2013

ISR
University of Coimbra

Customer:

European Commission, DG Energy

Customer reference:

ENERG/C3/413-2010-LOT 27-SIi2.611335

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Ricardo-AEA reference:

Ref: ED56828- Issue Number 1

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01 March 2013

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1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design working plan 2009-20111. This preparatory study is the starting point of this process. It aims to identify what are the current market size and composition, technical solutions, potential future technology improvements and possible policy options.

The Preparatory Study will follow the Commissions established methodology and will address the following Tasks:

- Task 1: Definition
- Task 2: Economic and Market Analysis
- Task 3: Consumer Behaviour and Local Infrastructure
- Task 4: Technical Analysis Existing Products
- Task 5: Definition of Base Case
- Task 6: Technical Analysis of BAT
- Task 7: Improvement Potential
- Task 8: Scenario, Policy, Impact and Sensitivity Analysis

In order to ensure the study is conducted in an open and transparent manner and allow the public to review and comment on the work being carried out, the study team has established a project specific website: www.ecoups.org. The website allows the following important functions to be fulfilled:

- Raising awareness and understanding of the project with product developers, manufacturers and other stakeholders
- Informing stakeholders about the procedures of the study and the input requested from them
- Keeping stakeholders informed of developments and current findings
- Enabling stakeholders to provide feedback, information/data and to raise questions
- Putting into practice the principle of two-way dialogue and an exchange of information
- Allowing the project team to make contact with stakeholders who are unable to attend workshops. This will be particularly useful in terms of gathering information and data.
- Project questionnaires will be posted on the website for stakeholders who cannot attend workshops.

This report presents Task 3 which addresses user behaviour and information in relation to real life efficiency, load and usage patterns and repair and maintenance. End of life behaviour is identified, including product lifetimes and best practice. Aspects relating to local infrastructure and the implications for UPS are identified.

We continue to welcome feedback and input from stakeholders.

2 Subtask 3.1 – Real Life Efficiency

This subtask considers the real life efficiency and in use practices of UPS. It addresses UPS loads, usage patterns and characteristics of use, repair and maintenance and the availability of spare parts. These in use parameters will affect the efficiency and lifetime of the UPS in practice. Key information required by the consumer/end user to maximise real life efficiencies is highlighted.

2.1 UPS Efficiency and load profiles

UPS operation costs are always a very important issue to the user, in terms of lifecycle costs. Therefore, the user must be informed about the power consumption and losses of the UPSs in the market. However, in several applications of UPSs, energy efficiency is not the most important issue. The most important issue can be reliability/safety and redundant systems are used to increase the reliability but leading to a lower energy efficiency.

In UPSs the losses not only cause a direct increase of the consumed energy by the UPS but also increase the consumption of air conditioning, which is required to maintain optimum temperatures, essential to good battery life too, where the UPS is located.

The efficiency of an UPS, as defined by the International Electro-technical Committee, is “the ratio of (active) output power to (active) input power under defined operating conditions” (IEC, 1999). Defined operating conditions refer to a specific load level and load type. The efficiency of an UPS depends of the load level, achieving the highest efficiency with a 100% load (Figure 1). However, the curve is relatively flat with load levels higher than 50%.

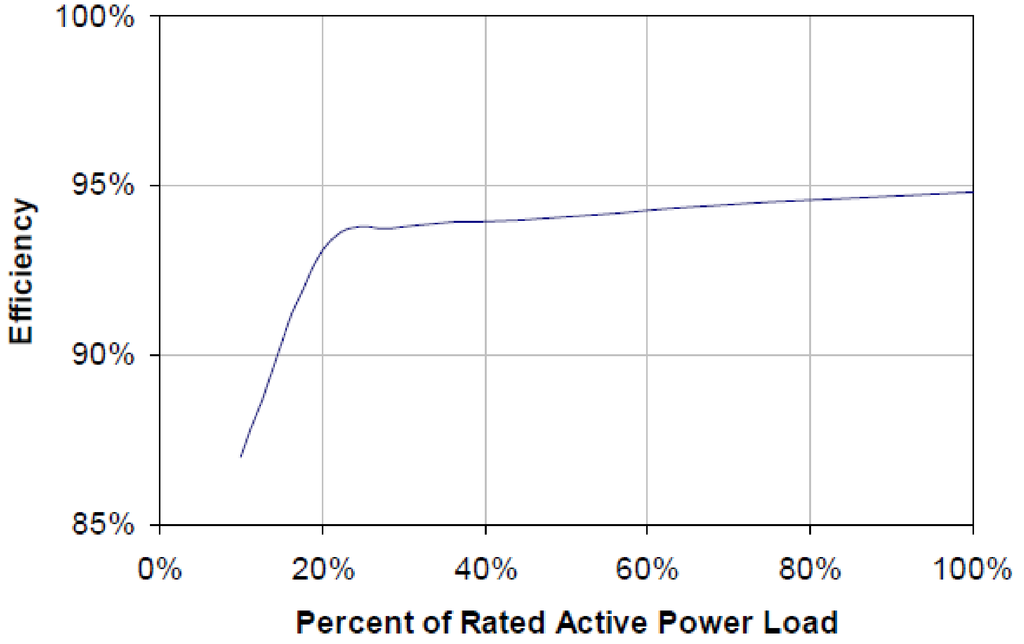

Figure 1: Typical UPS efficiency curve (PIER, 2008)[1]

[1] PIER. “Uninterruptible Power Supplies, a Data Center Efficiency Opportunity.” Technical brief. California Energy Commission’s Public Interest Energy Research (PIER) Program, 2008.

An UPS operating with a low load level will have significant losses when compared with the same UPS operating at full load. In a realistic scenario the load level is typically between 10 and 30% (Sawyer, 2006)[2], which leads to a 4-17% reduction of efficiency (Figure 2). Therefore, knowing the efficiency with loads below 50% is very important to estimate the real efficiency.

