ErP Lot 27 – Uninterruptible Power Supplies

Preparatory Study - Final Report

Report for European Commission, DG Energy

Ricardo-AEA/R/ED56828
Issue Number 1
Date 12/06/2014

University of Coimbra

Customer:

European Commission, DG Energy

Customer reference:

ENERG/C3/413-2010-LOT 27-Sli2.611335

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12 June 2014

Ricardo-AEA reference:

Ref: ED56828- Issue Number 1

Executive summary

This is the final report for the Lot 27 preparatory study: Uninterruptible Power Supplies. Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design working plan 2009-2011.

This preparatory study aims to identify the scope and definition of the product group, current market size and composition, technical solutions, potential future technology improvements and possible policy options.

The Preparatory Study has followed the Commission's established methodology comprising:

- 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

This report is structured on the individual tasks undertaken as part of this study, a summary of the key findings from each task are provided below:

Task 1 – Definition

The aim of the first task is to develop a product definition to be used throughout the work and to identify the existing legislation and standards pertinent to these products.

The worldwide market for UPS is very closely linked to the continuous and expanding deployment of electronic facilities that must have security of function. These include, in particular, server centres, ICT equipment, retailer money and card processing tills and equipment insecurity and safety systems. In these applications UPS provide protection from grid power quality voltage instability and increasingly unacceptable power downtime.

The present, major UPS market in terms of product volume across the EU27 is for Alternating Current (AC) single-phase, semi portable and static (installed) products. Three design topologies characterise these products:

- Double conversion (with or without bypass);
- Line interactive(with or without bypass); and
- Standby (offline).

For manageability and focus, the study primarily considers, but is not restricted to, AC powered static and semi portable UPS utilising, for energy storage, various battery technologies

A review of existing definitions from existing sources, including relevant standards and existing labels has been undertaken, followed by an evaluation of the definitions identified, to inform the preliminary definition for the purposes of this study. The following preliminary definition has been established:

"A UPS is a combination of electronic power converters, switches and energy storage devices (such as batteries) constituting a power system for maintaining the continuity of power to a load in the case of input power failure."

Qualifying Notes:

Input power failure is usually understood to mean the failure of the main primary continuous power source (e.g. the AC grid). It can also mean the failure of the primary *power source to maintain voltage and frequency within rated steady state and transient bands or to allow distortion or interruptions to the supplied power outside specified limits.*

A UPS is commonly understood to be a short duration (minutes/hours) power supply system that maintains the functions of the connected load when the main continuous power source has failed. The primary purpose of a UPS is to bridge an unexpected power gap and/or to provide the amount of power needed to safely power down the connected load. A UPS may also be used to continuously maintain the quality (distortion content) and stability (voltage and frequency) of the power to the connected load.

In the case of a primary AC grid failure, the UPS may run in isolated mode and is not grid-connected on the supply side.

In standby (when it is not replacing primary grid power) a UPS could operate in on-mode or off-mode, as an AC or DC operated device depending on the specific design.

A system providing electrical power, that supplements or is capable of continuously replacing the main source of grid power, is not a UPS (e.g. an engine or generator system).

Portable devices designed to operate using battery power such as laptop computers are excluded from the product group.

A scope and definition for the policy proposals is also included in Task 8. This is based on the above preliminary definition, but takes into account subsequent research undertaken and stakeholder feedback received throughout the study.

In addition to the preliminary definition, Task 1 identifies and comments on standards, existing legislation, voluntary agreements and existing labelling initiatives relevant to UPS products at the European Union, Member State and international level.

In terms of standards, the key standard relevant to UPS is EN 62040. This covers aspects relating to general and safety requirements for UPS, electromagnetic compatibility and methods for specifying the performance and test requirements.

Key European Directives relevant to UPS include the Low Voltage Directive (2006/95/EC), Electromagnetic Compatibility Directive (2004/108/EC) and the Directive on batteries and accumulators, and waste batteries and accumulators (2006/66/EC). Following the revision of the WEEE Directive (2012/19/EU), it is anticipated that this and the RoHS Directive (2002/95/EC) will be applicable to UPS in the future.

The UPS industry in Europe has had a voluntary code of conduct since 2006. This specifies efficiency levels. In addition to the code of conduct other key labelling initiatives for UPS include the Blue Angel in Germany and the US Energy Star.

Task 2 – Economic and Market Analysis

Task 2 analyses generic economic data from official statistics and uses a modelling approach to establish stock and sales figures. Market trends have been identified, along with market and production structures, key product design and innovation trends and consumer expenditure base data.

Historically the market for UPS has experienced significant growth due to the expansion of information technology, although it has suffered in recent times due to the global recession. In Europe, the UPS market is relatively mature compared to other parts of the world, for example China, where the market is experiencing significant growth. Limited information relating specifically to the market trends in European has been identified. However in the long term, growth is anticipated as data centres continue to be built and expand, together with a decreasing acceptance of downtime.

In terms of market and production structures, the research identified three tiers of UPS manufacturers. The first tier consists of the three main companies; APC, Eaton and Emerson Network Power, who dominate the global UPS market. For example APC and Eaton have

26% and 12% of the global UPS market respectively. The second tier consists of other global manufacturers with growing sales revenues, and will compete with the three main tier 1 manufacturers. The third tier of manufacturers consists of those supplying products to particular niche markets, for example specialising in healthcare or particular industrial settings.

Assessment of the production and trade data extracted from Eurostat indicates that UPS data is included alongside a range of other products. It is not possible to extract UPS-only data. In addition trade data is reported by value and quantity in kilograms, and not number of units. The lack of transparency on the different types of products included within the Eurostat data, which in some cases is very general, means that these sources do not provide the comprehensive information required for the purposes of this preparatory study.

As a result, an alternative approach was used to establish the EU sales and stock figures for UPS, which are used in later tasks to quantify the potential impacts of proposed improvements. The modelling indicated that for 2011, 1.4 million UPS units were sold, with the following key trends identified:

- Germany and the UK have the highest unit sales, representing 19% and 17% of the market respectively.
- The top four countries in terms of units sales, Germany, UK, France and Italy account for 63% of total unit sales
- Luxembourg, Latvia, Estonia, Slovakia, and Lithuania all have sales of less than 1% of the EU27 total
- UPS below 1.5 kVA represent the largest proportion of unit sales, with 69% of the market, followed by 1.5 kVA to 5 kVA with 28% of the market

Existing stock for 2011 was calculated as 7.5 million UPS units, with the following key trends identified:

- The below 1.5 kVA size group represents the largest proportion of stock in 2011, with 53%, followed by the 1.5 to 5 kVA products, with 41% of total stock.
- Germany and the UK have the highest stock, representing 19% and 17% of the total stock respectively.
- The top four countries in terms of stock, Germany, UK, France and Italy account for 63% of total stock.
- Luxembourg, Latvia, Estonia, Slovakia, and Lithuania all have stock of less than 1% of the EU27 total.

Detailed information regarding extra and intra EU trade for UPS is not identifiable from official statistics or alternative sources. Stakeholder feedback indicates that almost all single phase UPS and 80% of three phase UPS are manufactured outside of the EU27. This would suggest there are significant imports of UPS by the EU27.

Task 2 also collated cost information on UPS products and their consumables through the first questionnaire. This information is used in subsequent tasks to inform assumptions relating to costs.

Task 3: Consumer/user behaviour and local infrastructure

Task 3 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.

UPS operation costs are 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 consumer decisions regarding UPS acquisition, clear information is required. Labelling schemes are one possible means for this.

The key factors that must be considered regarding energy efficiency are the size of the UPS, in comparison to load, 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. 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 also leads 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 maintaining correct operating temperatures and maintenance procedures. Battery packs with cells that provide a similar internal resistance could extend the lifetime of the battery packs as well.

Options for repair and maintenance are different in the various market segments. For UPS devices in private homes, maintenance is not common, neither are repair services. Battery replacement of lead-acid cells is possible with some products. For UPS systems in server farms and for 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.

At the end of life stage, a number of manufacturers offer a trade-in service where manufacturers take back old UPSs (regardless of brand) including free return shipping of old battery backup units, with some offering new units at a discounted price when an old unit is returned.

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. Recycling processes for UPS systems can be separated between the electronic components and the batteries. This varies across member states, however in general there is a high level of battery recycling. Limited data has been identified in terms of electronic component recycling.

Task 4: Technical analysis of existing products

The objectives of Task 4 are to present an overview of the current products available on the market and the type of technologies used. It addresses the technical analysis of existing products across the different life cycle phases, looking at production, distribution, in use, and end of life characteristics. Data gathered in Task 4 is used to inform the inputs for the environmental impact analysis of UPS undertaken using the EcoReport[1] tool as part of Task 5.

EcoReport is a simplified life cycle assessment tool, developed for use in Ecodesign preparatory studies to quantify the environmental impact of the product being investigated. In order to generate environmental impact analysis, EcoReport requires inputs relating to the materials used to make the product (a bill of materials), its use, and end of life management.

For each of the four UPS size categories (agreed with stakeholders), information on representative products has been obtained through the second questionnaire and dismantling trials as follows:

- Below 1.5 kVA – based on measurements from dismantling of a typical 0.6 kVA UPS;

[1] For the purposes of this study we are using the EcoReport tool developed as part of the MEErP methodology - http://www.meerp.eu/

- 1.5 to 5 kVA – based on the average of four BoMs received from UPS manufacturing industry stakeholders covering this size range and the key topologies;
- 5.1 to 10 kVA – based on the average of two BoMs provided by UPS manufacturing industry stakeholders covering this size range and the key topologies; and
- 10.1 kVA to 200 kVA – based on the average of two BoMs provided by UPS manufacturing industry stakeholders and from dismantling of an 11kVA UPS.

Generally the materials used in UPS products are similar for the three largest UPSs, with metal dominating. For the smallest UPS there is a higher proportion of plastic due to its increased use in the casing. This information is important to understanding the production impacts of UPS:

Materials	Below 1.5kVA	1.5 to 5 kVA	5.1 to 10 kVA	10.1 to 200 kVA
Plastics	34%	9%	4%	4%
Metals	53%	79%	82%	89%
Electronics	13%	12%	14%	6%
Total	100%	100%	100%	100%

The use phase electricity consumption has been characterised by using efficiency levels from existing sources, such as Energy Star and the industry Code of Conduct. In addition when characterising the in use energy consumption it is important to take into account product features such higher efficiencies at lower loads and multi-mode operation, where the UPS can switch between modes depending on the load characteristics. User behaviour is also an important aspect of in use energy consumption, with decisions regarding availability, reliability and redundancy having an effect.

The end of life phase of existing UPS products varies for different sizes of products. The small, cheaper, UPS products are dealt with in a similar manner to other small electrical goods and recycled or disposed of rather than repaired and re-used. The research identified some level of repair and refurbishment for larger UPS products, however this is limited and generally the materials are recycled. The energy storage mechanism of a UPS represents a key component. For the majority of current products this is achieved through the use of lead acid batteries, which are mostly recycled at end of life.

Task 5: Definition of base cases

Task 5 involves undertaking an environmental assessment of UPS using the EcoReport Tool. The EcoReport tool developed as part of the Methodology for the EcoDesign of Energy Related Products (MEErP)[2] is used in all Ecodesign Preparatory Studies and provides a streamlined life cycle assessment of the product, together with a life cycle cost assessment. The purpose of this assessment is to provide an indication of the representative environmental impacts for a typical product across the different life cycle phases. This allows the importance of non-energy environmental impacts to be understood alongside the environmental impacts associated with in use energy consumption.

As a first step in this analysis, base cases reflecting different UPS sizes and topologies were defined and agreed with stakeholders:

[2] http://www.meerp.eu/ - This website provide further information about the MEErP methodology, including a copy of the EcoReport tool.

Base Case	UPS size	Main topology	EU-27 Stock – Million Units (2011)*	EU-27 Sales – Million Units (2011)*
1	Below 1.5 kVA	Standby	3.98	0.99
2	1.5 to 5.0 kVA	Line Interactive	3.06	0.40
3	5.1 to 10 kVA	Double Conversion (Online)	0.24	0.03
4	10.1 to 200 kVA	Double Conversion (Online)	0.14	0.01

These base cases cover the majority of sales (based on units), which are highest in the smaller UPS sizes, and the main UPS typologies. A base case has not been selected for products above 200 kVA, as these are generally bespoke and cannot be represented by a typical bill of materials. Stakeholders agreed with this rational for products above 200 kVA.

Following the definition of the base cases, their characteristics are used to generate the input parameters for EcoReport. This includes a bill of materials (a list of materials and their weight fractions) for different sizes of UPS in order to assess the extraction, production, and manufacturing phases of the life cycle. Stakeholders helped inform this part of the study via their responses to the second questionnaire. Dismantling trials undertaken by the project team and a review of existing literature completed the information gathering activity.

In addition, the in use energy consumption has been calculated for each base case using information from existing standards, in particular the UPS Code of Conduct[3], the Energy Star specification for UPS[4], and stakeholder feedback.

For Base Cases 2, 3 and 4, the in use phase, driven by in use energy consumption dominates the impacts for eleven of the fifteen environmental indicators:

- **Resources and Waste**
    - Total Energy
    - Electricity
    - Water (Cooling)
- **Emissions to Air**
    - Greenhouse gases (Global warming potential)
    - Acidification
    - Persistent Organic Pollutants (POPs)
    - Heavy metals
    - PAHs
    - Particulate Matter (PM)
- **Emission to Water**
    - Heavy Metals
    - Eutrophication

For all these indicators the use phase contributes between 45 to 100% of the impact depending on the base case and parameter. Clearly this indicates the use phase, on account of in use energy consumption, is a key factor in driving the majority of the impacts of UPS.

[3] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011
[4] ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.

Base Case 1 has a different profile to Base Cases 2, 3 and 4. While the use phase, as a result of in use energy consumption, contributes the highest to the following environmental indicators, the dominance of the use phase is not as significant as the other three base cases.

- **Resources and Waste**
  - Total Energy
  - Electricity
  - Water (Cooling)
- **Emissions to Air**
  - Greenhouse gases (Global warming potential)
  - Acidification
  - Persistent Organic Pollutants (POPs)
  - Heavy metals
  - PAHs
  - Particulate Matter (PM)

A number of reasons have been identified for this. Firstly, the product weight, output and lifetime for Base Case 1 means that weight of materials per kWh output over the lifetime of the product is higher for Base Case 1. For Base Case 1 there is approximately 5g of material per kWh of output compared to approximately 3g for Base Cases 2, 3 and 4. This higher weight to kWh output means that proportionally the production impacts are greater when compared to use phase energy consumption.

A further factor to consider is the materials used in the manufacture of Base Case 1. There is a higher proportion of plastic compared to metals in Base Case 1 compared to Base Cases 2, 3 and 4. This will influence the balance between the various impact indicators.

Aggregating the results for the base cases and using installed stock to provide EU-27 totals indicates that Base Cases 2 and 4 account for the majority of the impacts for the different indicators, while having significantly different proportions of the market in terms of number of units installed (41% for Base Case 2 and just 2% for Base Case 4). The EU-27 totals indicate approximate energy consumption of 131PJ, of which electricity is 14 TWh.

At the EU-27 level aggregated consumer expenditure is dominated by electricity, which accounts for approximately half of total consumer expenditure. However it is important to note that this varies between the base cases, for example, product purchase and electricity expenditure are similar for Base Cases 1 and 3.

Task 6: Technical Analysis of BAT

Task 6 concerns identifying and technically reviewing the best available technologies (BAT) for UPS. BAT is defined as the currently available technology, which is expected to be introduced at product level and reach the mainstream market within two to three years. The outcome of this BAT analysis will enable evaluation of technology in terms of its feasibility and cost. Best not yet available technology (BNAT) is defined as the technology that is in the research and development stage and not yet ready for large-scale implementation.

The assessment of BAT forms an input to Task 7, which involves analysis of the improvement potential that could be achieved via a range of design options. A summary of the main improvements at the component level of UPS products is provided below, with an indication of whether they are considered BAT or BNAT:

Components	Improvement	BAT/BNAT
Intelligent multi-mode operation	Up to +2% increase in efficiency	BAT
Improved Lead-acid batteries	Better performance and lifetime	BAT
Lead-carbon batteries	Increased cycle life	BNAT
Lithium-ion batteries	+20% of efficiency	BNAT
Supercapacitors	Better performance and lifetime	BNAT

Fuel cells	Better performance	BNAT
Transformerless UPS	+3% of efficiency and 25% less weight	BAT
High-frequency transformer	alternative to the transformerless topology	BAT
Three-level converter	reduction of 35% on the semiconductor losses	BAT
Transformerless + Three-level converter + elimination of active components	+3% of efficiency and 46-60% less weight	BNAT
Delta-conversion line-interactive UPSs	Better performance	BAT

Task 7: Improvement Potential

Task 7 involves the identification and assessment of design options based on the information collated in Task 6 – Best Available Technology. The aim of Task 7 is to identify the improvement potential of the product and consider these in relation to life cycle costs, by identifying the least life cycle costs and environmental improvement of the different options. This analysis is undertaken using the EcoReport tool and compares the design options against the base cases defined in Task 5.

The five main areas identified for consideration are:

1. High Flat Efficiency
2. Improved Components
3. Multi-mode UPS
4. Batteries, including longer battery lifetime and design for replacement
5. Reduced levels of redundancy

Each of these options are outlined and considered in detail. Where it is not considered appropriate to take forward a design option for detailed analysis the reasons for this are provided in the relevant section of the report.

A summary of the design options relevant to each of the base cases is provided below:

Base Case	Use of Improved Components for High Flat Efficiency	Use of Improved Components for Transformer less design	Extended battery lifetime	Redundancy	Multi-mode operating
BC - 1 (< 1.5 kVA)	Y	N/A	N/A	System level issue – see Task 8	N/A
BC - 2 (1.5 – 5 kVA)	Y	N/A	Y		N/A
BC - 3 (5.1 - 10 kVA)	Y	N/A	Y		Y
BC - 4 (10.1 - 200 kVA)	Y	N/A	Y		Y

Task 7 focuses on the following design options:

- Option A: Intermediate flat efficiency (average between the reference Base Case and BAT levels)
- Option B: Best Available Technology (BAT) flat efficiency from current Energy Star database
- Option C: Base Case modified by intelligent multi-mode technology (CoC efficiency level)
- Option D: Base Case modified by flat efficiency and intelligent multi-mode technology (both at BAT efficiency levels)
- Option E: Base Case modified by long life batteries

A summary of the base case design options is provided below:

BC	Flat Efficiency Intermediate	Flat Efficient BAT	Multimode (CoC)	Multimode (BAT)	Longlife Battery
1	Option 1A	Option 1B	n/a	n/a	n/a
2	Option 2A	Option 2B	n/a	n/a	Option 2E
3	Option 3A	Option 3B	Option 3C	Option 3D	Option 3E
4	Option 4A	Option 4B	Option 4C	Option 4D	Option 4E

Looking at the total energy consumption (GER) for each base case and the applicable design options, it is noteworthy that Base Case and Base Case design option 1A and 2A deliver the largest GER savings in percentage terms (-43%) compared to their base case, as well as for design option 1B and 2B (-86%). These are much higher percentage savings than for any design options for Base Cases 3 and 4 as shown below. However it should be noted that the absolute savings for Base Case 1 are significantly lower than for Bases Cases 2, 3 and 4.

	BASE CASE (GER - MJ)	Option A	Option B	Option C	Option D	Option E
BC1	14 242	8 059	1 936	N/A	N/A	N/A
Saving % change to BC		6183 -43%	12 306 -86%			
BC2	140 779	80 275	19 769	N/A	N/A	140 590
Saving % change to BC		60 504 -43%	121 010 -86%			189 0%
BC3	285 279	238 714	193 628	275 117	155 563	284 813
Saving % change to BC		46 565 -16%	91 651 -32%	10 162 -4%	129 716 -45%	466 0%
BC4	4 662 190	3 896 663	3 153 487	3 789 098	2 825 205	4 654 958
Saving % change to BC		765 527 -16%	1 508 703 -32%	873 092 -19%	1 836 985 -39%	7232 0%

The long life battery option design as discussed earlier does not generate any savings in term of energy and only results in reduced environmental impacts for process water, hazardous and non-hazardous waste, and volatile organic compounds.

In terms of least life cycle costs for the different design options, the cost assumptions (based on stakeholder feedback) mean options with highest energy consumption savings are also the least life cycle cost options across the four base cases.

For the design options identified and modelled, the results clearly show that for energy related design options for Base Cases 1 and 2 the least life cycle cost option is flat efficiency at BAT levels. For Base Cases 3 and 4 it is the use of flat efficiency at BAT levels combined with multi-mode operation that enables switching between VFI and VFD modes. These are considered within the policy scenarios in Task 8.

In addition to energy related design options, the use of longer life batteries has been considered. Due to uncertainties regarding the life time of batteries which is influenced by external factors, and the relatively small life cycle cost savings and reductions in environmental impact when compared to the energy related design options, the use of longer life batteries has not been considered further as part of Task 8 except in the form of an information requirement. For Base Case 1 products, where long life batteries are not necessarily appropriate, an alternative design option enabling the easy replacement of batteries has been proposed for consideration in Task 8.

At the product level the absolute impacts are small, however the relative potential improvement that could be achieved when compared to the business as usual base case is relatively significant, for example over 80% in energy consumption in some cases. However it is important to understand the absolute impacts for the market as a whole when considering the development of policy options to fully understand how important the savings will be. This is analysed in Task 8 using a simple stock model. In addition other options affecting resource use, which cannot be modelled at a product level, but nonetheless affect the system i.e. features that enable a reduction in redundancy, are also considered in Task 8.

Task 8: Scenario, policy, impact and sensitivity analysis

Task 8 of the study involves developing scenario, policy, impact and sensitivity analysis based on findings from previous tasks, in particular Task 6 and 7. Task 8 considers what policy scenarios might be viable in terms of future regulations (or other policy options) for implementation.

The report presents policy options and feedback from stakeholders and the European Commission. Following this the task determines the environmental impacts/benefits of the proposed policies as well as the economic impacts. Finally a sensitivity analysis is completed.

The first policy scenario considered is the implementation of Minimum Efficiency Performance Standards (MEPS) for UPS. The analysis in Task 5 indicates that the main environmental impact of UPS is from their in use energy consumption; therefore a focus on MEPS is appropriate. The MEPS policy option implements efficiency requirements for different UPS sizes and topologies using a tiered approach to implement improvements in line with product design cycles. The efficiencies reflect developments in flat efficiency and multi-mode functionality.

A second policy option complementary to MEPS is an energy label. The proposed label includes a number of allowances to take into account variations in products, and promote product features addressing material resource efficiency in addition to energy efficiency. The allowances proposed are:

- Compensation for transformer losses in UPS where galvanic isolation for safety purposes compromises the efficiency of the UPS for label scaling purposes
- Resource impact bonus for UPS which allow automatic UPS replacement and deactivation in an installation system which facilitates a significant reduction in UPS units for a given load without compromising supply security (resilience and availability)
- Compensation for VFI (full double conversion) topology
- Resource impact bonus for UPS which provide battery internal resistance monitoring and correction

Based on the MEPS proposal, savings have been identified through the use of a simple stock model. Aggregating the impact of the four base cases, the total impact of the MEPS scenario was assessed. A total of 10.96 TWh/year savings can be reached in 2025, representing a reduction of 54.4%.

Base Case 1 and Base Case 2 present the highest percentage savings, with 86.4% and 81.0% of savings in 2025, respectively. Due to its higher share of the stock, Base Case 2 also presents the highest absolute savings, with 6.7 TWh/year in 2025.

The introduction of the MEPS scenario results is reduced life cycle costs for each base case over the period 2011 – 2025, with the aggregated total life cycle costs for Base Cases 1-4 reducing from €4.68 billion per year under business as usual to €3.48 billion per year under the MEPS scenario in 2025. This is a reduction of approximately 26%. Under the MEPS scenario total expenditure in 2025 would be only slightly above 2011 expenditure (€3.48 billion compared to €3.29 billion), despite the large increase (29%) in the stock of Base Case 1-4 products in 2025 compared to 2011.

Due to data limitations it is difficult to model the environmental savings and economic impacts of the label, however example saving scenarios have been included where relevant in the report e.g. reducing the number of units when using automatic UPS replacement/deactivation functionality. The basic functionality of the product would remain the same, with allowances made for these specific aspects.

In addition to these two options, additional recommendations are made with regards consumer information and other ecodesign requirements including the provision of information on the benefits of longer life benefits, optimal operating conditions, battery checking and monitoring and design to facilitate easy battery replacement.

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Appendices

List of Abbreviations

AC	Alternating Current
AMS	Automatic Management Systems
AP	Acidification Potential
ATIS	Alliance for Telecommunications Industry Solutions
B2B	Business to Business
B2C	Business to Consumer
BAT	Best Available Technology
BAU	Business As Usual
BC	Base Case
BNAT	Best Not yet Available Technology
BoM	Bill of Materials
CATV	Cable TV
CE	European Conformity
CEMEP	Committee of Manufacturers of Electrical Machines and Power Electronics
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CN	Combined Nomenclature
CoC	Code of Conduct
DC	Direct Current
DCIE	Data Centre Infrastructure Efficiency
DER	Distributed Energy Resource

DL	Delta-conversion Line-interactive UPS
DMFC	liquid-fed Direct Methanol Fuel Cell
DoD	Deep of Discharge
DSP	Digital Signal Processing
ECA	Enhanced Capital Allowance
EDLC	Electric Double-Layer Capacitor
EMC	Electromagnetic Compatibility
EN	European Standards
EP	Eutrophication Potential
EPA	Environment Protection Agency
ErP	Energy Related Product
ETSI	European Telecommunications Standards Institute
EU	European Union
FC	Fuel Cell
g	Grams
GaN	Gallium Nitride
GDP	Gross Domestic Product
GHS	Globally Harmonised System
GPSD	General Product Safety Directive
GW	Gigawatt
GWP	Global Warming Potential
HFT	High-Frequency Transformer
HGO	High permeability Grain Oriented electrical steel
HRG	High-Resistance Ground
HVAC	Heating Ventilation and Air Conditioning
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGBT	Insulated-Gate Bipolar Transistor
ISO	International Organisation for Standardisation
ITU	International Telecommunications Union
JRC	Joint Research Centre
kg	Kilograms
kVA	Kilovolt-Ampere
kW	Kilowatt
kWh	Kilowatt Hour
LBNL	Lawrence Berkeley National Laboratory
LC	Resonant Circuit
Li-ion	Lithium Ion
LLCC	Least Life Cycle Cost
Ltr	Litre
LVD	Low Voltage Directive
MEErP	Methodology for the Ecodesign of Energy-related Products
MEPS	Minimum Efficiency Performance Standards
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair

Ni-Cd	Nickel Cadmium
Ni-MH	Nickel Metal Hydride
NPC	Neutral-Point Clamped
OEM	Original Equipment Manufacturer
PAHs	Polycyclic aromatic hydrocarbons
PBBs	Polybrominated Biphenyls
PBDEs	Polybrominated Diphenyl Ethers
PC	Personal Computer
PCB	Polychlorinated Biphenyl
PCBAs	Printed Circuit Board Assemblies
PDU	Power Distribution Unit
PEMFC	Proton Exchange Membrane Fuel Cell
PEP	Product Environmental Profile
PF	Power Factor
PLC	Programmable Logic Controller
PM	Particulate Matter
POPs	Persistent Organic Pollutants
PPDS	Power and Performance Data Sheet
PSU	Power Supply Unit
PWM	Pulse-Width Modulation
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RMS	Root Mean Square
RoHS	Restriction of Hazardous Substances
SC	Super-Capacitor
SFOE	Swiss Federal Office of Energy
SiC	Silicon Carbide
SL	Single-conversion Line-interactive UPS
SME	Small and Medium Enterprises
SRUPS	Surge Resistant UPS
SST	Solid-State Transformer
THDi	Total Harmonic Distortion
TWh	TerraWatt Hour
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
UUT	Unit Under Test
V	Volts
VA	Voluntary Agreement
VFD	Voltage Frequency Dependent
VFI	Voltage Frequency Independent
VI	Voltage Independent
VOCs	Volatile Organic Compounds
VRLA	Valve-Regulated Lead-Acid
W	Watt
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive

1 Task 1 – Definition

1.1 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 section presents the results of Task 1, which includes input from the first questionnaire and first stakeholder meeting held in September 2012.

1.2 Subtask 1.1 - Product category and performance assessment

The worldwide market for UPS is very closely linked to the continuous and expanding deployment of electronic facilities that must have security of function. These include, in particular, server centres, ICT equipment, retailer money and card processing tills and equipment insecurity and safety systems. In these applications UPS provide protection from grid power quality voltage instability and increasingly unacceptable power downtime. Consequently across the EU27, UPS equipment is being installed in millions of units each year according to the European Committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP).

The present, major UPS market in terms of product volume across the EU27 is for Alternating Current (AC) single-phase semi portable and static (installed) products providing 500 VA to 5000 VA standby power. In revenue terms, the largest market, driven by the ever expanding use of communication and multimedia entertainment products processing data, is for AC single phase and 3-phase static UPS providing up to 800 kVA. Three design topologies characterise these products:

- Double conversion (with or without bypass);
- Line interactive(with or without bypass); and
- Standby (offline).

For manageability and focus, the study primarily considers, but is not restricted to, **AC powered static and semi portable UPS utilising, for energy storage, various battery technologies** (principally lead-acid, with some Ni-Cd application and growing interest in or Li-Ion) applications. The market relevance and application of other standby energy systems categorised as UPS will also be identified and discussed with stakeholders, to determine if such systems are important within the context of the market such as:

- Fuel cell based UPS (mobile communication)
- Engine/motor driven UPS (hospitals and mobile communication)
- Grid connected or isolated battery storage UPS systems deriving electrical energy from solar PV and wind generation
- Gas turbine driven UPS
- Flywheel/motor driven modules
- Hydro power pump storage
- Compressed air storage
- Non-grid connected UPS (solar house systems).

At this stage of the project we have focused on the most ubiquitous UPS systems, i.e. **those that operate with no or fractional time delay**, as this equipment is responsible for the highest market share and deployed stock. The Ecodesign Directive advises that the number of units sold per year should exceed **200,000,** which is readily achieved in the European market for UPS.

It is anticipated that the environmental aspect that will be of main concern is in use energy consumption, which will be affected by both the efficiency of the product and the installation configuration. These issues will be considered and discussed in further detail in subsequent tasks. In addition to energy consumption, other environmental impacts related to the use of materials may also be important. For example, the battery can be a significant part of the product by weight, which by extending battery lifetime and reducing the need to replace batteries could reduce environmental impacts for those aspects associated with particular materials. Again, this will be considered further in subsequent tasks.

1.2.1 Existing definitions

Definitions of UPS are available from a range of existing sources. This includes official statistic classifications, other UPS studies, standards and existing labels or codes of conduct. The definitions used by these different sources are summarised below.

1.2.1.1 ProdCom

ProdCom statistics provide information on the production of particular products through the use of different category codes. The Eurostat guidance[5] indicates that the manufacture of UPS is covered by ProdCom class 27.90. A review of the codes for this class indicates there is no specific code of UPS, with the most potentially appropriate code as follows, which covers electrical machines and apparatus, having individual functions:

[5] http://tuikapp.tuik.gov.tr/DIESS/FileUpload/yayinlar//NACE%20Rev.2%20-%20EN.pdf

- 27.90.11.50: Machines with translation or dictionary functions, aerial amplifiers and other electrical machines and apparatus, having individual functions, not specified or included elsewhere in HS 85[6] (excluding sunbeds, sunlamps and similar suntanning equipment)

In addition, a review of other PRODCOM codes suggests that UPS could also potentially be covered by the following:

- 27.11.50.40: Power supply units for telecommunication apparatus, automatic data-processing machines and units thereof

These definitions are very broad and will include products other than UPS. They are therefore not considered appropriate to use in terms of a definition for UPS for the purposes of this study.

1.2.1.2 Definitions in other UPS Studies

The two key studies at international and European levels related to UPS are those conducted in support of the Energy Star UPS specification Version 1.0 July 2012 and the European Code of Conduct (CoC) "Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Supplies (UPS) Version 2.0 2011-03-16" For the definition of UPS these studies draw on the definition in the International Electrotechnical Commission (IEC) standard IEC 62040-3-2011 Edition 2.0.

Further information regarding this definition is presented below.

1.2.1.3 Definition in Standards

The following definition of UPS is used in the current overarching group of international standards for UPS, IEC 62040 -1 IEC 62040 -2, IEC 62040 -3 and scheduled for publication in 2013 / 2014 IEC 62040 -4 These standards are fully described in section 1.3.

For the purposes of the IEC 62040 group of standards a UPS is defined as a "Combination of convertors, switches and energy storage devices (such as batteries), constituting a power system for maintaining continuity of load power in case of input power failure."

This standard is applicable to UPS which are movable, stationary, fixed or for building-in, for use in low-voltage distribution systems and intended to be installed in any operator accessible area or in restricted access locations as applicable. It specifies requirements to ensure safety for the operator and layman who may come into contact with the equipment and, where specifically stated, for the service person.

This standard group does not cover UPS based on rotating machines.

In IEC 62040-3-2011 Edition 2.0 it is stated that:

This International Standard applies to movable, stationary and fixed electronic uninterruptible power systems (UPS) that deliver single or three-phase fixed frequency AC. output voltage not exceeding 1000 V AC. and that incorporate an energy storage system, generally connected through a DC. link.

The IEC 62040 standard group does not cover:

- Conventional AC input and output distribution boards or DC boards and their associated switches (e.g. switches for batteries, rectifier output or inverter input);
- Stand-alone static transfer systems covered by IEC 62310-3;
- Systems wherein the output voltage is derived from a rotating machine.

1.2.1.4 Definition in existing labels

The US Energy Star and Blue Angel are the only two existing product labels identified for UPS. The Energy Star label has recently been developed in the USA, with the first version

[6] HS is the Harmonized System of the World Customs Organisation, with HS 85 covering Electrical Machinery and equipment and parts theerfof: http://www.wcoomd.org/en/topics/nomenclature/instrument-and-tools/hs_nomenclature_2012/hs_nomenclature_table_2012.aspx

published in 2012. Energy Star[7] Version 1.0 2012 draws on the IEC standard IEC 62040-3 general definition for Static UPS:

Combination of convertors, switches, and energy storage devices (such as batteries) constituting a power system for maintaining continuity of load power in case of input power failure.

a) Power conversion mechanism:
   1) Static UPS: solid-state power electronic components provide output
   2) Rotary UPS: electrical rotating machines provide the output.
b) Power Output:
   1. AC-output UPS: supplies power with a continuous flow that periodically reverses direction.
   2. DC-output UPS/Rectifier: supplies power with a continuous flow that is unidirectional (Includes individual DC rectifier units and entire frames or systems, consisting of rectifier modules, controllers, and supporting components).