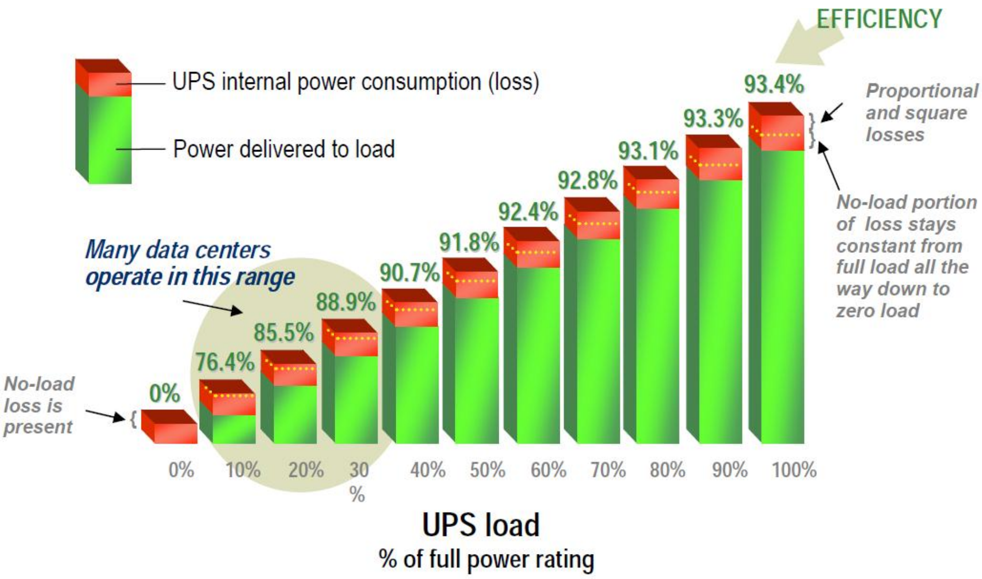

Figure 2: Breakdown of total UPS input power (Sawyer, 2006)[2]

This trend in efficiency of the UPS is due to the three types of UPS losses (Figure 3):

- “no-load” losses - independent of load and attributed to powering transformers, capacitors, logic boards, and communication cards;
- proportional” losses - with higher load more power is need by several components (e.g. switching losses from transistors, and the resistance losses from capacitors and inductors);
- “square-law” losses - with the current increasing loses with the square of the current are caused (the power losses dissipated in the form of heat).

There are two major contributors to UPS inefficiency: the inherent losses of the UPS modules themselves and how the system is integrated with the load (e.g. load level, load type and controls).

[2] Richard L. Sawyer, “Making Large UPS Systems More Efficient”, 2006

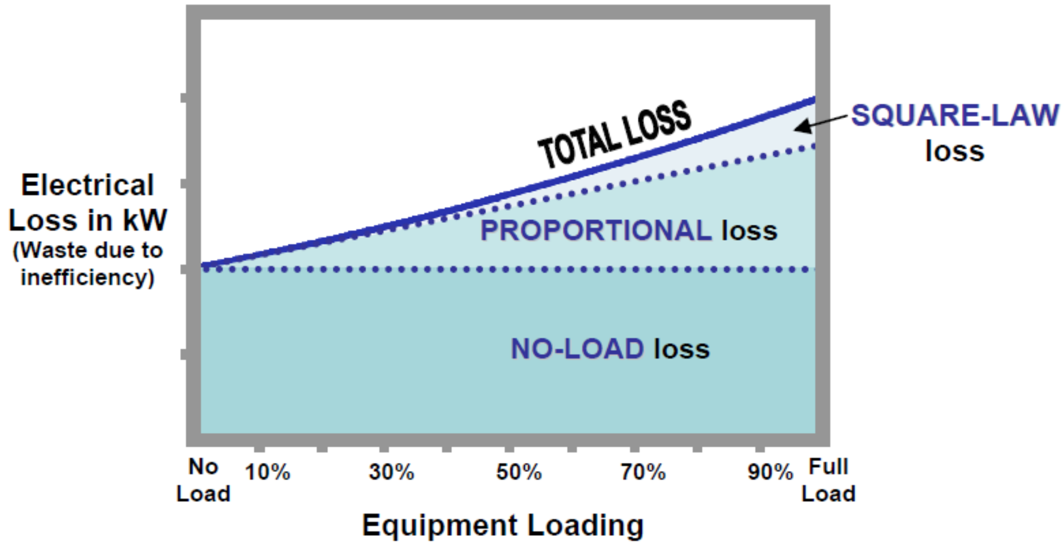

Figure 3: Power loss graph (Sawyer, 2006)[2]

The load type has a strong influence on the achieved efficiency. UPS efficiency is usually tested with resistive or linear loads, but several UPSs are used with non-linear loads, with poor power quality (low power factor and high total harmonic distortion). The low power factor will require a higher peak current from the UPS, decreasing its efficiency (Figure 4).

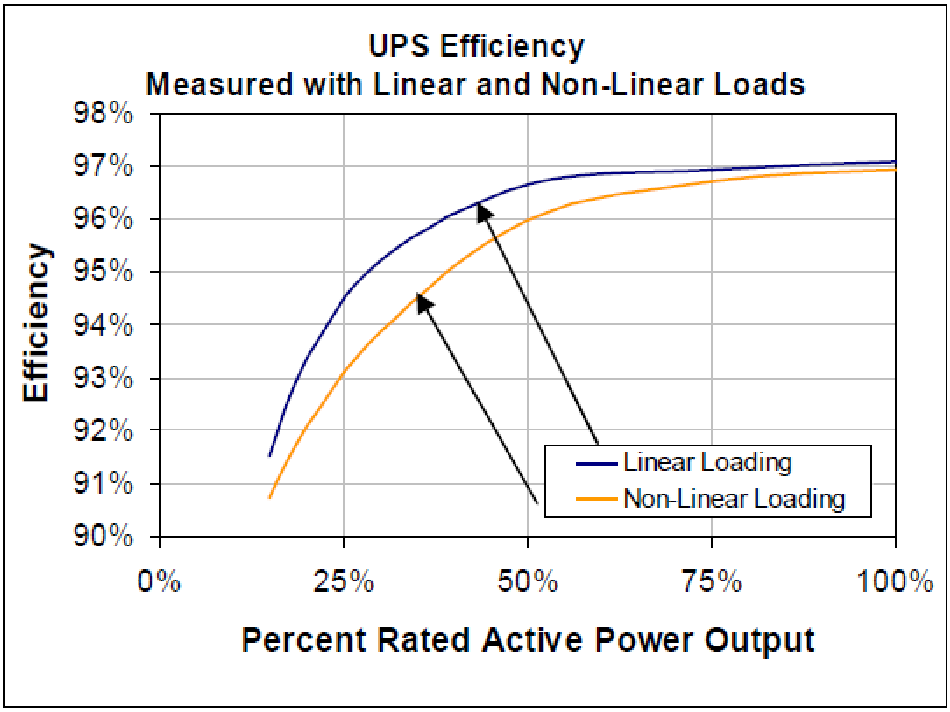

Figure 4: UPS efficiency with linear and non-linear loads (PIER, 2008)[3]

To increase the energy efficiency of UPSs, several technological improvements have been implemented, such as (CEMEP, 2009)[4]:

- The new topologies (conversion mode, Eco-mode) provide better UPS efficiency;

[3] PIER. "Uninterruptible Power Supplies, a Data Centre Efficiency Opportunity." Technical brief. California Energy Commission's Public Interest Energy Research (PIER) Program, 2008
[4] CEMEP Environmental Considerations, Focus on UPS, 2009.