Included Products

I. Consumer - desktop computers and peripherals and home entertainment devices such as TVs, set top boxes, DVRs, Blu-ray and DVD players;
II. Commercial - small business and branch office ICT equipment such as servers, network switches and routers, and small storage arrays;
III. Data Centre - large installations of information and communication technology equipment such as enterprise servers, networking equipment, and large storage arrays; and,
IV. Telecommunications Dc-output UPSs/Rectifiers - telecommunication network systems - central or at a remote wireless/cellular site.

Excluded Products

I. Products that are inside a computer or product (e.g., battery-supplemented power supplies or backup for modems, security systems, etc.);
II. Industrial UPSs designed to protect industrial manufacturing operations;
III. Utility UPSs designed as part of electrical transmission and distribution (e.g. substation or neighbourhood UPSs);
IV. Cable TV (CATV) UPSs that power the cable signal distribution system outside plant equipment and connected to the cable itself. The “cable” may be metallic wire, fibre-optic or wireless
V. UPSs designed to comply with specific UL safety standards, such as emergency lighting, or medical diagnostic equipment.

The Blue Angel ecolabel criteria for UPS, published in February 2013, defines UPS as follows:

> *‘Uninterruptible Power Supply systems describe intermediate circuit AC converter systems fitted with semiconductor calve elements with storage equipment for electrical energy in the DC intermediate circuit that are used for bridging power outages’*

In addition, when specifying energy efficiency for double conversion operation, reference is made to UPS systems that meet the relevant classification (VFI-SS-111) in accordance with EN 62040 Part 3.

[7] www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies

1.2.1.5 EU Code of Conduct UPS[8]

An EU Code of Conduct for UPS has been developed, which a number of manufacturers participate, including the three major manufacturers. The most recent version published in March 2011. Further information regarding the details of the Code of Conduct is included in section 1.4.2.2 of this report.

In terms of definition, the Code of Conduct covers UPSs (UPS according to EN 62040-3 Ed. 1.0 b: 1999)[9] delivering 1-phase and 3-phase uninterruptible power above 0.3kVA at 230/400 V designed in different configurations and operations. Typical circuit arrangements are “UPS double conversion” with or without bypass, “UPS line interactive operation” with or without bypass and “UPS stand-by operation”.

It excludes UPS designed or complying with specific customer requirements impacting efficiency such as DC/battery voltage, additional isolation, special cooling, or Rotary UPS.

1.2.2 Evaluation of definitions

The review of UPS definitions included in existing standards, labelling schemes and the industry code of conduct indicates that all definitions draw on the common reference source of IEC 62040-3. It is therefore proposed that for consistency, in particular with the test standards and code of conduct, that this study should follow a similar approach.

Stakeholders were consulted on the proposed definition based on IEC 62040-3 via the first questionnaire and at the first stakeholder meeting held in September 2012. The general consensus from stakeholder feedback was that the proposed definition is appropriate as it reflects relevant standards, the code of conduct and the Energy Star. The proposed product group definition, together with qualifying notes, for use in this study is presented below.

1.2.3 Proposed product group definition

“A UPS is a combination of electronic power converters, switches and energy storage devices (such as batteries) constituting a power system for maintaining the continuity of power to a load in the case of input power failure.”

Qualifying Notes:

Input power failure is usually understood to mean the failure of the main primary continuous power source (e.g. the AC grid). It can also mean the failure of the primary power source to maintain voltage and frequency within rated steady state and transient bands or to allow distortion or interruptions to the supplied power outside specified limits.

A UPS is commonly understood to be a short duration (minutes/hours) power supply system that maintains the functions of the connected load when the main continuous power source has failed. The primary purpose of a UPS is to bridge an unexpected power gap and/or to provide the amount of power needed to safely power down the connected load. A UPS may also be used to continuously maintain the quality (distortion content) and stability (voltage and frequency) of the power to the connected load.

In the case of a primary AC grid failure, the UPS may run in isolated mode and is not grid-connected on the supply side.

In standby (when it is not replacing primary grid power) a UPS could operate in on-mode or off-mode, as an AC or DC operated device depending on the specific design.

A system providing electrical power, that supplements or is capable of continuously replacing the main source of grid power, is not a UPS (e.g. an engine or generator system).

[8] http://re.jrc.ec.europa.eu/energyefficiency/html/standby_initiative.htm
[9] This standard replicates the text of IEC 62040 -3 -2011 Edition 2 in the context of UPS definition and qualifications.

Portable devices designed to operate using battery power such as laptop computers are excluded from the product group.

1.3 Subtask 1.2 - Test Standards

This subtask identifies and describes existing EU and International test standards and those under development that are particularly related to the qualification of the environmental performance of UPS.

In order to commence this task it is necessary to define the term 'test standard'. As a generalisation a test standard is a written procedure that sets out a methodology to quantify by a measurement process one or more performance characteristics of a defined unit under test (UUT). The required accuracy, confidence level of results and repeatability of this measurement process is carefully specified. The quantitative value of the results of the measurement process are not specified in the normative part of a test Standard but may be provided in an informative part. Only the normative part of a test standard must be complied with if the UUT is deemed to have been tested according to the standard.

Test standards are often defined in Technical Standards. The latter provide a specification for the UUT against which all others may be measured or tested and indicates the required performance.

Test standards are drawn up by expert working groups in an approved and recognised standardisation body and through a process of consultation and approval by relevant stakeholders often involving a voting process. Standardisation bodies provide guidelines, characteristics and rules for the standards drafting process and this section makes reference principally to standards from the following standardisation bodies:

- International; Electrotechnical Commission (IEC Standards)
- European Committee for Electrotechnical Standardisation CENELEC, European Committee for Standardisation CEN and European Telecommunications Standards Institute ETSI, These bodies ratify European Standards (EN Standards) NB:. Under the Dresden agreement to reduce duplication of international standardisation activities EN and IEC standards are often drawn from each other's working groups and published under a common numerical reference e.g. IEC/EN 62040.
- International Organisation for Standardisation (ISO Standards)
- International Telecommunications Union (ITU Standards)
- Underwriters Laboratory (UL Standards)

Standards published by the above principal standardisation bodies may be adopted or compiled and published by approved national standardisation bodies (e.g. British Standards Institute – BS standards) or compiled and published by Industry associations and other stakeholders for specific purposes.

1.3.1 Test Standards applicable to UPS products in the scope of this study and to relevant aspects of their installation infrastructure

EN 62040-1:2008 - Uninterruptible power systems (UPS). General and safety requirements for UPS apply to uninterruptible power systems (UPS) with an electrical energy storage device in the DC. link. It is applicable to UPS which are movable, stationary, fixed or for building-in, for use in low-voltage distribution systems and intended to be installed in any operator accessible area or in restricted access locations as applicable. It specifies requirements to ensure safety for the operator and layman who may come into contact with the equipment and, where specifically stated, for the service person.

EN 62040-2:2006 - Uninterruptible power systems (UPS). Electromagnetic compatibility (EMC) requirements is intended as a product standard allowing the EMC conformity assessment of products of categories C1, C2 and C3 as defined in this part of EN 62040, before placing them on the market. The requirements have been selected so as to ensure an adequate level of electromagnetic compatibility (EMC) for UPS at public and industrial locations.

EN 62040-3:2011 - Uninterruptible power systems (UPS). Method of specifying the performance and test requirements applies to movable, stationary and fixed electronic uninterruptible power systems (UPS) that deliver single or three phase fixed frequency AC output voltage not exceeding 1,000 V AC. and that incorporate an energy storage system, generally connected through a DC. link. This standard is intended to specify performance and test requirements of a complete UPS and not of individual UPS functional units.

IEC 62040-4 Ed. 1.0 Uninterruptible power systems (UPS) - Part 4: Environmental aspects - requirements and reporting. This International product standard, currently under the IEC development process and scheduled for publication in 2013/2014, will specify the process and requirements to declare the environmental aspects of UPS. The object of the standard is to reduce any adverse environmental impacts during the complete UPS life-cycle. This standard will be harmonised with the applicable generic and horizontal environmental standards and will contain additional details relevant to UPS.

Other Standards relevant to UPS and the installation of UPS

- IEC 60146. Semiconductor Electronic Converters.
- EN 60950. Information Technology equipment – safety.
- EN/IEC 60269-1 Low Voltage Fuses – general requirements.
- EN/IEC 61000-4 – 1 -2 -3 -4 -5 – 6 -11. Electromagnetic Compatibility (EMC) Testing and Measurement techniques
- EN/IEC 61000-4 -2.2. Electromagnetic Compatibility (EMC) Environment.
- EN 5502. Information Technology Equipment. Radio Disturbance characteristics. Limits and methods of measurement.
- EN 60529. Specification of degrees of protection provided by enclosures (IP Code)
- EN 50171. Central power supply systems.
- EN 50310. Application of equi-potential bonding and earthing in buildings with Information Technology equipment.
- EN/IEC 60896. Stationary lead-acid batteries.
- EN 50272 – 2. Safety requirements for secondary batteries and battery installations, stationary batteries.
- EN/IEC 60439. Low voltage switchgear and control gear assemblies.
- EN/IEC 60947. Low voltage switchgear and control gear.
- EN/IEC 60694. Common specifications for high voltage switchgear and control gear standards.
- EN 50098-1. Customer premises cabling for Information Technology. ISDN basic access
- EN 50173-1. Information Technology. Generic cabling systems.
- EN 50174 -1 – 2 – 3. Information Technology equipment Cabling Installation.
- EN 50178. Electronic equipment for use in power installations.
- IEC 60364 – 4. Electrical Installations of buildings.
- EN 50160. Voltage characteristics of electricity supplied by public distribution system.
- IEEE 519. Harmonics in Power Supplies.
- IEEE 1459. Standard definitions for the measurement of electrical power qualities under sinusoidal and non-sinusoidal, balanced or unbalanced conditions.

1.4 Subtask 1.3 - Existing Legislation and Policy Measures

This subtask identifies existing legislation and policy measures that are relevant to UPS at both a European and International level. This includes legislation and policy at both the product level and cross product level. Relevant information relating to a range of aspects including product design, safety and resource management are covered.

It is important that exiting legislation and policy measures are understood in order to consider the business and consumer issues involved. This will ensure any potential implementing measures that may follow this study are consistent and not contradictory with exiting legalisation and policy measures.

The information is structured as follows, and includes a brief explanation of the relevant legislation or policy.

- European legislation
- European Agreements and Policy Measures
- Legislation and policies at member State level
- Third country legislation and policy measures

A summary table is included in section 1.4.5 for all existing legislation and policy measures relevant to UPS.

1.4.1 European legislation

1.4.1.1 Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE) was recast on 24 July 2012 as Directive 2012/19/EU[10]

The Directive implements the principle of "extended producer responsibility" where electrical and electronic product manufacturers are responsible for the costs of collection, treatment, recovery and disposal of their own products and hence preventing such object products from entering municipal waste collection systems.

Furthermore, it states that Member States should encourage the design and production of electrical and electronic equipment that facilitates reuse, recycling and other forms of recovery of such wastes in order to reduce them. Producers should not prevent, through specific design features or manufacturing processes, WEEE from being reused, unless such specific design features or manufacturing processes present overriding advantages, for example with regard to the protection of the environment and/or safety requirements.

The WEEE Directive applies to all electrical and electronic equipment listed in the categories below, which is dependent on electric current or electromagnetic fields in order to work properly, and equipment for the generation, transfer and measurement of such currents and fields, and designed for use with a voltage rating not exceeding 1000V for AC and 1500V DC, provided that the equipment concerned is not part of another type of equipment that does not fall within the scope of the Directive (Annex I (covering the period 14 August 2012 to 14 August 2018, of the WEEE Directive):

- Large household appliances
- Small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
- Toys, leisure and sports equipment
- Medical devices (with the exception of all implanted and infected products)
- Monitoring and control instruments

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

- Automatic dispensers

UPS are not separately listed in any of the 10 above categories, 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.

From 15th August 2018, the WEEE Directive will apply to products covered by the categories outlined in Annex III of the Directive:

- Temperature exchange equipment
- Screens, monitors, and equipment containing screens having a surface greater than 100 cm^2
- Lamps
- Large equipment (any external dimension more than 50 cm) including, but not limited to:
  Household appliances; IT and telecommunication equipment; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3.
- Small equipment (no external dimension more than 50 cm) including, but not limited to:
  Household appliances; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3 and 6.
- Small IT and telecommunication equipment (no external dimension more than 50 cm)

The list of electronic and electrical equipment (EEE) in Annex III is non exhaustive and it is anticipated UPS will be covered by the large or small equipment category, depending on size.

1.4.1.2 Directive 2002/95/EC on Restrictions of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment[11] (RoHS)

This Directive restricts the use of hazardous substances in electrical and electronic equipment for the protection of human health. As from 1 July 2006, new products should not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs)[12]. This Directive covers electrical and electronic equipment as defined in the WEEE Directive. There are exemptions for some of these materials when used in certain products.

Batteries used within UPS are classed as hazardous waste[13].

1.4.1.3 Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators[14]

The Directive aims to reduce the impact on the environment of the manufacture, distribution, use, disposal and recovery of batteries (primary-single use, and secondary battery cells-rechargeable, accumulators). The Directive introduces measures to prohibit the marketing of some batteries containing hazardous substances. It contains measures for establishing schemes aiming at high level of collection and recycling of batteries with quantified collection

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[11] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:201:0054:0057:EN:PDF
[12] http://ec.europa.eu/environment/waste/rohs_eee/events_rohs1_en.htm
[13] http://www.greenit.net/downloads/GreenIT-EnvIssues-Batteries.pdf
[14] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:266:0001:0014:en:PDF

and recycling targets. The Directive sets out minimum rules for producer responsibility and provisions with regard to labelling of batteries and their removability from equipment.

1.4.1.4 Waste Framework Directive, 2008/98/EC[15]

The revised Waste Framework Directive (WFD) coordinates waste legislation by repealing the WFD (2006/12/EC), the directive on hazardous waste (91/689/EEC) and part of directive on waste oils (75/439/EEC). This Directive retains much of the principles and aims of the previous directive while clarifying terms and strongly encouraging greater reuse of products. The revised WFD provides the overarching legislative framework for the collection, transport, recovery and disposal of waste, and includes a common definition of waste. It encourages the prevention and reduction of harmful waste by requiring that Member States ensure that measures exist to recover or dispose of waste without endangering human health or causing harm to the environment.

1.4.1.5 Registration, Evaluation, Authorisation and Restriction of Chemical substances (REACH) Regulation (EC) 1907/2006[16]

The REACH Regulation came into force on 1st June 2007 and deals with the Registration, Evaluation, Authorisation and restriction of Chemical substances. The aim of REACH is to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. At the same time, REACH aims to enhance innovation and competitiveness of the EU chemicals industry.

REACH was introduced because many thousands of chemicals are used in the EU, some in very large quantities, but the risks to human health and to the environment from many of these are not widely understood. REACH addresses this by making manufacturers and importers of chemicals responsible for producing data to define the hazards and risks from around 30,000 substances that are manufactured or imported in quantities of one tonne or more per year in the EU[17].

Manufactures are required to register the details of the properties of their chemical substances on a central database, which is run by the European Chemicals Agency in Helsinki. The Regulation also requires the most dangerous chemicals to be progressively replaced as suitable alternatives develop.

1.4.1.6 The Classification, Labelling and Packaging of Substances Regulations (EC) 1272/2008[18]

The Regulation entered into force on 20 January 2009 and will ultimately replace the current rules on classification, labelling and packaging of substances (Directive 67/548/EEC) and preparations (Directive 1999/45/EC). Substance classification and labelling must all be consistent with the new rules by 1 December 2010 and for mixtures 1 June 2015.

The aim of the regulation is to reduce confusion and potential errors among workers and consumers due to differing forms of labelling and safety data sheets in different countries. The United Nations developed a Globally Harmonized System (GHS) for the classification and labelling of chemicals. As an international agreement GHS is non-legally binding in Europe, therefore the GHS criteria was introduced into Europe via Classification, Labelling and Packaging Regulations.

The Regulation aims to ensure a high level of protection of human health and the environment, as well as the free movement of chemical substances, mixtures and certain specific articles, whilst enhancing competitiveness and innovation. This should be achieved by ensuring that the same hazards will be described and labelled in the same way all around the world.

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[15] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:EN:PDF

[16] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=oj:l:2006:396:0001:0849:en:pdf

[17] http://www.element14.com/community/community/legislation/reach?CMP=KNC-EU-LEGREACH&s_kwcid=TC|21070|reach%20regulation||S||8299726988

[18] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:353:0001:1355:en:PDF

1.4.1.7 Directive 94/62/EC on Packaging and Packaging Waste[19]

Packaging legislation is driven by the Packaging & Packaging Waste Directive (94/62/EC). The aim of the directive is to harmonize national measures concerning the management of packaging and packaging waste in order to provide a high level of environmental protection to all Member States and to ensure function of the internal market and to avoid obstacles to trade and distortion and restriction of competition within the Community[20]. The EC Packaging Directive seeks to reduce the impact of packaging and packaging waste on the environment by introducing recovery and recycling targets for packaging waste, and by encouraging minimisation and reuse of packaging[21].

Directive 94/62/EC has been amended twice, first by Directive 2004/12/EC and later by Directive 2005/20/EC. Recycling and recovery targets set by the original Directive for packaging waste were amended in 2004 by Directive 2004/12/EC. In 2005, the Directive was revised again to allow new Member States a transitional period for attaining the recovery and recycling targets.