- The newly-developed low resistance IGBTs (Insulated-Gate Bipolar Transistor) and rectifiers used in UPS allows further savings for the user
- The improved capacitors with lower field aging (EMERSON, 2008)[5];
- The transformer-less UPS reduces heat dissipation, thus allowing additional savings on power and cooling infrastructures.

To improve performance and minimize maintenance requirements other options are being used such as:

- The power monitoring and remote management (requiring an additional infrastructure of monitoring, communications and control) help minimizing on-site service engineers intervention;
- The intelligent management of battery increases battery lifetime;
- The modularity of UPS brings adaptability (right size for the needs of newly purchased equipment) and scalability (capability to expand equipment without complete product replacement).
- High efficiency UPSs also allow smaller electrical network devices (e.g. cables, breakers, gen set).

To encourage the high-efficiency design of UPS and to support the consumers on the decision of a UPS acquisition (considering energy efficiency as one of their criteria for buying), a means of providing information to the user is through labelling schemes.

Since the efficiency is dependent on the load level, the requirements to define an efficient product must also take into consideration the load level. Therefore, the average efficiency is used, considering different load levels. The following equations are approved by the Energy Star program to evaluate UPSs (Energy Star, 2012)[6]. Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy for labelling efficient appliances. Only the appliances achieving all the requirements of the program can receive the Energy Star label.

For AC-output UPSs the average efficiency is expressed as:

$$Eff_{AVG} = t_{25\%} \times Eff|_{25\%} + t_{50\%} \times Eff|_{50\%} + t_{75\%} \times Eff|_{75\%} + t_{100\%} \times Eff|_{100\%}$$

Where:

- Eff_{AVG} is the average loading-adjusted efficiency;
- $t_{n\%}$ is the proportion of time spent at the particular n% of the reference test load;
- $Eff_{n\%}$ is the efficiency at the particular n% of the reference test load.

For DC-output UPSs the average efficiency is expressed as:

$$Eff_{AVG} = \frac{Eff|_{30\%} + Eff|_{40\%} + Eff|_{50\%} + Eff|_{60\%} + Eff|_{70\%} + Eff|_{80\%}}{6}$$

The approved minimum efficiency to receive an Energy Star label is presented in Table 1.

[5] EMERSON, Capacitors Age and Capacitors Have an end of Life, 2008.
[6] ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.

Table 1: Minimum average efficiency requirement to the Energy Star label (Energy Star, 2012)

Rated Output Power	Input Dependency Characteristic		
	VFD[7]	VI[8]	VFI[9]
P ≤ 1500 W (AC)	0.967		0.0099xln(P)+0.815
1500 W < P ≤ 10,000 W (AC)	0.970	0.967	
P > 10,000 W (AC)	0.970	0.950	0.0099xln(P)+0.805
P > 10,000 W (AC with metering and communication)	0.960	0.940	0.0099xln(P)+0.795
(DC)	0.955		
P > 10,000 W (DC with metering and communication)	0.945		

A test method and reporting template was developed by the Energy Star program for the UPSs evaluation. A Power and Performance Data Sheet (PPDS) and an Electronic Comparison Tool have been developed to allow the publication of the performance information for qualified products and enable the comparison between products.

However, more detailed labelling schemes have been proposed with regards UPS. The Swiss Federal Office of Energy (SFOE) drafted a proposal for an energy label for UPS systems back in 2002, using a Q/E (Power Quality/Energy) matrix to evaluate both the process-oriented quality criteria and the energy relevant parameters. The proposed label (Figure 5) was designed to match the style of the existing EU labels for other electric appliances[10]. It displays the measured power losses in different modes of operation, providing information about the expected energy consumption due to the energy losses. Different efficiency classes were attributed for different levels of losses:

- A – losses <2%;
- B – losses <4%;
- C – losses <6%;
- D – losses <8%;
- E – losses <10%;
- F – losses <12%;
- G – losses >=12%.

It was also proposed that the label would provide information about the UPS's capability to filter the power grid disturbances and the presented power quality (power factor and total harmonic distortion). This proposal was not taken any further.

[7] VFD - Voltage and Frequency Dependent
[8] VI - Voltage Independent
[9] VFI - Voltage and Frequency Independent
[10] http://ec.europa.eu/energy/efficiency/labelling/labelling_en.htm

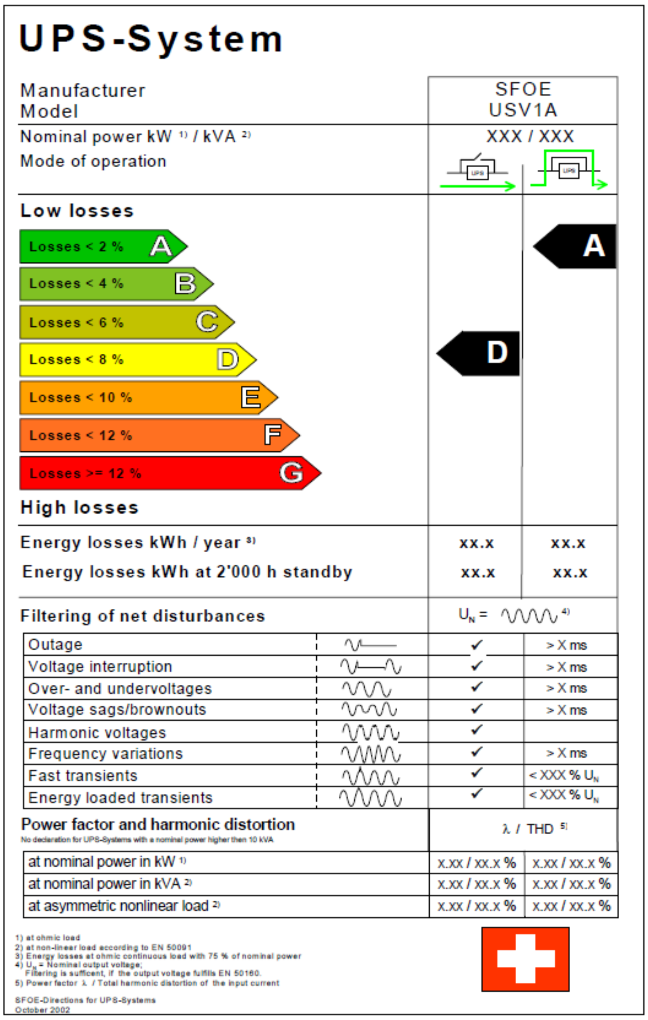

Figure 5: Label proposed by SFOE[11]