1.4.1.8 Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy related products[22]

This Directive is a recast of the original Energy Labelling Directive (92/75/EEC) and came into force on the 31 July 2011. The recast has been undertaken to clarify the Directive in light of the number of changes, and further changes that have been made to the original directive. Directive 92/75/EEC was only applicable to household appliances. The recast Directive (2010/30/EU) aims to improve the overall environmental performance of products and to help consumers buy more eco-friendly products, through its application to energy related products. This extension of the scope to energy related products reinforces potential synergies between existing legislation, and in particular Directive 2009/125/EC establishing a framework for the setting of Ecodesign requirements for energy related products. The recast Directive for the labelling of energy related products forms part of the broader legal framework to bring about energy savings and environmental gains.

There is not currently an EU energy label for UPS, although the energy labelling of UPS has been the subject of previous research. Further details are provided in the Task 3 report.

1.4.1.9 Ecolabel Regulation EC 66/2010[23]

The EU Ecolabel scheme was introduced in 1992 by Council Regulation 880/92 to enable consumers to easily identify better performing environmental products. The scheme was reviewed in 2010 resulting in the updated Ecolabel Regulation EC 66/2010. There is currently no EU Ecolabel criterion for UPS.

1.4.1.10 Directive 2009/125/EC establishing a framework for the setting of Ecodesign Requirements for Energy-related products[24]

The original Directive (2005/32/EC) on the Ecodesign of energy using products was adopted in July 2005 and focused on energy using products. This Directive has subsequently been repealed by Directive 2009/125/EC, which is a recast and increases the scope from energy using products to energy related products.

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[19] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1994L0062:20050405:EN:PDF
[20] Packaging and Packaging Waste Directive Article 1 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31994L0062:en:HTML
[21] http://ec.europa.eu/environment/waste/packaging/index_en.htm
[22] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0001:0012:en:PDF
[23] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:027:0001:0019:EN:PDF
[24] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:285:0010:0035:EN:PDF

This Directive sets a clear framework for the setting of Ecodesign requirements for energy-related products, aimed at avoiding disparities in regulation amongst individual Member States, ensuring the free movement of such products within the internal market. This Directive provides for the setting of requirements which the energy-related products covered by implementing measures must fulfil in order to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply.

The Ecodesign Directive does not in itself set binding requirements for specific products, however, it does define conditions and criteria for setting, through subsequent implementing measures, minimum requirements regarding environmentally relevant product characteristics and allows them to be improved quickly and efficiently.

Currently most European standards that concern Uninterruptible Power Supplies (UPS) address safety issues. These standards fall under EU directives such as the Low Voltage Directive (LVD) 2006/95/EC. The EN standards also closely correspond to international standards.

It is under this Directive that this Preparatory Study for UPS has been commissioned. Other preparatory studies potentially relevant to UPS have been reviewed to check for overlaps in requirements that may have already been set in relation to UPS. None specifically cover UPS or requirements in relation to UPS, for example Lot 7 preparatory study and subsequent regulation (Commission Regulation 278/2009[25]) specifically excludes UPS. It will however be important to take into consideration the outcomes from the ENTR Lot 2 Distribution and Power Transformers preparatory study and subsequent regulation proposals from the perspective of transformer efficiency in larger UPS. In addition, the preparatory study on Enterprise Servers, Data Storage and ancillary equipment, is expected to commence in 2013 and may have implications for UPS and should therefore be considered as appropriate when developing the final policy for UPS.

1.4.1.11 Directive 2001/95/EC on General Product Safety[26]

The GPSD applies to all products placed on the market, not only electronics. Under the Directive, manufacturers and distributors are responsible for ensuring the safety of these products. A safe product is defined as one that "poses no threat or only a reduced threat in accordance with the nature of its use and which is acceptable in view of maintaining a high level of protection for the health and safety of persons."

1.4.1.12 Low Voltage Directive 2006/95/EC[27]

This Directive of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits. This Directive aims at ensuring that electrical equipment may be placed on the market only if it does not, when installed and maintained, endanger the safety of persons, domestic animals or property, and at promoting the free movement of this equipment in the European Union. This Directive applies to electrical equipment designed for use with a voltage rating of between 50 and 1000 Volts for alternating current and between 75 and 1500 Volts for direct current.

1.4.1.13 Directive 93/68/EC on CE Marking

This Directive of the European Parliament and of the Council of 22 July 1993 amends Directives 87/404/EEC (simple pressure vessels), 88/378/EEC (safety of toys), 89/106/EEC (construction products), 89/336/EEC (electromagnetic compatibility), 89/392/EEC (machinery), 89/686/EEC (personal protective equipment), 90/384/EEC (non-automatic weighing instruments), 90/385/EEC (active implantable medicinal devices), 90/396/EEC

[25] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:093:0003:0010:EN:PDF
[26] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:011:0004:0004:EN:PDF
[27] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:374:0010:0019:en:PDF

(appliances burning gaseous fuels), 91/263/EEC (telecommunications terminal equipment), 92/42/EEC (new hot-water boilers fired with liquid or gaseous fuels) and 73/23/EEC (electrical equipment designed for use within certain voltage limits). Such directive makes mandatory the CE marking on the products.

For UPS CE marking in accordance with the Low Voltage Directive and Electromagnetic Directive is required.

1.4.1.14 Directive 2004/108/EC on Electromagnetic Compatibility[28]

The main objective of the Directive is to regulate the electromagnetic compatibility of equipment:

- equipment (apparatus and fixed installations) needs to comply with EMC requirements when it is placed on the market and/or taken into service;
- the application of good engineering practice is required for fixed installations, with the possibility for the competent authorities of Member States to impose measures if non-compliance is established.

The EMC Directive first limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment. The Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended.

1.4.2 European Agreements and Policy Measures

1.4.2.1 European Energy Star[29]

The EU ENERGY STAR programme follows an Agreement between the Government of the US and the European Community (EU) to co-ordinate energy labelling of office equipment. At present it is managed by the European Commission and the US partner is the Environmental Protection Agency (EPA) that started the scheme in the US in 1992. At present there is no agreement in relation to UPS.

The US Energy Star UPS specification was published on the 1 August 2012[30], further details are presented in section 1.4.4.1.

1.4.2.2 EU Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems (UPS) version 2.0 2011[31]

The European Commission Code of Conduct is a voluntary agreement that invites all UPS manufacturers to design UPS to operate with maximum energy efficiency.

The Code covers Uninterruptible Power Systems (UPS) according to EN 62040-3 (Uninterruptible power systems - Method of specifying the performance and test requirements) delivering 1-phase and 3-phase uninterruptible power above 0.3 kVA at 230/400 V. UPS are designed in different configurations and modes of operation. Typical circuit arrangements are:

- “UPS double conversion” with or without bypass;
- “UPS line interactive operation” with or without bypass; and
- “UPS stand-by operation”.

The Code does not cover:

- UPS designed or complying with specific customer requirements impacting efficiency such as DC/battery voltage, additional isolation, special cooling; or
- UPS based on rotating machines.

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[28] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:390:0024:0037:en:PDF
[29] http://www.eu-energystar.org/
[30] http://www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies
[31] http://re.jrc.ec.europa.eu/energyefficiency/Code%20of%20conduct/UPS/Code_of_conduct_UPS_16032011.pdf

Minimum efficiency targets are introduced over a four year timescale, with targets set for 1/01/11- 31/12/12 and 1/01/13 to 31/12/14 respectively. UPS energy efficiency should be measured according to EN 62040-3.

Each UPS configuration (as defined in EN 62040-3) has a set of targets:

- UPS double conversion in the basic configuration with the classification
- "VFI – S…"
- For all VI and VFI UPS, except "VFI – S…"
- For all VFD UPS

Targets are set for UPS ranging from 10 to 500 kVA, and for 25% to 100% loading. For example, the benchmark for a 200 kVA UPS at full load (i.e.100%) is 93.3% in full on-line mode.

Further efficiency allowances (i.e. maximum losses per device) are given for additional components when added to equipment in the basic configuration (where there is no stand-by connection on the bypass line), i.e. for an input or output isolation transformer, and for input harmonic current filtering.

Each year signatories provide the European Commission with market data on all UPS models, including all types sold since 2007. The energy efficiency of models according to the target values as specified by the Code is declared as part of the reporting. Each signatory reports the previous year's data at the beginning of the subsequent year. Each signatory's dataset is held confidentially.

1.4.2.3 EU Code of Conduct Data Centres Energy Efficiency 2008[32]

This Code of Conduct aims to inform and stimulate data centre operators and owners to reduce energy consumption in a cost-effective manner and recommends energy efficiency best practice and targets. It is a voluntary initiative and invites interested stakeholders such as data centre owners and operators, data centre equipment and component manufacturers, service providers, and other large procurers of such equipment to abide by a set of agreed commitments.

'Data centres' includes all buildings, facilities and rooms which contain enterprise servers, server communication equipment, cooling equipment and power equipment, and provide some form of data service (e.g. large scale mission critical facilities all the way down to small server rooms located in office buildings).

The focus of the Code of Conduct covers two main areas:

1. IT Load – this relates to the consumption efficiency of the IT equipment in the data centre and can be described as the IT work capacity available for a given IT power consumption. It is also important to consider the utilisation of that capacity as part of efficiency in the data centre.

2. Facilities Load – this relates to the mechanical and electrical systems that support the IT electrical load such as cooling systems (chiller plant, fans, pumps) air conditioning units, UPS, Power Distribution Units etc.

The data centre is considered as a complete system, trying to optimise the IT system and the infrastructure together to deliver the desired services in the most efficient manner.

Initially, and in common with other industry bodies the Code of Conduct uses the ratio of IT Load to Facilities Load as the key metric in assessing infrastructure efficiency - known as the 'facility efficiency'. The Code of Conduct also considers the efficiency with which the IT equipment utilises the power delivered - known as the 'asset efficiency'. As efficiency metrics for data centres are further developed and agreed, it is expected that the Code of Conduct will adopt more comprehensive metrics which may also cover the IT system design, the IT

[32] http://ec.europa.eu/information_society/activities/sustainable_growth/docs/datacenter_code-conduct.pdf

hardware asset utilisation, and the IT hardware efficiency. To understand the entire efficiency of a data centre both facility and asset efficiency should be considered.

The Code of Conduct has both an equipment and system-level scope. At the equipment level, this Code of Conduct covers equipment typically used within data centres required to provide data, internet and communication services. This includes all energy using equipment within the data centre, such as: IT equipment (e.g. rack optimised and non-rack optimised enterprise servers, blade servers, storage and networking equipment), cooling equipment (e.g. computer room air-conditioner units) and power equipment (e.g. uninterruptible power supplies and power distributions units), and miscellaneous equipment (e.g. lighting). At the system level the Code of Conduct proposes actions which optimise equipment interaction and the system design (e.g. improved cooling design, correct sizing of cooling, correct air management and temperature settings, correct selection of power distribution), to minimize overall energy consumption.

The Code of Conduct applies the following metric for Data Centre infrastructure Efficiency (DCiE):

$$\textbf{DCiE} = \frac{\textbf{Main IT equipment energy consumption}}{\textbf{Total facility energy consumption}}$$

The metric reports how much of the energy consumed by the data centre is used by the equipment that is producing useful IT services. Higher figure indicates better energy efficiency of the data centre.

The Code of Conduct is addressed primarily to the Data Centre Owners and Operators which may become Participant, and secondly to the supply chain and service providers which may become Endorsers (this will include UPS manufacturers). Endorsers are expected to utilise this Code of Conduct in order the develop products, solutions and programmes to enable data centre owners and operators to meet the expectations of the Code of Conduct.

One of the aims of the Code of Conduct is to support procurement, by providing criteria for equipment (based on the Energy Star Programme specifications, when available, and other Codes of Conduct and best practice recommendations. For UPS the specifications are given in the European Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems (UPS) (except for those UPS technologies that are not included in the UPS Code of Conduct, such as rotary devices).

The best practice commitments for vendors/manufacturers are:

- Provide product/service assistance and information to data centre owners and operators or consultants, including but not limited to:
    + Equipment power consumption labelling using standard metrics
    + Load / power data for equipment
    + Expand and clearly label temperature and humidity limits in warranties
    + Offer hardware / services to meet power limitation
    + Develop and assist in training programmes
    + Promote the Code of Conduct best practices

1.4.2.4 Ecopassport – Product Environmental Profile (PEP)[33]

The PEP ecopassport® programme is established for electrical, electronic and HVAC products and is a voluntary initiative. The PEP is neither a label, nor a regulatory obligation. This is a guarantee of reliability and conformity to international standards for all companies, aiming to place its products on eco-responsible markets. A Product Environmental Profile (PEP) is a document used to communicate the environmental impacts of electrical, electronic and HVAC products. The environmental impacts are calculated according to a Life Cycle Assessment, taking into account the different life cycle stages of the product (manufacturing,

[33] http://www.gimelec.fr/images/gimelec/publication_correct_pdf/pep-ecopassport-plaquette-en.pdf

distribution, installation, use, end of life) and their respective impacts on the environment (water, air, soil). The PEP ecopassport® programme has an international vision and meets the requirements of for Type III environmental product declarations as detailed in the ISO 14025 standard.

A Type III environmental declaration is a declaration meeting the requirements of the ISO 14025 standard, meaning it should:

- Be based on life cycle assessment,
- Quantifie the relevant environnemental impacts,
- Be performed in the framework of a declaration program with a critical review of rules and the consultation of stakeholders on those rules, as well as an independent verification of declarations.

ISO 14025:2006 establishes principles for the use of environmental information, in addition to those given in ISO 14020:2000. ISO 14025:2006 establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations. It specifically establishes the use of the ISO 14040 series of standards in the development of Type III environmental declaration programmes and Type III environmental declarations.

Type III environmental declarations as described in ISO 14025:2006 are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication under certain conditions is not precluded.

Stakeholders have indicated that product specific rules for UPS that will enable the development of consistent Product Environmental Profiles for UPS products under the EcoPassport programme are currently under development.

1.4.3 Member State Policies

1.4.3.1 Enhanced Capital Allowance Scheme for UPS (United Kingdom)

The UK's Enhanced Capital Allowance Scheme[34] (ECA) enables businesses to claim enhanced tax relief for products and equipment that meet specified energy saving criteria. The scheme is part of the UK Governments programme to manage climate change and covers a wide range of products, including UPS.

The ECA scheme covers the following UPS products:

- Static uninterruptible power supply units or packages (as defined in BS EN 62040-3:2011 or IEC 62040-2:2011); and
- Rotary uninterruptible power supply units or packages (as defined in BS EN 88528-11:2004 or IEC 88528-11:2004).

In order to qualify for enhanced capital allowances, businesses must purchase products that are named on the Energy Technology Product List. In order to be included on the list, products must meet specific energy saving criteria[35] that include the following:

- Minimum efficiency requirements at full and part load conditions. These efficiencies range from 90.9% to 94.5% for static UPS and 89% to 96% for rotary UPS, depending on the load;
- Input power factor requirements must be greater than or equal to 0.93 at 25%, 50%, 75% and 100% of rated maximum power output; and
- Input total harmonic distortion requirements must be less than or equal to 5% at 100% of rated maximum power.

[34] https://etl.decc.gov.uk/etl/site.html
[35] https://etl.decc.gov.uk/etl/site/etl/browse-etl/ups/criteria.html?SUB_TECH_ID=70

The criteria are reviewed and updated regularly to reflect any technological and market developments. The latest criteria are available in full from the schemes website[36].

1.4.3.2 Blue Angel (Germany)

The Blue Angel[37] is a voluntary ecolabel scheme based in Germany, which has developed environmental criteria for a wide range of products. In February 2013, the Blue Angel criteria for UPS were published[38].

The criteria focus on static uninterruptible power supplies with an output of at least 5kW that are designed for bridging power outages. The full criteria are available from the Blue Angel website, however to summarise they cover the following key areas:

- Energy efficiency requirements, which vary depending on the load size and type;
- Material requirements for plastics used in the housing and housing parts;
- Requirements for batteries, which focus on the exclusion of cadmium, requirements for the spectral internal resistance of the batteries, longer battery lifetimes, protective mechanisms for the charging system and guarantee terms of the battery;
- Durability, ensuring the availability of spare parts, for at least 10 years following the termination of production;
- Designed and constructed to ensure easy and quick dismantling for the purpose of separating recyclable components and materials; and
- Consumer information, including information on optimal ventilation, power consumption during operation, energy efficient use, maximising battery lifespan, the chemical system in the battery and safety instructions for exchanging batteries.

1.4.4 Non EU Policies

1.4.4.1 US Energy Star[39]

ENERGY STAR is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. ENERGY STAR is a voluntary partnership between government, businesses, and purchasers designed to encourage the manufacture, purchase, and use of efficient products to help protect the environment. The ENERGY STAR program originated as an energy-efficiency label within the United States. The label signifies a high performing product strictly in terms of energy efficiency.

Version 1 of the ENERGY STAR Uninterruptible Power Supplies specification was finalized on 10th May 2012 and took effect from 1st August 2012. Qualifying products must comply with the eligibility criteria, which define which types of UPS products are eligible and those that are not. The criteria also define the UPS performance requirements and sets out the test procedures[40].

Products that meet the definition of the UPS specified in the criteria include Static and Rotary UPSs and Ac-output UPSs and Dc-output UPSs/Rectifiers and include:

- Consumer UPSs intended to protect desktop computers and related peripherals, and/or home entertainment devices such as TVs, set top boxes, DVRs, Blu-ray and DVD players;
- Commercial UPSs intended to protect small business and branch office information and communication technology equipment such as servers, network switches and routers, and small storage arrays;

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[36] https://etl.decc.gov.uk/etl/site/etl/browse-etl/ups/criteria.html?SUB_TECH_ID=70
[37] http://www.blauer-engel.de/en/
[38] http://www.blauer-engel.de/en/products_brands/search_products/produkttyp.php?id=718
[39] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=UPS
[40] http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/uninterruptible_power_supplies/UPS_ENERGY_STAR_Program_Requirements.pdf?309b-7bba

- Data Centre UPSs intended to protect large installations of information and communication technology equipment such as enterprise servers, networking equipment, and large storage arrays; and,
- Telecommunications DC-output UPSs/Rectifiers intended to protect telecommunication network systems located within a central office or at a remote wireless/cellular site.

Products that are excluded include:

- Products that are internal to a computer or another end-use load (e.g. battery supplemented internal power supplies or battery backup for modems, security systems, etc.);
- Industrial UPSs specifically designed to protect critical control, manufacturing, or production processes or operations;
- Utility UPSs designed for use as part of electrical transmission and distribution systems (e.g. electrical substation or neighbourhood-level UPSs);
- Cable TV (CATV) UPSs designed to power the cable signal distribution system outside plant equipment and connected directly or indirectly to the cable itself. The “cable” may be coaxial cable (metallic wire), fibre-optic, or wireless (e.g., “Wi-Fi”);
- UPSs designed to comply with specific UL safety standards for safety-related applications, such as emergency lighting, operations or egress, or medical diagnostic equipment; and,
- UPSs designed for mobile, shipboard, marine or airborne applications.

Energy efficient requirements are stipulated for Ac-output UPSs and Dc-output UPSs/Rectifiers. Each UPS configuration must comply with Minimum Average Efficiency Requirement which must be evaluated using directly measured or calculated values.

For AC-output UPSs the test set-up and instrumentation is generally in accordance with IEC 62040-3:2011, and for DC-output UPSs/Rectifiers with standards ATIS-0600015.2009, and ATIS-0600015.04.2010.

1.4.5 Summary and Evaluation of Relevant Legislation and Policies

A summary of the legislation and policies relevant to UPS have been identified and are summarised in Table 1. This provides an indication of the key areas the different legislation and policies cover, for example, design, safety, energy etc.

Table 1: Summary of legislation and policies

Title	Type	High level summary	Product Design	Safety	Energy Efficiency	Labelling	Quality	Waste
Directive 2002/96/EC on Waste Electrical and Electronic Equipment (WEEE) was recast on 24 July 2012 as Directive 2012/19/EU	EU Directive	- Implements "extended producer responsibility" - electrical and electronic product manufacturers are responsible for collection, treatment, recovery and disposal of their own products. - States that Member States should encourage the design and production of electrical and electronic equipment that facilitates reuse, recycling and other forms of recovery of such wastes in order to reduce them.	✓	✓		✓		✓
Directive 2002/95/EC on Restrictions of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)	EU Directive	- Restricts the use of hazardous substances in electrical and electronic equipment for the protection of the environment and human health.	✓	✓				✓
Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators	EU Directive	Aims to: - Reduce the environmental impact of batteries; - Prohibit the marketing of some hazardous batteries; - Provide measures to establish high level collection and recycling schemes and: - Set out rules for minimum producer responsibility.				✓		✓
The Revised Waste Framework Directive, 2008/98/EC	EU Directive	- Coordinates all waste legislation from previous WFD, Hazardous Waste Directive and part of the waste oils directive. - It clarifies terms, promotes greater reuse of products, provides framework for all collection, transport, recovery		✓				✓

Title	Type	High level summary	Product Design	Safety	Energy Efficiency	Labelling	Quality	Waste
		and disposal of waste. - Introduces 70% target for recycling and recovery of non-hazardous and construction waste by 2020 by all Member States.						
Registration, Evaluation, Authorisation and Restriction of Chemical substances (REACH) Regulation (EC) 1907/2006	EU Regulation	- Regulation for the Registration, Evaluation, Authorisation and restriction of Chemical substances. - Aims to improve the protection of the environment and human health along with the innovation and competitiveness of the EU Chemicals industry. - Requires the most dangerous chemicals to be progressively replaced as suitable alternatives develop.	✓	✓				
The Classification, Labelling and Packaging of Substances Regulations (EC) 1272/2008	EU Regulation	- Replaces all previous regulations and substance classification and labelling must be consistent with the new rules by 1 December 2010 and for mixtures 1 June 2015. - Aims for consistency in substance labelling across different countries - Protection to the environment and human health and: - The free movement of chemical substances and mixtures.		✓		✓		
Directive 94/62/EC on Packaging and Packaging Waste	EU Directive	- Aims to provide consistency across the Member States for the management of packaging and packaging waste; - Introduces targets to reduce its environmental impact and: - Encourages its minimisation and reuse.	✓					✓

Title	Type	High level summary	Product Design	Safety	Energy Efficiency	Labelling	Quality	Waste
Directive on the indication by labelling and standard product information of the consumption of energy and other resources by energy related products 2010/30/EU	EU Directive	- A recast of the original 92/75/EEC Energy Labelling Directive to clarify changes that have occurred. - Aims to improve ALL products rather than just household appliances. - Forms part of the broader legal framework for energy savings and environmental gains.	✓		✓	✓		
Ecolabel Regulation EC 66/2010	EU Regulation	- Enables consumers to easily identify better performing environmental products.	✓	✓	✓	✓		
Directive 2009/125/EC establishing a framework for the setting of Ecodesign Requirements for Energy-related products	EU Directive	- Replaces the 2005/32/EC Directive. - Increases the scope from energy using products to energy related products. - Aims for consistency among Member States for Ecodesign requirements. - Defines conditions and criteria for setting of binding requirements, through subsequent implementing measures, minimum requirements regarding environmentally relevant product characteristics and allows them to be improved quickly and efficiently.	✓		✓			
Directive 2001/95/EC on General Product Safety	EU Directive	- The GPSD applies to all products placed on the market, not only electronics		✓			✓	
Low Voltage Directive 2006/95/EC	EU Directive	- Aims at ensuring electrical equipment may be placed on the market only if it does not, when installed and maintained, endanger the safety of persons, domestic animals or property.		✓			✓	
Directive 93/68/EC on CE Marking	EU Directive	- Amends numerous Directives, making it mandatory for CE marking to be present on all products.		✓		✓	✓	

Title	Type	High level summary	Product Design	Safety	Energy Efficiency	Labelling	Quality	Waste
Directive 2004/108/EC on Electromagnetic Compatibility	EU Directive	- Aims to regulate the electromagnetic compatibility of equipment; - It limits electromagnetic emissions of equipment to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment and: - It governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended.		✓		✓	✓	
European Energy Star	Agreement	- The EU ENERGY STAR programme follows an Agreement between the Government of the US and the European Community (EU) to co-ordinate energy labelling of office equipment.	✓		✓	✓		
EU Code of Conduct on Energy Efficiency and Quality of AV Uninterruptible Power Systems (UPS) version 2.0 2011	Voluntary agreement	- Invites all UPS manufacturers to design UPS to operate with maximum energy efficiency. - The Code covers Uninterruptible Power Systems (UPS) according to EN 62040-3 delivering 1-phase and 3-phase uninterruptible power above 0.3 kVA at 230/400 V and three typical circuit arrangements. The Code does not cover: • UPS designed or complying with specific customer requirements impacting efficiency • Such as DC/battery voltage, additional isolation, special	✓		✓			

Title	Type	High level summary	Product Design	Safety	Energy Efficiency	Labelling	Quality	Waste
		cooling; or • UPS based on rotating machines. - Minimum efficiency targets are introduced over a four year timescale, with targets set for 1/01/11- 31/12/12 and 1/01/13 to 31/12/14 respectively. - Each year signatories provide the European Commission with market data on all UPS models, including all types sold since 2007. - Each signatory reports the previous year's data at the beginning of the subsequent year and is held confidentially.						
EU Code of Conduct Data Centres Energy Efficiency 2008	Voluntary agreement	- This Code of Conduct aims to inform and stimulate data centre operators and owners to reduce energy consumption in a cost-effective manner and recommends energy efficiency best practice and targets. - It is a voluntary initiative and invites interested stakeholders such as data centre owners and operators, data centre equipment and component manufacturers, service providers, and other large procurers of such equipment to abide by a set of agreed commitments.			✓			
Ecopassport – Product Environnemental Profile (PEP)	Voluntary initiative	- A programme established for electrical, electronic and HVAC products. It is a guarantee of reliability and conformity to international standards for all companies, aiming to place its products on eco-responsible markets.	✓		✓	✓		✓

Title	Type	High level summary	Product Design	Safety	Energy Efficiency	Labelling	Quality	Waste
		- It is a document that communicates the environmental impacts of electrical, electronic and HVAC products. - The environmental impacts are calculated according to a Life Cycle Assessment - The PEP ecopassport® program has an international vision and meets the requirements of for type III environmental product declarations as detailed in the ISO 14025 standard.						
Enhanced Capital Allowance Scheme for UPS (UK)		- The ECA scheme encourages the purchase of high efficiency products - Businesses can claim enhanced tax relief by purchasing products that meet the specified criteria. - Criteria focus on the energy performance of UPS		✓	✓			
Blue Angel (Germany)		- Blue Angel is voluntary ecolabel. - Criteria across a range of requirements must be met for the Blue Angel to be awarded to a product. - The label includes criteria relating to energy efficiency and materials.	✓		✓	✓		✓
US Energy Star	US voluntary agreement	- ENERGY STAR is a joint programme of the U.S. Environmental Protection Agency and the U.S. Department of Energy. - A voluntary partnership between government, businesses, and purchasers designed to encourage the manufacture, purchase, and use of efficient products to help protect the environment. - The label signifies a high performing product in terms of energy efficiency.	✓		✓	✓		

2 Task 2 – Economic and Market Analysis

2.1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design Working Plan 2009-2011. This preparatory study is the starting point of this process. It aims to identify the current market size and composition, technical solutions, potential future technology improvements and possible policy options for the product group.

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 Best Available Technology (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 stakeholders to review and comment on the work, 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 section presents the results of Task 2, which includes input from the first questionnaire and first stakeholder meeting held in September 2012 and subsequent feedback received at the second stakeholder meeting held in May 2013.

Task 2 analyses generic economic data from official statistics and proposes a modelling approach to establish stock and sales figures. Market trends have been identified, along with market and production structures, key product design and innovation trends and consumer expenditure base data.

2.2 Subtask 2.1- Generic Economic Data

The aim of this section is to identify generic economic data for UPS from official EU statistics where possible in order to understand the size of the market for UPS. This information is used in later tasks to quantify the impact of any potential improvements. The data sought from official EU statistics includes:

- EU production
- EU sales
- Extra EU trade
- Intra EU trade
- Apparent consumption (calculated)

Whilst the preferred source for this information is official EU statistics, where this is not available other sources and methods, for example modelling, can be used to derive estimates. In order to establish the level of information available from official statistics and whether alternative approaches are required, Eurostat databases[41] have been analysed and relevant data extracted.

The Eurostat guidance[42] indicates that the manufacture of UPS is covered by PRODCOM class 27.90: Manufacture of other electrical equipment. A review of the codes for this class does not indicate a specific code for UPS itself, but instead a number of potential PRODCOM codes. The most appropriate codes are as follows:

- 27.90.11.50: Machines with translation or dictionary functions, aerial amplifiers and other electrical machines and apparatus, having individual functions, not specified or included elsewhere in HS 85[43] (excluding sunbeds, sunlamps and similar sun-tanning equipment)

In addition, a review of other PRODCOM codes suggests that UPS could also be covered by the following:

- 27.11.50.40: Power supply units for telecommunication apparatus, automatic data-processing machines and units thereof

The PRODCOM data, where available, provides information on the number and value of the units sold for a particular code. The data for 2010 is summarised in Table 2 for the PRODCOM codes identified above:

Table 2: Value and number of units sold for PRODCOM codes identified.

ProdCom Code	Product description	Products Sold (units 000s) 2010	Value of Products Sold (Euros 000s) 2010
27.90.11.50	Machines with translation or dictionary functions, aerial amplifiers and other electrical machines and apparatus, having individual functions, not specified or included elsewhere in HS 85 (excluding sunbeds, sunlamps and similar sun tanning equipment)	No data	1,965,946
27.11.50.40	Power supply units for telecommunication apparatus, automatic data-processing machines and units thereof	2,424	451,095

[41] http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database and http://epp.eurostat.ec.europa.eu/portal/page/portal/international_trade/data/database
[42] http://tuikapp.tuik.gov.tr/DIESS/FileUpload/yayinlar//NACE%20Rev.2%20-%20EN.pdf
[43] HS is the Harmonized System of the World Customs Organisation, with HS 85 covering Electrical Machinery and equipment and parts thereof: http://www.wcoomd.org/en/topics/nomenclature/instrument-and-tools/hs_nomenclature_2012/hs_nomenclature_table_2012.aspx

In addition to sales data, Eurostat databases can be used to identify extra and intra EU trade. PRODCOM codes have equivalent CN codes[44], which can be used to provide information on trade. The following CN codes have been identified as the most likely to cover UPS:

- 85437090: Electrical machines and apparatus with individual functions, not specified or included elsewhere in this chapter
- 85044030: Power supply units of a kind used with automatic data processing machines (Excluding for civil aircraft of subheading no. 85044010)

Extra and intra imports and exports for these codes are summarised in Table 3 and Table 4 for the EU27 in terms of value and quantity respectively.

Table 3: Value of Extra and Intra EU Trade for selected CN codes

CN Code	Code description	Extra EU Trade 2010 (Value million Euros)		Intra EU Trade 2010 (Value million Euros)	
		Imports	Exports	Imports	Exports
85437090	Electrical machines and apparatus with individual functions, not specified or included elsewhere in this chapter	1,881	1,69	1,7945	1,911
85044030	Power supply units of a kind used with automatic data processing machines (Excl for civil aircraft of subheading no. 85044010)	1,914	756	1,116	1,408

Table 4: Quantities of Extra and Intra EU Trade for selected CN codes

CN Code	Code description	Extra EU Trade 2010 (Quantity in 100kg)		Intra EU Trade 2010 (Quantity in 100kg)	
		Imports	Exports	Imports	Exports
85437090	Electrical machines and apparatus with individual functions, not specified or included elsewhere in this chapter	476,433	209,133	460,106	493,156
85044030	Power supply units of a kind used with automatic data processing machines (Excl for civil aircraft of subheading no. 85044010)	1,602,287	347,947	1,171,359	940,792

Assessment of the production and trade data extracted from Eurostat and summarised in Table 3 and Table 4 indicates that UPS data is included alongside a range of other products. It is not possible to extract UPS-only data. In addition trade data is reported by value and quantity in kilograms, and not number of units. The lack of transparency on the different types of products included within these codes, which in some cases is very general, means that these sources do not provide the comprehensive information required for the purposes of the preparatory study. This finding is not unusual and has been observed when conducting other ecodesign preparatory studies.

As a result of this, an alternative approach is required using modelling in order to establish the sales and stock figures for UPS, which are used in later tasks to quantify the potential impacts of any proposed improvements. To inform the modelling approach and provide the context in which it has been developed, Section 2.3 presents the market trends for UPS (Subtask 2.3). Section 2.4 then provides full details of the approach used and the results of our sales and stock calculations (Subtask 2.2). It includes the use of data provided by stakeholders, together with a number of assumptions and modelling.

[44] http://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL&StrLanguageCode=EN&IntCurrentPage=3

2.3 Subtask 2.3 - Market trends

2.3.1 Introduction

This section outlines the general market trends for UPS based on available literature and insights from industry and technical experts. UPS are used in a wide range of applications, including banking and finance operation, information and communication technology, data centres, infrastructure, telecommunication and medical/healthcare.

The trends and insights provided in this section have been used to develop our sales and stock model, which is used to estimate the number of units in terms of stock and sales for UPS. Full details of the modelling approach and results are presented in Section 2.4.

2.3.2 Global Market Trends

Historically the market for UPS has experienced significant growth due to the expansion of information technology; however it has experienced fluctuations as a result of specific events. For example, in 2001 the UPS market experienced decline as a result of the technical downturn following the September 2001 terrorist attacks in the USA[45]. More recently, the global market for UPS has been affected by the global recession, and although information relating specifically to the European Market has not been identified, it is assumed that the European market will have been affected in a similar manner to the global market.

Market research[46] indicates that as a result of the global recession, the global UPS market experienced a 20% decline between 2008 and 2009; with market research forecasts suggesting it would be 2011 before 2008 demand levels are reached again. Figure 1 indicates that between 2006 and 2010 global revenues for the UPS market experienced little growth; however by 2020 it is forecast to almost double when compared to 2010[47].