The Lawrence Berkeley National Laboratory (LBNL)[12] put forward a modified version of the above proposal for a label with the following changes (Figure 6):

- The energy losses in each class were replaced by the energy conversion efficiency;
- The energy losses incurred by operating the UPS for 2000 hours with no load were removed;
- The information about other issues was removed (filtering net disturbances and power quality).

[11] Schnyder Engineers Ltd. *Label for UPS Systems*. The Swiss Federal Office of Energy. 2002.
[12] http://hightech.lbl.gov/documents/ups/final_ups_report.pdf

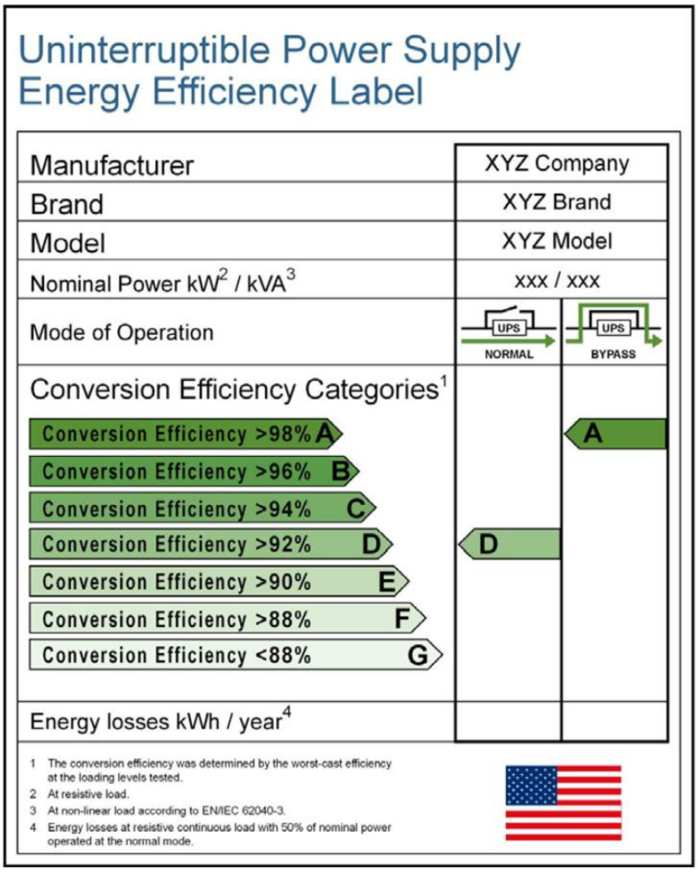

Figure 6: Label proposed by LBNL[13]

Such proposal received comments from the manufactures with the following main concerns:

- The label should also display information about general design and performance (filtering power grid disturbances and power quality);
- The column with the UPS efficiency in bypass mode should be removed (because such operation only happens some hours during the year);
- Lower load levels (below 50% of the nominal load) should be required during the tests, because the majority of UPSs operate with such load levels;
- The used scale (between "G" and "A") is already obsolete, because several appliances already have the additional categories of "A" and "A++".

As with the initial proposal from the Swiss Federal Office of Energy, this updated proposal was not taken forward.

2.1.1 Conclusion

UPS operation costs are always a very important issue to the user, in terms of lifecycle costs. Therefore, the user must be informed about the power consumption and losses of the UPSs in the market. To encourage the high-efficiency design of UPS and support the consumers on the decision of a UPS acquisition, clear information is required, labelling schemes are one possible means for this. The US Energy Star program will label the UPS with a minimum level of efficiency. However, more detailed labelling schemes have been proposed by Swiss Federal Office of Energy and by the Lawrence Berkeley National Laboratory LBNL), but not yet implemented. Given that labelling is not in place (except Energy Star) the product information is currently provided through datasheets and product brochures.

[13] LBNL, High Performance Buildings: Data Centers Uninterruptible Power Supplies (UPS), 2005

The key factors that must be considered regarding energy efficiency are the size of the UPS, load type and load level. Larger UPS modules typically have higher energy efficiency than smaller ones, because the support power required for control electronics and auxiliary components becomes a smaller portion of the total capacity of the UPS system.[14] The load type and load level have a strong influence on the achieved efficiency. The UPS will not be operated under full load and therefore the peak efficiency rating is not enough to evaluate the efficiency of a UPS, since with lower load levels the efficiency is also lower. The use of non-resistive loads will also lead to lower energy efficiency.

Higher UPS efficiency also provides more battery runtime for the same battery capacity and produces cooler operating conditions within the UPS environment, which in turn extends the service life of components and increases the overall reliability and performance. Other important factors to ensure a good efficiency level are the correct operating temperatures and maintenance procedures.

2.2 Usage patterns - operation conditions

The ambient temperature in locations such as server farms is significantly higher than 20°C, which is commonly used as the reference temperature for the lifetime calculation of batteries. A temperature increase of 10°C reduces the battery lifetime by 50% [15]

The usage patterns of UPS systems are given by the stability of the local grid and safety concerns related to the connected equipment. In some cases as private or most office PCs the risk of failure is relatively low and simple UPS units are common. UPS systems in server farms, for air traffic, railway, healthcare and similar purposes need 100% availability, so they use redundant UPS units. In uses such as these reliability will be a more important consideration than energy efficiency.

2.2.1 Purposes and characteristics of use

The purposes that UPS systems are put to may vary between EU countries as user habits and national grid conditions differ. Users may own more than one type of UPS for different purposes and the correlation between ownership and use habits needs to be established.