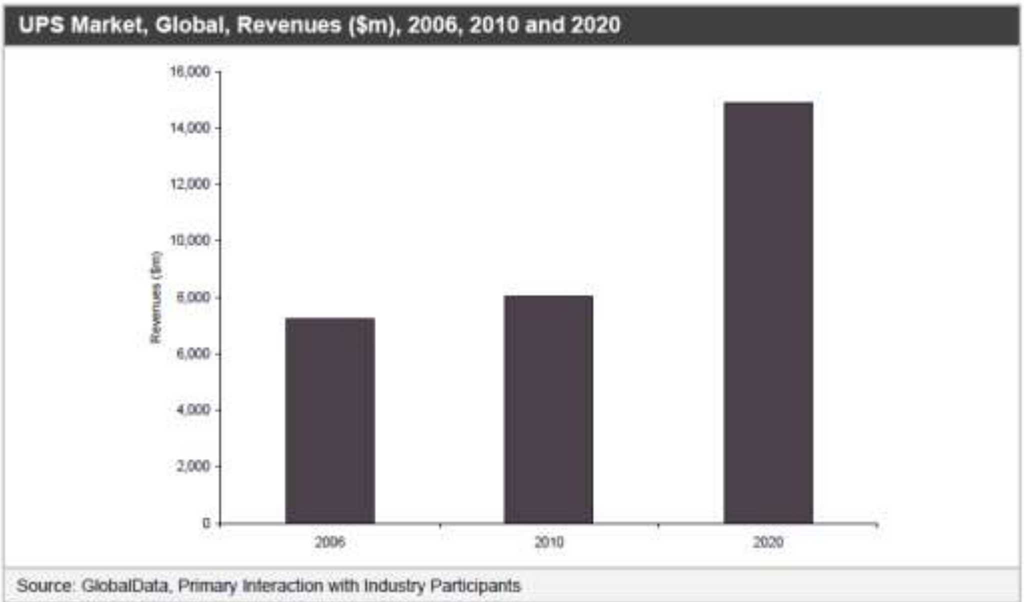

Figure 1: Revenues for the global UPS market

Other research indicates that revenues generated from the global UPS market are expected to rise by 12%[48] in 2011, mainly driven by the expansion of the market in China and other emerging economies in Asia and Latin America. However a more recent market press release indicates that despite some recovery in 2010 and early 2011, revenues have

[45] High Performance Buildings: Data Centres Uninterruptible Power Supplies (UPS), EPRI and Ecos Consulting, 2005
[46] http://www.microscope.co.uk/news/2240157851/UPS-market-has-the-power-to-perform
[47] http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf
[48] http://www.pikeresearch.com/research/next-generation-uninterruptible-power-supplies

subsequently declined again in 2012, mainly as a result of the on-going economic struggles[49].

The market for UPS can be distinguished by size. Figure 2[50] suggests that the market composition in 2020 will be similar to that in 2006.

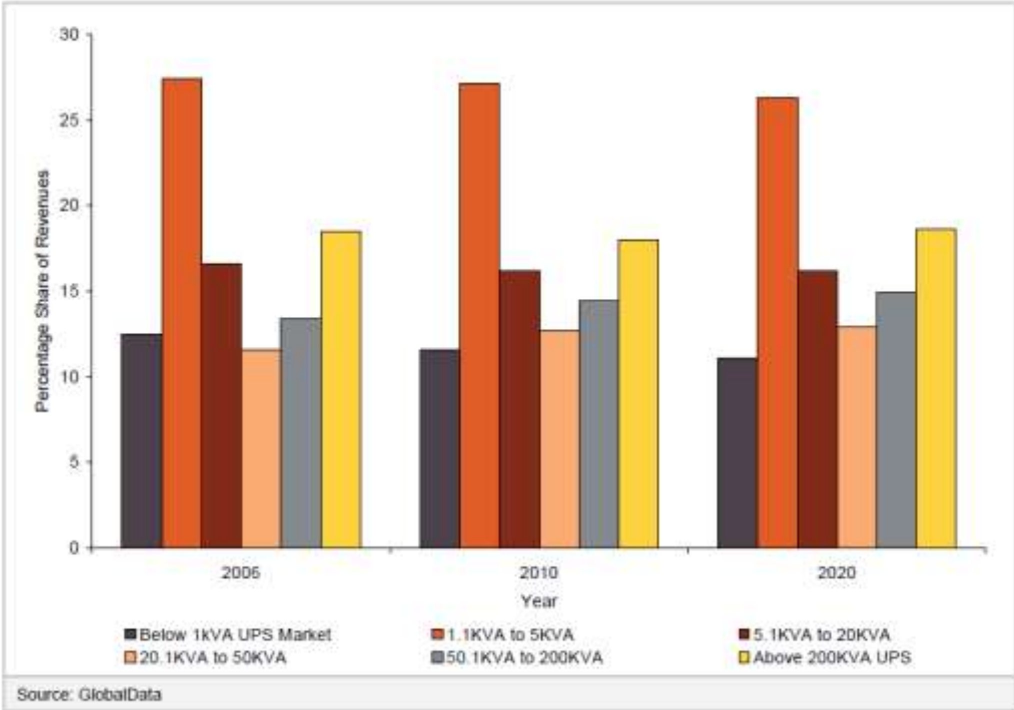

Figure 2: Percentage share of revenues by UPS size

Further research indicates that the global market is expected to grow in the future, driven by the digital economy[50] and the increasing uptake in cloud servers, which will have an effect on the data centre UPS market in particular[51].

2.3.3 European Market Trends

The UPS market in Europe is relatively mature compared to other parts of the world, for example China, where the market is experiencing significant growth. Limited information relating specifically to the market trends in European has been identified. However in the long term growth is anticipated as data centres continue to be built and expand, together with a decreasing acceptance of downtime. In the short term the UPS market in Europe continues to be affected by the European debt crisis, with the market expected to contract slightly as a result[51].

2.3.4 Product Features and Innovation/Design Trends

As noted above particular types of UPS can be used depending on the size required. Aside from this, there are a number of product features and design trends that can be highlighted for UPS.

Recent studies have highlighted that modular or scalable UPS products are expected to become increasingly popular and experience growth within Europe[52]. At present, the market for modular UPS is an emerging one, however it is anticipated that a shift from conventional

[49] http://imsresearch.com/news-events/press-template.php?pr_id=2956
[50] http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf
[51] http://www.prnewswire.com/news-releases/frost--sullivan-considerable-interest-in-cloud-computing-helps-the-world-data-center-ups-market-average-a-6-percent-growth-from-2010-to-2017-140697193.html

[52] http://www.frost.com/sublib/display-market-insight-top.do?id=219871988

UPS to modular UPS will occur as a result of the technological advances that make modular UPS possible.

Modular UPS offer a number of technical and commercial benefits:

- UPS can be matched to critical load demand by operating a number of smaller UPS in parallel, resulting in low operating costs.
- Allows space required by UPS only to be used as required.
- Greater resilience by allowing upgrades and maintenance e.g. battery replacement or the use of swappable modules, to be undertaken whilst the system is still on line
- Greater flexibility, allowing the UPS to expand as the load is increased instead of having to replace the UPS with a entirely new system

Modular UPS will not necessarily be applicable for all applications, but it is expected to be suitable for mid-sized data centres and business networks that start off small but are expected to grow over time. All of the main manufacturers have modular UPS products as part of their ranges.

Another development in UPS technology is the introduction and increasing use of transformerless UPS designs[53]. Figure 3 shows that transformer-less UPS can achieve higher efficiencies compared to transformer based UPS products.

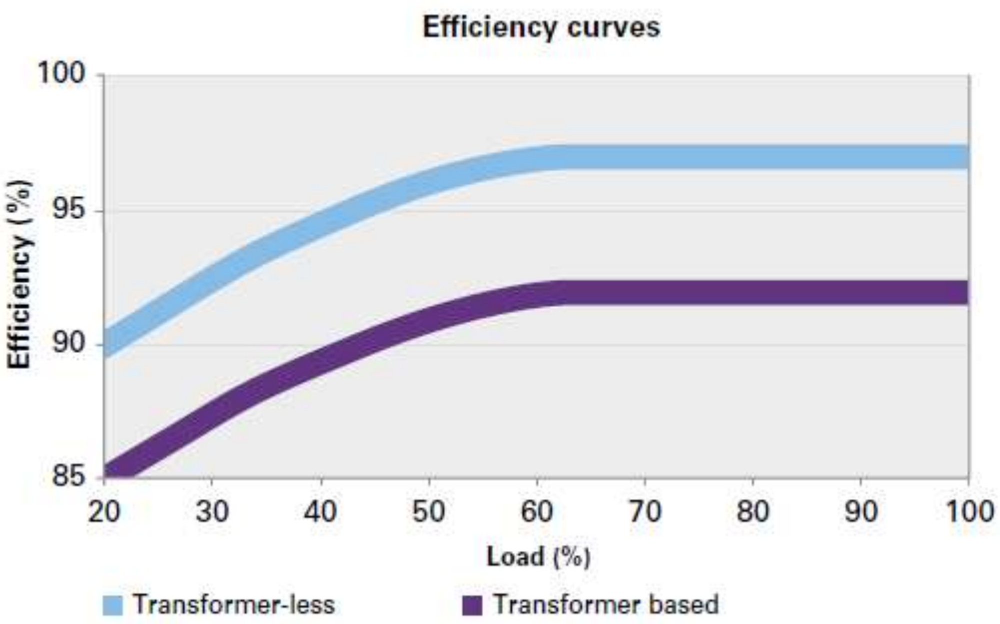

Figure 3: Typical efficiency/load curves for transformer and transformer-less UPS systems[54]

Although transformerless designs have been available for over 10 years, interest in them has increased over the years as technologies have improved, allowing them to be considered for higher power uses instead of just lower power level requirements[55].

The primary difference between transformerless and transformer based UPS, is the use of transformers in the design. A transformer-based UPS may use a transformer before the rectifier and requires an isolation transformer after the inverter to derive the voltage being delivered to the critical load. In contrast, a transformerless UPS design will use

[53] http://www.pikeresearch.com/newsroom/uninterruptible-power-supply-market-to-expand-by-12-in-2011-with-strong-growth-ahead
[54] Figure reproduced from Carbon Trust Technology information leaflet ECA778; Uniterruptible power supply: A guide to equipment eligible for Enhanced capital Allowances, Published February 2010 Source data: The Handbook Uninterruptible Power Supplies, Peter Bentley
[55] http://www.emersonnetworkpower-partner.com/Network-News-May-2010-In-This-Issue-/default.aspx

developments in power and control electronics technology to eliminate the need for an isolation transformer on the output of the inverter.

The drivers behind the increased use of transformerless UPS are cost, size and efficiency. Transformerless UPS are generally accepted as more efficient, which can result in lower operating costs. A number of key considerations are highlighted that should be taken into account when deciding between transformerless and transformer based designs[56]:

- Initial Purchase Cost – Removal of the transformer and reduced space requirements mean transformerless modules will be less expensive. This saving however, can be mis-interpreted if when installing the UPS an input/output isolation is required outside of the UPS.
- Operating costs – these will be similar for both types of UPS design, with both having similar high efficiency and full load performance factors.
- Physical size – transformerless UPS are smaller and lighter weight UPS systems making them more suitable to installation environments where space is limited or the provision of additional space will incur costs.
- Availability – transformer based UPS provide a safer and more robust solution, essential for any critical systems requiring the highest level of reliability

As with modular UPS, transformerless UPS suitable for all applications. Industry information indicates that they are particularly appropriate to lower power, small and medium business applications, where space and weight may limit the use of transformer based designs[55].

In addition to the trends in modular and transformerless UPS products outlined above, key features of a UPS have been identified as part of research that considers the choice of UPS vendor[56]. Standard requirements for consideration are shown in Table 5. More advanced features for consideration are also identified in the research; these are shown in Table 6.

Table 5: Standard features/requirements for consideration when choosing a UPS vendor

Features	Requirements
Scalability	The solution is scalable from 200kW-900kW and up and allows for quick upgrades of power capacity and additional run time.
Power Conditioning	The solution provides built in protection for the critical load from power disturbances (surges, spikes etc.).
Management Software	The solution contains management software to monitor battery status both locally and remotely and conducts automatic self-test of batteries.
Efficiency	The solution is designed to achieve at least 94% uptime efficiency level per month.
Warranty	The solution includes at least a one-year standard warranty on UPS that is included in its price.
Batteries	Battery design life is at least 5 years.
Redundancy	The solution provides high availability by allowing configuration with one or more power modules to support the connected load and redundant batteries.
Generator Capacity	The solution is compatible to work with generators to transfer load in the case of an extended outage.

[56] http://www.titanpower.com/public/downloads/Gamatronic_-_Leader_in_UPS_Innovation_-_Infotech_Research_Group.pdf

Table 6: Advanced features/requirements for consideration when choosing a UPS vendor

Features	Requirements
Smart Modes	The solution includes an eco-mode or can select from various intelligent modes based on historical data.
Advanced Integration and PDU	The solution allows for easy expansion without rip and replace to add additional cabinets for future requirements that is available as an add-on or included in price.
Advanced Management Software	The solution includes remote management or allows the vendor to access the UPS and remotely take it over for remote diagnostics and support.
Extended Warranty	The solution comes with an extended warranty that is included in the price or offers an extended warranty that is additional to price.
Extended Battery Design Life	The solution includes batteries with improved (over 5 years) or extended (10 years) design life.
Transformer Options	The solution offers transformer and transformer-free options.
Power Reporting	The solution has enhanced capabilities for reporting power usage and trends in power usage.

Clearly there are aspects shown Table 5 and Table 6 which relate specifically to the UPS, whereas others relate to service or software used to manage the UPS. These include modular and transformerless UPS, but also aspects relating to the battery life, monitoring of the UPS and its maintenance. In addition to aspects shown in Table 5 and Table 6, the maintenance element is an important aspect of manufacturer's offerings and is discussed in more detail in Section 2.3.6 below.

Battery technology is a vital component of any UPS. At present the standard battery type used in the majority of UPS are lead acid (approximately 95%[57]). In addition to battery types, the charging and interchanging of batteries are important features that can help minimise costs and ensure battery life is maximised, and therefore provide the highest level of resilience/protection.

Alternative battery technologies to lead acid are available, although they are not used widely in UPS. These include Ni-Cd and Ni-MH cells which represent a very small share (few percent) for industrial UPS. Li-ion batteries are also being proposed and again only have a small market share. It is anticipated that lead-acid will continue to be the dominant battery type in UPS for the foreseeable future[57].

The nature of the maintenance charge of a battery is important to its performance and longevity. This can be provided in different ways, for example as a continuous current, or pulses, or current or voltage controlled. Evidence from manufacturer's product catalogues indicates that they have developed various means of charging that prolong battery life, for example Eaton's ABM technology.

The other important aspect in relation to batteries is the operating temperature. Changes in temperature can affect the lifetime of the battery, and it is therefore important to regulate temperatures where necessary to ensure battery performance is optimised. Some manufacturers offer solutions to optimise battery performance, for example cabinets designed to help regulate the ambient temperature[58].

[57] Direct Communication with SAFT
[58] http://www.northstarbattery.com/sitesolutions/sitestar/index.php

Batteries are the main consumable used in UPS. In order to minimise the time and cost of replacing batteries many UPS products are equipment with quick switch functionality for batteries, allowing them to be changed rapidly. This will also reduce the downtime of the UPS.

2.3.5 Market and Production Structures

Market research[59] indicates that the global market for UPS products is largely consolidated. The research identified three tiers of UPS manufacturers. The first tier consists of the three main companies; APC, Eaton and Emerson Network Power, who dominate the global UPS market. For example APC and Eaton have 26% and 12% of the global UPS market respectively. The second tier consists of other global manufacturers with growing sales revenues, and will compete with the three main tier 1 manufacturers. The third tier of manufacturers consists of those supplying products to particular niche markets, for example specialising in healthcare or particular industrial settings.

In addition to the manufacturers, there are also many suppliers who will offer additional advice and services for the choosing, installation and servicing and replacement of the UPS throughout the products life time. They market products from a number of different angles.

2.3.6 Product marketing

There are a number of ways in which UPS manufacturers and suppliers market their products. Evidence suggests that a key element is the promotion of UPS as a cost saving solution, by prompting customers to be proactive rather than reactive i.e. by getting them to think about potential problems before they exist, and their implications for the customers' business, when it comes to installing a UPS, and therefore avoiding potentially costly downtime or repair costs to damaged equipment[60].

Increasingly, manufacturers and suppliers are focusing on additional services that can be provided alongside the actual UPS product to provide support throughout the product's lifetime. This includes, for example installation, servicing and maintenance contracts and provision of spare parts and replacement batteries. Growth trends in the service market for UPS generally follow those of UPS hardware, although the revenues for services tend to lag approximately 1 year behind hardware revenues[61].

The green agenda is seen by the industry as becoming increasingly important[62 63]. This includes for example increased product energy efficiency as a result of pressures from businesses to limit energy bills and reduce carbon footprints.

Other marketing initiatives include the Trade UPS campaigns. These are product take back schemes run by manufacturers to take back old products when replaced for recycling[64]. As part of the incentive a discount on the new UPS is often provided when an old UPS is returned. These schemes help promote the use of efficient UPS. Research has not identified any information on the extent these take back schemes are used.

[59] http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf

[60] http://www.microscope.co.uk/news/2240157851/UPS-market-has-the-power-to-perform
[61] http://imsresearch.com/news-events/press-template.php?pr_id=2887
[62] http://www.titanpower.com/public/downloads/Gamatronic_-_Leader_in_UPS_Innovation_-_Infotech_Research_Group.pdf
[63] http://newavenergy.com/blog/2012/02/report-ups-will-provide-a-key-element-in-green-it-efforts/
[64] **http://www.riello-ups.co.uk/ups-services/tradeups/** and **http://www.apc.com/extranets/reseller/trade-ups.cfm**, http://www.apc.com/site/company/index.cfm/company/environmental-and-community/recycling/

2.4 Subtask 2.2 - Market and stock data

2.4.1 Overview

The study team's initial approach to the collection of market and stock data focused on desk based research, using Eurostat and similar sources to build a picture of the market. However, as highlighted in Section 2.2 above, official EU statistics are limited and do not provided the required level of detail or confidence for identifying specific data for UPS.

Faced with this situation, we decided to build spreadsheet models describing the market. The approach taken is in line with similar approaches adopted by ourselves and other contractors working on ecodesign preparatory studies for other product groups. Using the models, estimated data for stock were calculated by using the sales data, lifetime and replacement rates from a variety of sources. The following sections present the approach adopted, provide full details of the assumptions developed and the data used, which takes into account the market trends and information identified in Section 2.3.

2.4.2 Sales

Information on sales is required to calculate stock, which is then used in the technical assessment (Task 5) and improvement scenarios (Task 6) to calculate the impact of the base cases at a European level.

Limited information is available in the public domain regarding the unit sales of UPS. A model has therefore been developed based on available revenue and unit price data and information provided by stakeholders, in particular CEMEP, in response to the first questionnaire. The model covers the period 1999-2025.

The model involves a number of key steps:

- Calculation of annual UPS sales revenues for each Member State
- Calculation of annual UPS sales revenues for different sizes of UPS
- Identification of average price information for different sizes of UPS
- Calculation of the annual number of units sold for the different sizes of UPS across different Member States

For each of these steps various data sources and assumptions have been used, including data from stakeholders and market research reports. Table 7 summarises the data sources and our assumptions. Some data identified is for the global market, and where necessary this has been used to calculate figures for Europe. Splitting the revenues by the different sizes of UPS allows different average prices to be taken into account when calculating the number of units sold, and will ensure the data is at a level that is applicable for future tasks, for example when calculating the EU-27 environmental impacts and life cycle costs based on typical products (bases cases) in Task 5.

Sales have been calculated for the period 1999-2025, which based on our lifetime assumptions for UPS is sufficient to calculate stock for the base year of 2011, and then for the period 2012-2025, see Section 2.4.3 below.

Due to the limited data available, further data and feedback on the assumptions was requested from stakeholders in order to refine the analysis and calculated sales of units further. In particular, the 2015-2025 sales revenue projection is based on the growth rate over the period 2005-2015. Revenue forecasts for UPS could also be used to estimate future sales revenue projections for 2015-2025; however limited data, together with questions over the forecasts identified mean this approach is not considered appropriate. A global revenue forecast for 2020 has been identified from market data, and a EU27 figure calculated using the assumptions in Table 7. However this forecast is thought to have been done before the extent of the current economic downturn was fully understood. This approach could therefore overestimate future stock and sales. Full details of the 2020 revenue forecast and the sensitivity analysis is presented in Section 2.4.4 to demonstrate the difference in sales and stock using the 2020 sales revenue projection, compared to the growth rate from 2005-2015. Table 7 provides a summary of the data and key assumptions used in the different steps outlined above.

Table 7: Summary of data and assumption used to model UPS sales

Parameter	Data Source	Comment / Assumption Made
Sales revenues split by Member State		
Revenue data	Stakeholder data	Sales revenues split by Member State for 2010 - 2015. It is assumed these revenue figures take into account inflation for future years.
European market as a proportion of the global market	Stakeholder and market research report data	Required to calculate size of European Market from global figures for 2000, 2001, 2005, and 2008 – see below. A figure of 20.5% have been derived, calculated on the basis of 2010 European revenue figure (€1.1 billion) suggested by stakeholders and a global figure of $7.2 billion (€5.4 billion) from market research[65].
European revenue figures	Market research report data	Global UPS market revenues for 2000 estimated at $5.92 billion[66]. European revenue calculated by applying the 20.5% figure from above and an exchange rate of 1USD = 0.7579 €.
	Market research report data	Global UPS market revenues for 2001 estimated at $5.29 billion[67]. European revenue calculated by applying the 20.5% figure from above and an exchange rate of 1USD = 0.7579 Euros.
	Market research report data	Western European UPS market revenues in 2005 were 958M Euros[68]. In the absence of other data, it has been assumed this is applicable to EU27, as Eastern European revenues are thought to be a very small fraction. This has been informed by stakeholder data for 2010-2015, which indicates the Eastern European market is small.
	Market research report data	Global UPS market revenues for 2008 are stated as over $8 billion[69]. No further data for 2008 has been identified, and a figure of $8 billion has therefore been assumed for the global market. European revenue calculated by applying the 20.5% figure from above and an exchange rate of 1USD = 0.7579 Euros.
Revenue trends for years without data	Stakeholder information	Stakeholder information indicates that between 1995 and 2000 global UPS revenue grew 5% each year. In the absence of any specific information regarding global or European market revenues this information has been used to calculate European revenues for 1995 to 1999, using the 2000 revenue figure above as the reference point.
	Market research report data	Sources confirm that there was a 20% drop in global revenues between 2008 and 2009[70]. In the absence of any specific information regarding the drop in the European market, this has been used to calculate 2009 revenue from the 2008 figure

[65] http://www.pikeresearch.com/newsroom/uninterruptible-power-supply-market-to-expand-by-12-in-2011-with-strong-growth-ahead
[66] http://ecmweb.com/contractor/ups-market-recover-after-decline-2002
[67] http://www.theengineer.co.uk/in-depth/ups-market-set-for-growth/280445.article
[68] http://www.prnewswire.com/news-releases/european-ups-market-rebounds-strongly-as-competition-heats-up-and-investments-increase-55754637.html
[69] http://imsresearch.com/news-events/press-template.php?pr_id=1961
[70] http://www.pikeresearch.com/newsroom/uninterruptible-power-supply-market-to-expand-by-12-in-2011-with-strong-growth-ahead

		Total European revenues for years without data have been calculated. Linear growth is assumed between 2001-2005 and 2005-2008.
		Availability of estimated revenue figures for 2016-2025 is limited. The growth rate for revenue for the period 2005-2015 has therefore been used to calculate the revenue figure for 2025, with linear growth assumed for the years between 2015 and 2025. Revenue forecast data for 2020 has been used to provide a sensitivity analysis against the figures calculated using the growth rate outlined above. Linear growth is assumed between the 2015 and 2020 data points and this growth rate is also used to calculate 2021-2025 revenues for the sensitivity analysis.
Split of total European revenues across Member States	Stakeholder data	For 2010-2015 revenue data provided by stakeholders is split across different Member States. Data for Belgium and Luxembourg was provided together, and has been split between the two countries on the basis of GDP. Data for Estonia, Latvia and Lithuania was provided together, and has also been split between the three countries using GDP. Stakeholder information indicated that for 2010-2015 the UPS markets in Bulgaria, Cyprus, Malta and Slovenia are not significant enough to be identifiable. It is assumed this is also the case prior to 2005 and after 2015. The split of revenues between Member States based on stakeholder data for 2010-2015 indicates this is largely similar for the different years. Therefore for years 2001-2009 and 2016-2025 the total European revenue figures calculated have been split across Member States based on the split of revenues for 2010.
Sales revenues split by UPS size		
Proportion of sales revenues for different sizes of UPS	Market research report data and stakeholder information	Market research indicates revenues for different sizes of UPS differ[71]. The research indicates that the percentage split of revenues is similar across different years (2006, 2010, 2020) therefore the same figures have been used across all years in our calculations. The information included in the market research does not align with the size groups included in the IEC standards for UPS. In order to align these as close as possible for use in subsequent tasks, stakeholders provided the following split following discussions at the second stakeholder meeting held in May 2013. The following have therefore been used to split the total revenue between the different sizes of UPS: • Below 1.5 kVA – 16% • 1.5 kVA to 5 kVA – 23% • 5.1 kVA to 10 kVA – 8% • 10.1 kVA to 200 kVA – 34% • Above 200 kVA – 19%
Sales in number of units		
2012 average price information for	Online retailer and stakeholder	In order to calculate the number of units sold from the revenue data, average price information has been used for the different

[71] http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf

different size groups of UPS	information	size groups of UPS identified above. For the first three size groups, an average prices was calculated based on a number of product prices from an on line supplier of UPS[72]. The averages used are as follows: • Below 1.5 kVA – €179.83 • 1.5 kVA to 5 kVA – €642.94 • 5.1 kVA to 100 kVA – €3,502.28 Price information for the remaining size groups is not readily available in the public domain, with price generally provided on application. Stakeholder information indicates that for larger UPS an average price of approximately $38,000 is applicable, which converts to €28,800 using the above exchange rate. This price has been used for UPS in the size groups: • 10.1 kVA to 200 kVA • Above 200 kVA For the purposes of calculating the number of units from revenue and product price data it is assumed that VAT is not included on the basis that the majority of UPS sales are business to business.
UPS prices over the period 1995-2025	Stakeholder information	Stakeholder information indicates that in general the prices of UPS have decreased since the 1970s and prices are expected to remain stable over the coming years. No information on detailed price trends since 2001 or after 2012 has been identified. Based on the insights from stakeholders, and the absence of other price trend data it is assumed that the prices have remained constant over the 2001-2025 period, and the 2012 prices identified above have been used across all years.

The model allows sales, in number of units to be calculated for all Member States (except those already identified as having very low volume markets: Bulgaria, Cyprus, Malta and Slovenia) for five different UPS size groupings. A summary of the sales revenue figures derived from stakeholder and market research information used to calculate unit sales is provided in Table 8 and Figure 4.

[72] http://www.criticalpowersupplies.co.uk/

Table 8: Summary of annual revenue data for UPS

Year	Revenue (million €)
1995	721
1996	757
1997	795
1998	834
1999	876
2000	920
2001	822
2002	856
2003	890
2004	924
2005	958
2006	1,053
2007	1,148
2008	1,243
2009	994
2010	1,119

Year	Revenue (million €)
2011	1,116
2012	1,108
2013	1,125
2014	1,149
2015	1,164
2016	1,214
2017	1,264
2018	1,314
2019	1,364
2020	1,415
2021	1,465
2022	1,515
2023	1,565
2024	1,615
2025	1,665

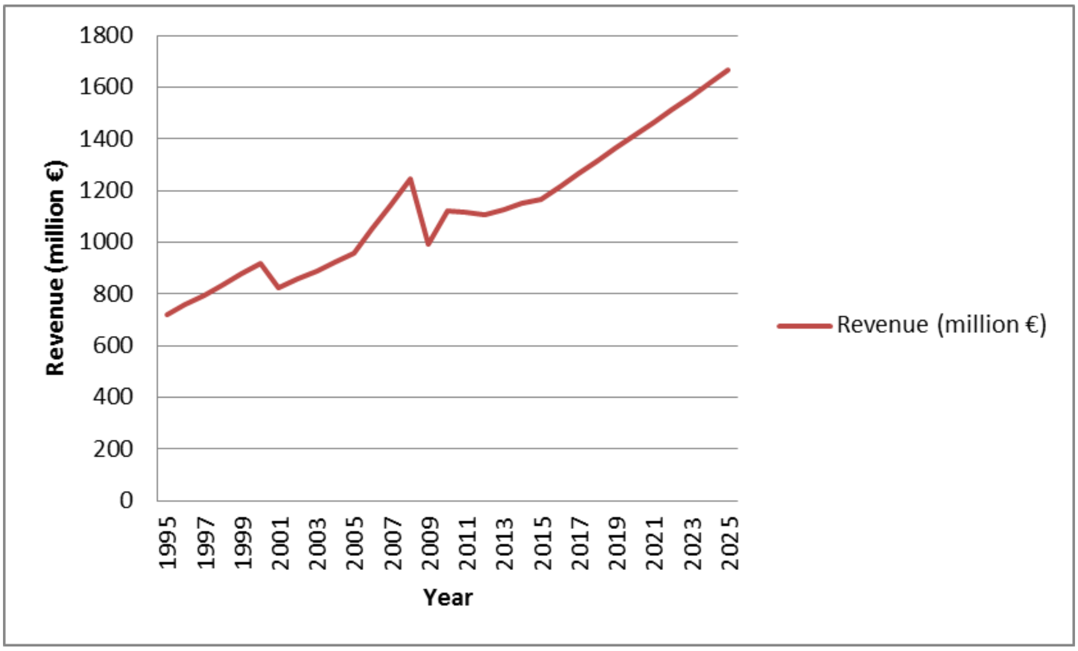

Figure 4: EU27 Annual Revenue Data for UPS

Table 9 presents the figures for 2011 across the member States and Table 10 shows EU27 annual totals for the whole period. Full details of all unit sales for all years, split by Member State and UPS size, are presented in Appendix 2.

Table 9: UPS Unit Sales by Member State and different sizes for 2011

State	Total 2011	Below 1.5 kVA	1.5 kVA to 5 kVA	5.1 kVA to 10 kVA	10.1 kVA to 200 kVA	Above 200 kVA
Austria	38,601	26,651	10,715	684	354	198
Belgium	28,796	19,881	7,993	510	264	147
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,095	11,112	4,468	285	147	82
Denmark	34,152	23,579	9,480	605	313	175
Estonia	3,866	2,669	1,073	69	35	20
Finland	24,993	17,255	6,938	443	229	128
France	203,475	140,480	56,483	3,607	1,864	1,042
Germany	277,930	191,885	77,151	4,926	2,546	1,423
Greece	17,011	11,744	4,722	302	156	87
Hungary	20,282	14,003	5,630	359	186	104
Ireland	23,684	16,352	6,575	420	217	121
Italy	174,295	120,334	48,383	3,089	1,597	892
Latvia	4,791	3,308	1,330	85	44	25
Lithuania	7,307	5,045	2,028	130	67	37
Luxembourg	3,394	2,343	942	60	31	17
Malta	-	-	-	-	-	-
Netherlands	67,781	46,797	18,815	1,201	621	347
Poland	44,621	30,806	12,386	791	409	228
Portugal	38,863	26,831	10,788	689	356	199
Romania	17,927	12,377	4,976	318	164	92
Slovakia	5,103	3,523	1,417	90	47	26
Slovenia	-	-	-	-	-	-
Spain	99,971	69,021	27,751	1,772	916	512
Sweden	37,947	26,199	10,534	673	348	194
United Kingdom	247,180	170,654	68,615	4,381	2,264	1,265
Total EU27	**1,438,067**	**992,849**	**399,193**	**25,490**	**13,174**	**7,362**

Table 10: EU27 UPS unit sales for 1995-2025 split by different sizes

Year	Total	Stock Below 1.5 kVA	Stock 1.5 to 5 kVA	Stock 5.1 to 10 kVA	Stock 10.1 kVA to 200 kVA	Stock Above 200 kVA
% split – see note	100%	69.0%	27.8%	1.8%	0.9%	0.5%
1995	928,774	641,231	257,818	16,462	8,508	4,755
1996	975,213	673,292	270,709	17,286	8,934	4,992
1997	1,023,974	706,957	284,245	18,150	9,380	5,242
1998	1,075,172	742,304	298,457	19,057	9,849	5,504
1999	1,128,931	779,420	313,380	20,010	10,342	5,779
2000	1,185,377	818,391	329,049	21,011	10,859	6,068
2001	1,059,231	731,298	294,032	18,775	9,703	5,422
2002	1,103,068	761,564	306,201	19,552	10,105	5,647
2003	1,146,905	791,830	318,369	20,329	10,506	5,871
2004	1,190,743	822,095	330,538	21,106	10,908	6,096
2005	1,234,580	852,361	342,707	21,883	11,310	6,320
2006	1,357,007	936,885	376,691	24,053	12,431	6,947
2007	1,479,434	1,021,409	410,676	26,223	13,553	7,574
2008	1,601,861	1,105,933	444,660	28,393	14,674	8,200
2009	1,281,489	884,747	355,728	22,714	11,739	6,560
2010	1,441,675	995,340	400,194	25,554	13,207	7,380
2011	1,438,067	992,849	399,193	25,490	13,174	7,362
2012	1,428,273	986,087	396,474	25,316	13,084	7,312
2013	1,449,794	1,000,945	402,448	25,698	13,281	7,422
2014	1,480,465	1,022,121	410,962	26,241	13,562	7,579
2015	1,500,182	1,035,734	416,435	26,591	13,743	7,680
2016	1,564,731	1,080,298	434,353	27,735	14,334	8,010
2017	1,629,280	1,124,863	452,271	28,879	14,925	8,341
2018	1,693,828	1,169,428	470,190	30,023	15,517	8,671
2019	1,758,377	1,213,992	488,108	31,167	16,108	9,002
2020	1,822,925	1,258,557	506,026	32,311	16,699	9,332
2021	1,887,474	1,303,122	523,944	33,455	17,291	9,662
2022	1,952,022	1,347,686	541,862	34,600	17,882	9,993
2023	2,016,571	1,392,251	559,780	35,744	18,473	10,323
2024	2,081,119	1,436,816	577,698	36,888	19,065	10,654
2025	2,145,668	1,481,380	595,616	38,032	19,656	10,984

Note: The percentage of unit sales between the different sizes of UPS is the same across all years as a result of the assumptions in Table 7 used to split the revenue data across different sizes of UPS and convert revenue to units, which are constant across all years.