There are different groups of UPS systems: one group of devices is supplied as standard off-the-shelf product as most business to consumer (B2C) products. This includes for example UPS units for desktop PCs, home servers and other domestic and office purposes. UPS systems for data centres, where standardised UPS modules are rack mounted are business to business (B2B) products. When batteries are exchangeable lead acid cells, cells are usually recycled after 3-15 years of operation, depending on used technology[16]. Most complex UPS systems use an alarm system that informs about battery or system failure. Single unit UPS systems could provide such a feature as well. An App based system that would make the alert available on a Smartphone could foster such a feature.

UPS systems for traffic infrastructure, hi-tech hospitals and manufacturing sites, especially in the chemical industry, are usually custom-made installations. These occupy one or more rooms in a building and use separate battery banks. The main configuration of these B2B installations lasts for 20 to 30 years with batteries exchanged periodically after about 3 years depending on the specification of the batteries. In server farms with the installation of new servers the respective UPS is exchanged. Therefore most server farm related UPS systems are exchanged prior to the technical end of their lifetime. As a consequence the real lifetime

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[14] Chris Loeffler, Which UPS is right for the job, Eaton, 2009
[15] http://www.northstarbattery.com/sitesolutions/sitestar/index.php
[16]http://www.apcdistributors.com/white-papers/Power/WP-30%20Battery%20Technology%20for%20Data%20Centers%20and%20Network%20Rooms%20-%20Lead-Acid%20Battery%20Options.pdf

of UPS system in server farms is shorter than their technical lifetime expectation compared to UPS systems used in industry.

Configuration on UPS systems appears to some degree to be 'led' by a company's approach to risk management as to how they configure one or more back-up UPS systems. The degree of reassurance and load/frequency security of units results in the configuration of the specific UPS. Multiple units increase power supply security, but would potentially increase energy consumption through reduced efficiency and standby consumption.

Detailed usage patterns will be defined through further consultation with industry.

The increasing impact for UPS batteries from additional stress by reduced stability of the national grid is shown in the Table 2.

Table 2 Stress factors and their impact on damage mechanisms (light blue: strong impact; yellow: medium impact; green: little impact) [17]

	Corrosion of the positive grid	hard/ irreversible sulfation	shedding	water loss / drying out	AM degradation	electrolyte stratification
discharge rate	Indirect through positive electrode potential	higher discharge rate creates smaller AM sulphate crystals and leads to inhomogeneous current distribution causes inh. SOC on the electrode	probably increased shedding; outer AM fraction cycles at higher DOD level cycling [pasted plates]	none	increases inner resistance due to AOS-model (agglomerate of sphere)	Higher discharge rate reduces electrolyte stratification. On the other hand less homogeneous current distribution plays negative role.
time at low states of charge	Indirect through low acid concentration and low potentials	A strong positive correlation: longer time at a low SOC accelerates hard/irreversible sulphation.	no direct impact	none	None	Indirect effect Longer time leads to higher sulphation and thus influences the stratification.
Ah throughput	no impact	no direct impact	impact through mechanical stress	no direct impact	loss of active material structure, larger crystals	A strong positive correlation: Higher Ah throughput leads to higher stratification
charge factor	a strong indirect impact because a high charge factor and an extensive charge is associated with a high charging voltages (high electrodes' polarisation)	negative correlation, impact through regimes with high charge factors which reduces the risk of sulphation	strong impact through gassing	strong impact	no direct impact	A strong positive correlation: Higher charge factor leads to lower stratification
Time between full charge	Strong negative correlation: shorter time increases corrosion.	Strong positive correlation: Frequent full recharge decreases hard/irreversible sulphation.	A negative influence, increasing with decreasing time.	A negative influence, increasing with decreasing time	no direct impact	A strong positive correlation: Higher Ah throughput leads to higher stratification
Partial cycling	An impact through potential variations (depends on frequency, SOC level, ..)	A positive impact. Higher Ah throughput at lower SOC increases sulphation. Partial cycling (f>1Hz) increases size of lead-sulfate crystals.	no direct impact However when the PC is of the minimal value, then the Ah throughput runs at very high SOC level and always to full recharge. It is also reflected by the "time between full recharge"	no direct impact However when the PC is of the minimal value, then the Ah throughput runs at very high SOC level and always to full recharge. It is also reflected by the "time between full recharge"	no direct impact However certain partial cycling may cause a preferential discharge and faster AM degradation in certain AM fraction.	Higher partial cycling at lower SOC leads to higher stratification.
Temperature	Strong impact, positive correlation	On one hand high temperature helps to better fully recharge (more sulfate can be recharged). On the other hand high temp. leads to more hard sulfate build up at a low SOC.	no direct impact	increasing with increasing temperature	low impact high temperature degrades neg. electrode expanders	no direct impact.

2.3 Maintenance and repair

The frequency of UPS equipment breakdown will depend on the quality of the products and on proper maintenance. A sealed lead-acid battery is maintenance-free only concerning the re-filling with water and acid. The battery needs permanent control of the optimal charging status. Microprocessor controlled maps optimise the charging process. With a relatively stable national grid the batteries are for most of the time in charging modus and discharging only in emergency modus. This may change due to more input from renewable sources.

A UPS system can include hundreds of single batteries, in parallel and series circuits and connected to the same charge controller. As batteries may vary concerning their key data the time for fully charging a battery could vary too. A battery, which needs less than the average time to be fully charged, is overloaded permanently; this could result in faster aging. Battery capacity varies according to the actual condition of the battery. Charging should be dependent on the actual condition of each battery. As all batteries age, it is necessary to

17 Source: Risø National Laboratory: Lifetime Modelling of Lead Acid Batteries http://www.risoe.dk/rispubl/VEA/veapdf/ris-r-1515.pdf

change them periodically. Using the appropriate measurement electronics the degraded batteries could be detected and replaced in time. The replacement of degraded batteries improves the performance of the UPS and partial battery replacement reduces the operating costs.

Options for repair and maintenance are different in the various market segments. For UPS devices in private homes, maintenance is not common, neither is any repair service for these devices. Battery replacement of lead-acid cells is possible with some products. A scheduled battery replacement is recommended after about 3 to 5 years. Many of these small systems have no proper battery testing procedure and are not serviced at all. Failure of such devices without proper maintenance happens in many cases. Energy consumption of malfunctioning devices is extremely inefficient.

For UPS systems in server farms and for custom-made mission-critical UPS systems used in the manufacturing industry, hospitals, traffic and other security relevant installations, maintenance contracts are common. The leading brand manufacturers offer maintenance programmes as an additional service and are generally on an annual basis for battery operated UPS.

As the most replaced spare parts of UPS systems are the batteries, specific exchange schemes from UPS manufacturers are available. In addition spare batteries from independent battery suppliers are available for example, via the Internet.

Transportation of the battery components of UPS systems is subject to specific conditions in some countries, such as the UK [18]. If the battery terminals are not isolated and connect accidentally, a short circuit could create an explosion/fire. The higher the energy density of the battery (for example, Li-Ion) the higher the potential damage could be. Complex UPS equipment is repaired and maintained at the owner's location whereas smaller devices or components are centrally transported for maintenance and repair.

UPS equipment is not normally upgraded in the same way as computers with the replacement or addition of components. The charging controllers are designed specifically for the selected types of batteries. Changes in the system's infrastructure and potential improvements are limited. The established structures could last for more than 30 years. The lifetime of the equipment is more often driven by advances and changes in technology type meaning that it is often not possible or practical to upgrade these types of products.

Frequency of maintenance procedures depends on the type of UPS. For small UPS devices inspection should be done once a year. For medium and large systems, inspection and maintenance schedule should include two inspections per year. The leading brand manufacturers offer maintenance programmes as an additional service and are on an annual basis for battery operated UPS.

Due to the high value of units and components in UPS assemblies such as copper and steel, remanufacturing is a feasible market solution. Eaton[19] the leading US manufacturer with 12% of global market share, places a range of remanufactured goods onto the market on a sale or trade-in basis for their most popular range, 'Powerware'. It could be assumed that the higher value and quality products, 3-phase systems, would experience longer 'in use' life and be more likely to be repaired. Also products in 'tier 3' OEM manufacturers (turnover less than $200m) that supply specific applications for healthcare and industry, present a strong case for refurbishment, repair and maintenance[20].

Mass-market UPS units for single PCs could see almost no maintenance. Repair options of such mass-market devices are limited. Some manufacturers of branded mass-market products offer take back or replacement programmes as described below.

18 http://www.mpoweruk.com/shipping_regs.htm
19 http://powerquality.eaton.com/Where-to-buy/Reman-ups.asp
20 http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf

2.4 Usage Patterns Conclusion

In the past with stable grids long charging periods and a few discharge situations were typical for UPS systems. Changing grid conditions due to the growing number of small-scale power stations (photovoltaic, wind, mini hydro etc.) could reduce grid stability and increase the number of short power failures. This would increase the number of discharge/charge cycles of the UPS systems batteries. Batteries need to handle these potential new conditions and specific battery technology should be used as appropriate. A hybrid solution using different battery technologies could be superior to old designs.

To reduce the costs for air conditioning the temperature in most server centres is higher than the batteries' reference temperature of 20°C. Separate air conditioning for the battery room with a temperature of 20°C would increase the batteries life expectation.

Maintenance for small-scale UPS systems is far from optimum at many offices and most home offices. Automatic testing procedures and surveillance for the devices as well as end of life alerts for batteries supported by specific Smartphone Apps could help resolve this problem. As these small end-consumer UPS systems are extremely price sensitive, almost all devices are imported from the Far East. Improvements options, for example concerning automatic testing, will be research and discussed with stakeholder as part of subsequent tasks and potential proposals could include mandatory demands for optimised monitoring of small UPSs.

3 Subtask 3.2 – End-of-Life behaviour

A UPS system consists of a minimum of three different segments, the electronics, the batteries and the casing and in addition the relevant cabling. Ageing and lifetime of the components varies depending of the design, the materials and the operating conditions. As a result the end of life of the components of a UPS is not coincident. This section provides details concerning the products' end-of-life behaviour.

Following a search on available reports and End of Life evidence the following were identified:

- "Uninterruptible power supply (UPS)[21] - a guide to equipment eligible for Enhanced Capital Allowances", the Carbon Trust.
- ENERGY STAR Specification Development for Uninterruptible Power Supplies (UPSs)[22] Stakeholder Meeting November 8, 2011

A lack of evidenced data exists for UPS. However, the project team will continue to source suitable studies and information through consultation with stakeholders.

3.1 Expected lifetime of components

This section had been informed by discussion with stakeholders and provided the following information:

- UPS systems life expectation if properly maintained is about 10 to 16 years.
- Well-maintained units can continue to provide economic benefits for 20 years or more.
- Custom-made UPS systems with permanent maintenance service by the manufacturer could last as long as 30 years.
- Lifetime of cheap UPS systems with integrated non-exchangeable sealed lead-acid batteries is about 3 years, depending on the battery lifetime.

As stakeholders remarked, lifetime of UPS systems in server farms is shorter than their technical lifetime expectation, since most UPS systems in such environments are exchanged with the server equipment. Due to technical improvement and demand for higher speed the life expectation of servers is significantly shorter than technical lifespan of UPS systems.

Mission-Critical UPS systems, for example those used in power stations, hospitals, railways, aerospace or industrial manufacturing processes follow different criteria, with availability and durability essential. Efficiency has a lower priority with these devices. Nevertheless some of these custom-made UPS systems use a feed-back-system for battery tests instead of a load resistor. The power is fed back to the grid. To reduce maintenance costs some of these UPS systems are fan-less and so they don't need a fan replacement.

UPS components have a limited life. Wear parts such as capacitors (DC electrolytic and AC polymeric film capacitors) and fans are to be replaced periodically as they degrade under operating conditions. Capacitors should be replaced when their measured capacitance is 5% below the nominal rate. Regular cleaning of the UPS systems by vacuum extractor is essential.

- Transformers: Lifetime of magnetic components is about 40 years[23].

21 http://etl.decc.gov.uk/NR/rdonlyres/7FA0B0D6-FDDC-4CB0-B1B6-C76C77B042A7/0/ECA778_UPS.pdf
22 http://www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies
23 Informed by discussion with stakeholders

- Electrolytic DC capacitors: Life of DC capacitors varies from eight to 30 years[23].
- Oil-filled AC capacitors: Oil-filled capacitors life is about of 10 years[23]. These capacitors should be inspected during the annual maintenance.

The batteries have the shortest lifetime. Batteries should be replaced when their full load is 20% below rated. There are lead-acid batteries with a nominal life of 3, 5 or 10 years. The lifetime of batteries is specified at a nominal temperature 20°C. The increase of the working temperature by 10°C could shorten the lifetime of a battery by the factor 2. The different categories for the battery life are[24]:

- Standard-Commercial: 3 to 5 years
- General-Purpose: 6 to 9 years
- High-Performance: 10 to 12 years
- Long life: more than 12 years.

The end of service life of batteries is defined as the point at which the battery's actual capacity has reached 80% of its nominal capacity. Some UPS manufacturers define the end of lifetime capacity as 50-60% of the rated capacity.

3.2 Take back / replacement

A number of manufacturers offer a trade UPS programme where manufacturers take back old UPSs (regardless of brand) including free return shipping of old battery backup units and will sell a brand new unit that can be up to 4X the power of the returned unit at a discount price and a standard 2 year warranty[25].

Some manufacturers provide free of charge recycling of batteries. Shipment of the battery/batteries is paid by the user at their own risk (shipping conditions may vary in EU-27 Member States). The respective shipping company could limit the maximum package weight and return policies vary in different countries.

According to the WEEE Directive, private customers that buy new UPS could return the replaced old equipment for recycling to the recycling system in their community. Shipping companies as DHL accept new and used lead acid batteries if the battery's terminals are covered/insulated with tape.

Sims[26] operates recycling and take-back for UPS batteries in the UK[27]. Other WEEE operators offer battery recycling for UPS in the UK but not the UPS units. The manufacture, distribution and recycling of batteries are required to comply with the Batteries Directive 2006/66/EC. Lead from lead acid batteries is of high value and there is increasing demand for recycled/secondary lead. As stakeholders mentioned, illegal exports of used lead acid batteries is an issue. Due to the high demand for secondary lead and a significant spread of price levels between different countries, illegal cross border transport and theft from waste storage is an issue and one identified by this study's stakeholders.

3.3 Recycling of UPS components

Recycling processes for UPS systems could be separated between the electronic components and the batteries. This varies across member states.

Batteries, including the battery casing and electronics including the UPS casing are handled by two different recycling schemes. The national battery recycling in each of the EU-27 member states must register the batteries. For the electronic components and the UPS

24 As defined by IEC 60896-2
25 For example http://www.apc.com/site/company/index.cfm/company/environmental-and-community/recycling/, http://www.riello-ups.co.uk/ups-services/tradeups/
26 http://uk.simsmm.com/products-and-services/ups-battery-recycling
27 http://www.simsrecycling.co.uk/electronics-recycling/UPS-Battery-recycling

casing the respective recycling scheme is handling the registration and organising the final recycling[28].

3.3.1.1 Batteries

As mentioned above batteries are the main consumable component of a UPS. Most UPS batteries will require removal and recycling within a three-to-five year period, depending on usage and environmental conditions.

Lead-acid batteries

Lead-acid batteries are about 70% lead by weight. The recycling process is simple and a robust global recycling infrastructure is available in all member states. This is supported through the high volume of lead acid batteries used in the automotive sector. Several battery manufacturers such as Johnson Controls or Exide Technologies operate their own recycling plants to insure a continuous supply of raw materials.

The recycling of lead-acid batteries, which are found in most UPS systems, is well established. A lead-acid battery holds a financial value and for this reason its recycling is economically successful. Industry says: More than 97% of all battery lead is recycled and lead acid batteries are handled in a kind of closed-loop life cycle.

A typical new lead-acid battery contains about 60 to 80 % recycled lead and plastic [29]. Used batteries are sent to a recycler where, the lead and plastic components are recycled and shipped to a battery manufacturer.

The lead components are cleaned and melted in smelting furnaces. In the next production step ingots are produced. Battery manufacturers use those for the manufacturing of new batteries. Under the assumption that German UPS systems in server farms provide a nominal power of 5 GW for 10 minutes each and there are 14 kg batteries per kW, 70.000 tons of lead acid cells are installed. Replacement after 4 years of operation gives 17.500 tonnes per year. The recycling cycle could go on indefinitely. This makes lead-acid battery recycling advantageous, both from an environmental and economical perspective[30].

Lithium batteries

The situation with Lithium battery recycling differs from the situation with lead acid. Until now the majority of Lithium batteries are used in mobile devices and are of smaller size. Recyclers have to collect a greater amount of batteries to start recycling them. As lithium-ion battery developers reduced costs of these batteries, for example by substituting costly cobalt and nickel with cheaper raw materials like iron, to provide lithium batteries as a substitute for gasoline for automotive purposes, it has resulted in reducing the value/worth of the content. Reducing the value of the materials means that recycling of Li Ion batteries is only viable with additional payment. Stakeholders indicated that the amount of recyclable content is about 53%[31]. At present recycling of Lithium batteries is economically viable for recycling companies only with an additional payment.

A robust recycling infrastructure for used lithium-ion batteries is still not available yet. As a worst-case scenario, used lithium-ion batteries could be stockpiled until there are so many used batteries available to start a recycling infrastructure.

Where lead acid recycling is profitable Lithium battery recycling is not. At present there are only three Lithium battery recyclers known in Europe: one each in Belgium, Finland and Germany. Since Lithium batteries are relatively new to the market, the amount of batteries available for recycling is still small. There were two recycling projects for Lithium traction batteries in Germany LithoRec and LiBRi in recent years.

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28 Information gathered from German Stiftung Elektroaltgerätereycling saw the electronics of UPS systems covered by the WEEE and the battery covered by the national battery recycling scheme.
29 http://batterycouncil.org/?page=Battery_Recycling
30 http://batterycouncil.org/?page=Battery_Recycling and discussion with stakeholders
31 SAFT mentioned this in the telephone conference.

Plastic

The plastic used for lead acid batteries is polypropylene. The pieces are washed and dried. At a plastic recycler these pieces are melted and the molten plastic is extruded to plastic pellets. The pellets are used for manufacturing battery cases.

Sulphuric acid

Sulphuric acid could be processed and converted to sodium sulphate, used in glass and textile manufacturing.

Electronics and PCBs

Recycling of electronic components in UPS is similar to other PCB based electronics. UPS electronics could contain lead soldering since there was a RoHS exemption for these devices.

3.3.2 Standards for End of Life

Batteries Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC.

Directive 2006/95/EC 'Low voltage equipment': Article 1 "For the purposes of this Directive, ‗electrical equipment's means any equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current and between 75 and 1 500 V for direct current, other than listed equipment and phenomena".

RoHS Directive 2002/95/EC on Restriction of the use of certain Hazardous Substances in electrical and electronic equipment is also not within scope for the same reason as for WEEE (see section 3.3.3 below). Further checks will be made to determine any implications arising as a result of the WEEE Directive recast.

3.3.3 Present fractions to recycling, reuse and disposal

A desk-based review of the WEEE related literature and data has been carried out and relating to volumes of UPS waste is recycled, reused and disposed. End of life data is absent from published sources. The ENERGY STAR Specification Development for UPSs Stakeholder Presentation November 8, 2011 states that Refurbishment and Recycling for UPS have been omitted in line with other IT product specifications.

Data on the recycling and reuse of UPS as a discreet category is unavailable as it falls outside of the present WEEE categories, although it is likely that a proportion is recycled by businesses (through the b2b stream in authorised treatment facilities), no published data has been identified.

UPS are not separately listed in Annex 1 of the WEEE Directive (covering the period 14 August 2012 to 14 August 2018)[32], but UPS are very often used in conjunction with products in several of the categories, i.e. IT and Telecom, Electrical and Electronic Tools (with the exception of large scale stationary tools), Medical devices and Monitoring and Control instruments. However following the WEEE recast it is anticipated UPS will be covered from 15th August 2018, once the revised categories outlined in Annex III of the recast Directive come into force. There was some uncertainty at the first stakeholder meeting regarding the implications of the recast WEEE directive for UPS systems, and whether some systems may fall under the exclusions. We will discuss this further with stakeholders at the second stakeholder meeting.

[32] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:197:0038:0071:EN:PDF

3.3.4 Second hand use

At present most second hand UPS systems are recycled. Re-use is not common in Europe. Some systems are shipped to emerging markets and developing countries outside the EU. Most second hand equipment is sold without batteries, as batteries are replaced by new units. This is the simplest way to refurbish UPS systems. Due to safety requirements, EU users are reluctant to use refurbished UPS as stakeholders mentioned in discussions.

4 Subtask 3.3 – Local Infrastructure

This section aims to identify the barriers and opportunities for ecodesign relating to local infrastructure. The MEErP methodology identifies the following areas for consideration:

- Energy;
- Water;
- Telecom;
- Installers; and
- Physical environment.

Clearly, some of these will be more important for Uninterrupted Power Supplies (UPS) than others, and they are discussed as appropriate below. The impact of any design improvements may only be fully realised if infrastructure elements are taken into consideration, as these in practice may limit the extent of any potential benefits. For example, are there any barriers that will inhibit the end user from using the product in the most environmentally sound manner e.g. training needs, is there a preference for established/proven technologies over added complexities, or are there internal organisation pressures e.g. budgets/costs.

The information present in this section reflects the initial desk based research, and we would welcome the opportunity to discuss this with stakeholders at the second stakeholder meeting in order to supplement the findings to date.

4.1 Energy

Given the purpose of UPS's, energy is a key factor when considering the local infrastructure. There are a number of key considerations relating to UPS and local infrastructure that will affect energy requirements, both for the UPS itself and the wider system. These are summarised below:

- A reduction in the energy consumption of the UPS itself will potentially reduce supply side infrastructure losses i.e. less supply is required, therefore the losses associated with that supply will be reduced.
- The variation in the energy supply i.e. level of disturbances required to protect against needs to be understood in order to ensure the correct type of UPS is chosen. For example, is the UPS required to allow continuing use, or ensure a clean shutdown of the system?
- Correct sizing of the UPS in relation to the local infrastructure it is designed to protect is critical to ensure optimal energy performance i.e. load analysis. It is likely that an extra power allowance will be included to take into account future expansion, typically 30%[33]
- For medium and large UPS, cooling is often necessary to prevent overheating. This may result in addition electrical energy use for air conditioning. The amount of ventilation may affect the level of cooling required.
- Local infrastructure, such as raised floors and existing air handling ductwork will affect system performance and uniformity of temperatures in facilities, for example data centres. Assessment of the heat load together with air distribution system architecture will ensure the level of engineering is appropriate for the data centre

33 CEMEP UPS Guide

design, and could potentially reduce the engineering requirements for data centre design[34].

4.2 Water

Water use is not relevant to UPS. Prevention of water ingress though good design, is important.

4.3 Telecom

Telecom infrastructure may be an important consideration for UPS installation. It will be important to understand the telecom set up at the local level to ensure the UPS is compatible and installed correctly to ensure communication between the UPS and the rest of the system is optimised where appropriate. UPS systems in telecom installations work at a different voltage level. In remote locations some operators tend to use fuel cell units as UPS.

4.4 Installers

A number of UPS suppliers offer installation and start up services to ensure correct and optimal installation. Typically this could include the following[35], depending on the level of service offered/purchased and where the UPS is to be installed e.g. data centre, or small scale:

- Compatibility checks to ensure the UPS is appropriate for the system it will be connected to;
- Review of mechanical and electrical installation requirements;
- Verify floor layout design to ensure efficiency;
- Equipment unloading;
- Upstream mains connection;
- Distribution switchboard connection;
- Battery connection;
- Air conditioning/ventilation

A key part of ensuring UPS lifetime is maximised and protecting against failure is maintenance. Many UPS supplier/manufacturers offer post sales maintenance packages and/or training. This is important to ensure the UPS continues to operate as designed and parts are replaced as necessary e.g. capacitors/batteries.

Where purchasers do not wish to use services offered by UPS suppliers, they will need to ensure their own or other contractors have the necessary skills to install and maintain the UPS. This may require additional training, and will need to be assessed on an individual basis.

4.5 Physical Environment

The physical environment for UPS has already been touched on in the energy section above in relation to heat load and cooling requirements/ventilation. Linked to this is ambient temperature. This can affect the lifetime of the batteries used, depending on their type, for example lead acid battery life reduces by half for every 10 degrees above the design reference temperature of 20/25°C[36] . UPS therefore tend to be installed in temperature controlled environments if optimum service life is to be achieved.

34 Cooling requirement report
35 CEMEP UPS guide and Schneider Electric ‘Critical Power and Cooling’ brochure
36 CEMEP UPS Guide

Although ventilation is considered above as part of heat dispersal, it also needs to be considered to ensure that any potential explosive mixtures of hydrogen and oxygen from batteries are dispersed. Standards, for example EN 50272-2 ‘Prescriptions for safety of batteries and installations’ are available to address such matters.

A further consideration of the physical location of UPS is noise, which may for example result from the fan. It needs to be located so as not to impact on noise levels for areas that staff are working in.

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