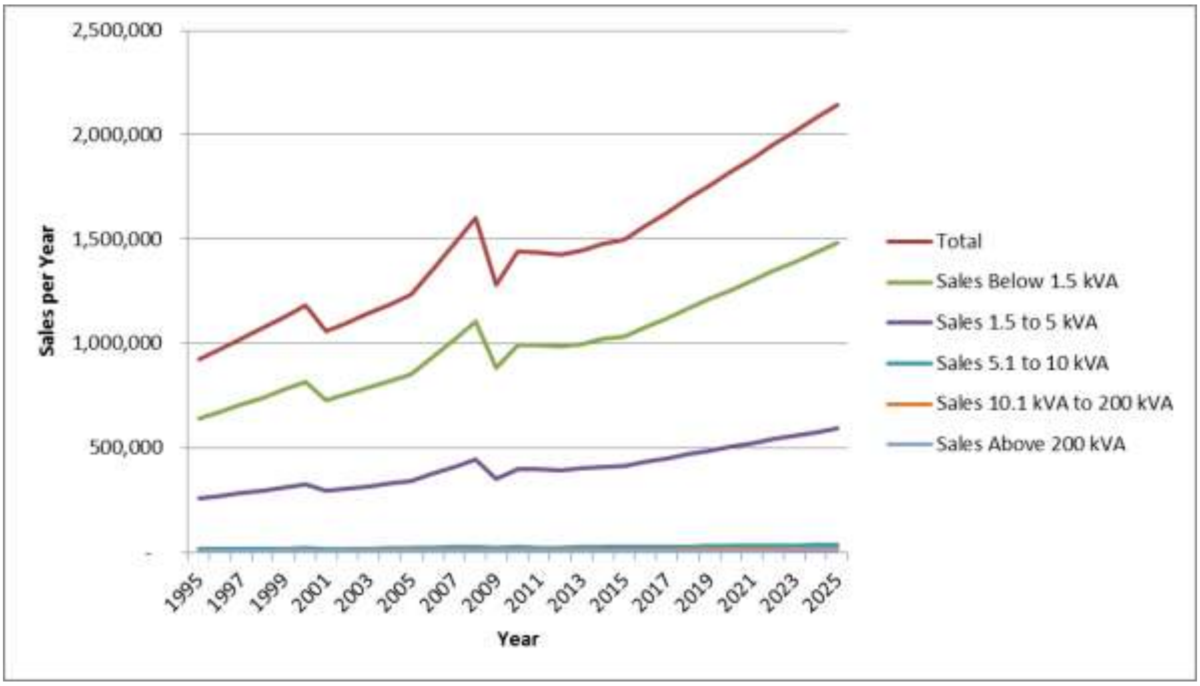

Figure 5: EU27 UPS unit sales for 1995-2025 split by different sizes

Figure 5 shows the general trend is of increasing unit sales for UPS over the period 1995-2025. These outputs from the model are broadly in line with what we anticipate. A key sales driver for UPS is the increasing uptake of servers and the demand for power back up from data centres and the IT sector[73], which need to be on line 24/7, Data centres and server farms are an essential part of the increasingly digital economy, providing important access to every day services such as email and the internet, with business and public expectation that this is available without interruption. In addition there has been the development of new services which are now considered main stream, but were previously unforeseen. This includes for example internet film services, increasing use of on-demand television[74], and cloud storage to protect against local hard drive failure or viruses. This increasingly reliance on digital services means it is important for data centres to protect themselves against power outages or disturbances through the use of UPS.

Although the overall trend is of increasing sales, it is however important to note recent decreases in sales due to the economic downturn, most notably in 2009, following a peak in 2008. The two smallest size groups, below 1.5kVA and 1.5 kVA to 5 kVA make up the majority of the number of units sold.

The following observations can be made following analysis of the 2011 data shown in Table 9:

- Germany and the UK have the highest unit sales, representing 19% and 17% of the market respectively.
- The top four countries in terms of units sales, Germany, UK, France and Italy account for 63% of total unit sales
- Luxembourg, Latvia, Estonia, Slovakia, and Lithuania all have sales of less than 1% of the EU27 total
- UPS below 1.5 kVA represent the largest proportion of unit sales, with 69% of the market, followed by 1.5 kVA to 5 kVA with 28% of the market

[73] http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf

[74] http://www.ft.com/cms/s/0/f5f9a58e-79fb-11e2-b377-00144feabdc0.html

2.4.3 Stock

Using the unit sales figures calculated in Section 2.4.2, stock has been calculated using assumptions regarding product lifetime (see Table 11 below). Due to the sales data available and differences in lifetime for the different UPS size groups, 2011 is the first year stock can be calculated for all UPS, this has therefore been taken as the base year. The stock figures calculated in this section will be used in later tasks when calculating the environmental and cost impacts for EU27 of the base case and improvement options.

In order to calculate stock from the sales figures, a number of key steps are required:

- Assumptions on product lifetime for the different sizes of UPS
- Calculation of replacement sales for a given year based on lifetime
- Calculation of new sales for a given year (i.e. those sales that contribute to stock growth)
- Calculation of total stock

Table 11 summarises the key data and assumptions used to calculate the stock of UPS. Table 12 presents the figures for 2011 across the Member States and Table 13 shows EU27 annual totals for the whole period. Full details of stock for all years, split by Member State and UPS size, are available in Appendix 3.

Table 11: Summary of data and assumptions used to model UPS stock

Parameter	Data Source	Comment / Assumption Made
Product Lifetime		
Lifetime for different sizes of UPS	Feedback from stakeholders	Some information on product lifetime has been provided by stakeholders on product lifetime. Generally the smaller sized UPS, below 1 kVA, have a shorter lifetime, as the battery in not generally replaced in these products. For the other size groups, the battery is usually replaced, extending the product lifetime. Further information regarding product lifetime is provided in the Task 3 report. Based on stakeholder information, the following lifetimes have been used: • Below 1.5 kVA – 4 years • 1.5 kVA to 5 kVA – 8 years • 5.1 kVA to 10 kVA – 10 years • 10.1 kVA to 200 kVA – 12 years • Above 200 kVA – 15 years
Replacement Sales		
Proportion of sales replaced		At the end of the estimated product lifetime, it is assumed 100% of products are replaced.
New Sales		
Calculation of new sales		New sales are calculated from total sales for a given year, minus replacement sales. Where total sales for a given year are insufficient to cover the replacement of units reaching the end of their life, for example as a result of a market down turn, new sales will calculate as a negative number in the model and result in a fall in overall stock.
Total stock		
		Total stock for a given year is calculated on the following

		basis: Stock in Year X = Stock Yr (X-1) – products reaching end of life in Year X + Yr X Replacement Sales + Yr X New Sales

Table 12: UPS Stock by Member State and different sizes for 2011 (in number of units)

Member State	Total 2011	Stock Below 1.5 kVA	Stock 1.5 to 5 kVA	Stock 5.1 to 10 kVA	Stock 10.1 kVA to 200 kVA	Stock Above 200 kVA
Austria	201,660	106,803	82,149	6,316	3,816	2,576
Belgium	150,434	79,673	61,281	4,712	2,847	1,922
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	84,082	44,531	34,252	2,633	1,591	1,074
Denmark	178,418	94,494	72,681	5,588	3,376	2,279
Estonia	20,196	10,696	8,227	633	382	258
Finland	130,566	69,150	53,188	4,089	2,471	1,668
France	1,062,988	562,979	433,021	33,293	20,116	13,579
Germany	1,451,953	768,982	591,471	45,475	27,477	18,548
Greece	88,867	47,066	36,201	2,783	1,682	1,135
Hungary	105,957	56,117	43,163	3,319	2,005	1,354
Ireland	123,730	65,530	50,403	3,875	2,341	1,581
Italy	910,547	482,243	370,922	28,518	17,231	11,632
Latvia	25,028	13,255	10,196	784	474	320
Lithuania	38,175	20,218	15,551	1,196	722	488
Luxembourg	17,730	9,390	7,223	555	336	226
Malta	-	-	-	-	-	-
Netherlands	354,102	187,539	144,248	11,090	6,701	4,524
Poland	233,105	123,457	94,958	7,301	4,411	2,978
Portugal	203,027	107,527	82,706	6,359	3,842	2,594
Romania	93,652	49,600	38,150	2,933	1,772	1,196
Slovakia	26,660	14,120	10,860	835	505	341
Slovenia	-	-	-	-	-	-
Spain	522,266	276,602	212,751	16,357	9,883	6,672
Sweden	198,242	104,993	80,756	6,209	3,752	2,532
United Kingdom	1,291,309	683,902	526,030	40,443	24,437	16,496
Total EU27	**7,512,695**	**3,978,869**	**3,060,389**	**235,296**	**142,169**	**95,973**

Table 13: EU27 UPS stock for 2011-2025 split by different sizes

Year	Total	Stock Below 1.5 kVA	Stock 1.5 to 5 kVA	Stock 5.1 to 10 kVA	Stock 10.1 kVA to 200 kVA	Stock Above 200 kVA
2011	7,512,695	3,978,869	3,060,389	235,296	142,169	95,973
2012	7,468,844	3,859,022	3,126,324	241,060	144,394	98,042
2013	7,655,648	3,975,221	3,186,066	246,429	147,972	99,960
2014	7,727,092	4,002,002	3,220,336	251,564	151,429	101,760
2015	7,785,292	4,044,887	3,226,096	256,272	154,666	103,371
2016	7,878,892	4,139,098	3,215,789	259,954	158,092	105,959
2017	8,108,318	4,263,016	3,312,332	262,610	161,707	108,653
2018	8,333,136	4,410,323	3,382,327	264,240	164,793	111,453
2019	8,614,223	4,588,582	3,471,242	272,693	167,348	114,359
2020	8,913,828	4,766,840	3,580,793	279,450	169,373	117,370
2021	9,229,814	4,945,099	3,702,289	287,416	174,925	120,086
2022	9,555,350	5,123,358	3,833,188	296,700	179,600	122,505
2023	9,894,422	5,301,616	3,976,532	306,746	184,899	124,628
2024	10,236,745	5,479,875	4,119,877	317,392	190,880	128,722
2025	10,579,768	5,658,133	4,263,221	328,833	197,255	132,326

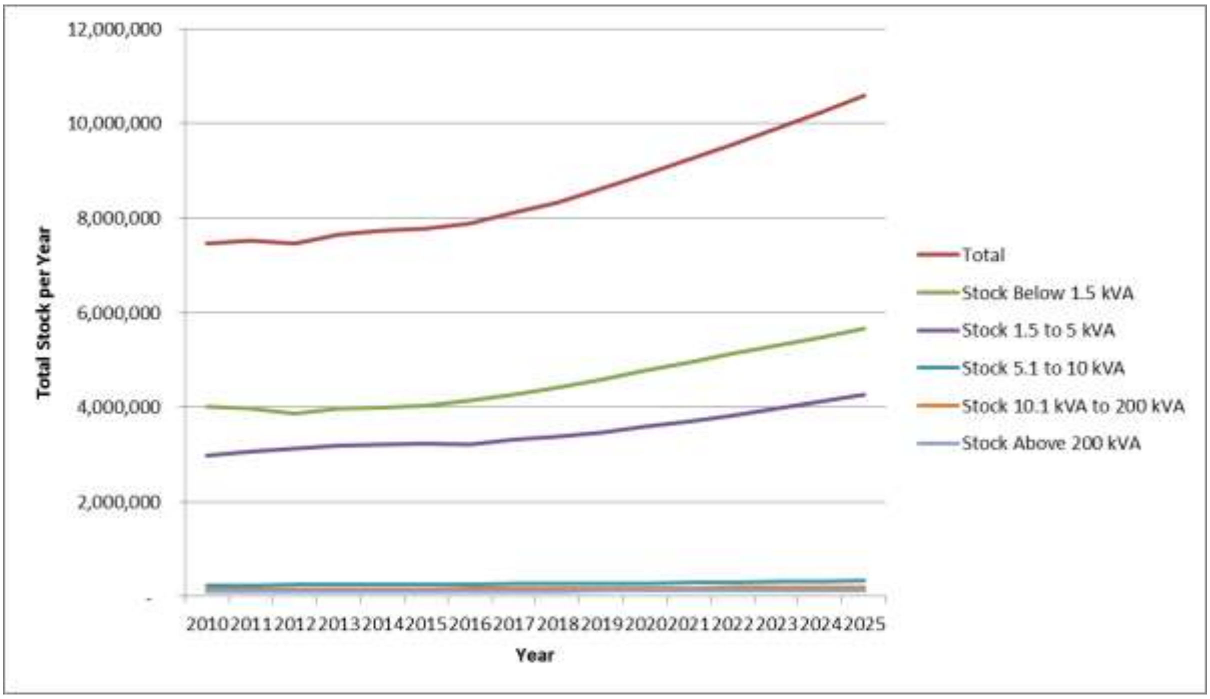

Figure 6: EU27 UPS Stock in units for 2011-2025 split by different sizes

The split of stock between the different sizes of UPS for individual Member States, shown in Table 12, is the same, which is to be expected due to the assumptions used to calculate sales, in particular the constant percentages used to calculate revenues for the different sizes from total revenue, and the prices used to calculate number of units from revenue figures. Similarly for stock over the period 2011-2025, as shown in Table 13, the percentage split between the different sizes groups of UPS is broadly similar for the same reasons, with the small variation, shown in Table 14, due to the different lifetimes of the products used to calculate stock.

Table 14: Summary of percentage split of different UPS sizes across years (2011-2025)

UPS Size	Average Percentage (Median)	Different between minimum and maximum percentage
Below 1.5 kVA	53	2
1.5 to 5 kVA	41	2
5.1 to 10 kVA	3	0
10.1 to 200 kVA	2	0
Above 200 kVA	1	0

As Figure 6 shows, the general trend is of increasing stock (number of units) for UPS, which is consistent with the sales trends, and is as anticipated due to the growth in data centres and increasing digital economy, as described above in relation to the sales trends.

The following observations can be made following analysis of the 2011 stock data shown in Table 12:

- The below 1.5 kVA size group represents the largest proportion of stock in 2011, with 53%, followed by the 1.5 to 5 kVA products, with 41% of total stock.
- Germany and the UK have the highest stock, representing 19% and 17% of the total stock respectively.

- The top four countries in terms of stock, Germany, UK, France and Italy account for 63% of total stock.
- Luxembourg, Latvia, Estonia, Slovakia, and Lithuania all have stock of less than 1% of the EU27 total.

2.4.4 Sales and Stock Sensitivity Analysis

As highlighted in Section 2.4.2, sales figures beyond those provide by stakeholders i.e. 2015 can be calculated in different ways. The analysis presented in Sections 2.4.2 and 2.4.3 uses a sales revenue growth rate from 2005-2015 and applies this to calculate a sales revenue figure for 2025. The assumption is summarised in Table 7.

An alternative method to calculate unit sales beyond 2015 is to use sales revenue forecasts from market research reports where available. Information on future market forecasts for UPS is limited, however a global forecast for 2020 of $14.8 billion[75] is provided in the literature. This has been used to calculate a European revenue figure of €2,299 million using the assumptions identified in Table 7. Details of this analysis are presented in Appendix 4, with the key outcome summarised below.

Using this revised revenue figure for 2020, unit sales, based on the price assumptions in Table 7, are calculated to reach approximately 2.96 million in 2020. This is significantly higher than the estimate provided by the analysis shown in Table 9 and Figure 5, which show unit sales of approximately 1.82 million in 2020. As stock is calculated directly from sales, this affects the estimate of stock for future years. The project team believe that the revenue forecast, which results in significantly higher unit sales, was made before the full extent of the economic downturn was known, therefore potentially over estimating sales and stock for UPS.

Given the limited data available and uncertainty regarding the sales revenue figures identified beyond 2015, it is proposed for the purposes of this study to use the sales figures presented in Table 9 and Figure 5 and the stock figures presented in Table 12 and Figure 6.

These stock and sales figures, estimated through our modelling, show a growth in the market for UPS, which is consistent with what would be expected given the market trends and drivers identified in Section 2.3.

2.4.5 Trade

Detailed information regarding extra and intra EU trade for UPS has not been able to be identified from official statistics or alternative sources. Stakeholder feedback indicates that almost all single phase UPS and 80% of three phase UPS are manufactured outside of the EU27. This would suggest that there are significant imports of UPS by the EU27. This trend was confirmed at the second stakeholder meeting held in May 2013.

2.4.6 Summary of stock and sales for UPS

Data for sales and stock of UPS is not readily available, and models have therefore been developed, using data that is available from stakeholders and market research reports, together with a number of assumptions. The modelling of market data has not resulted in any changes to the product scope or definition.

Both sales and stock are dominated by four main countries, Germany, UK, France and Italy. The type of UPS sold, in terms of their size, is dominated by the two smaller groups, below 1 kVA and 1.1-5 kVA for the number of units sold or installed (stock).

The overall trend of increasing sales and stock of UPS calculated by the models is consistent with the drivers and trends identified from the market research literature. Key drivers will continue to promote the demand for UPS in the long term as the expansion of IT and the

[75] http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf

digital economy/services continues. This will require additional data centres / servers, which need to be resilient to power outages or disturbances to ensure the continuity of service that businesses and consumers now expect. As Member States move to meet EU renewable energy targets, the energy system will become increasingly decentralised. The use of decentralised energy will mean the size and direction of power flows will be less predictable[76], requiring increased use of UPS to protect against this uncertainty.

2.5 Subtask 2.4 - Consumer expenditure base data

In order to assess the life cycle costs of different improvement options in later tasks, it is necessary to collate information relating to the costs of various parameters. This subtask therefore gathered and analysed data regarding the lifetime costs of the product, including purchase price, in-use costs, battery life-time (for example, costs of replacement batteries and repair) and end-of-life disposal. These issues have been addressed for different sizes of UPS under the definition outlined in the Task 1 report.

Life cycle costs for products include purchase, operating, installation, maintenance and disposal costs. Cost information for the purposes of undertaking calculations using the MEErP methodology has been split into two groups:

- Generic cost information, for example energy prices, interest and inflation rates etc.
- Product specific cost information, for example product prices, replacement parts etc.

The sections below summarise the cost information currently available, which will be used in later tasks for this project. This is based on information from on-line sources and additional stakeholder feedback.

All costs included in this section are exclusive of VAT unless it is indicated VAT has been included.

2.5.1 Generic Cost Information

The revised MEErP methodology utilises the same cost information for parameters that will be common across different preparatory studies to allow comparison of results between different preparatory studies. The key parameters relevant for the purposes of this study are summarised in Table 15.

Table 15: Summary of the generic cost information for preparatory studies

Parameter	Value	MEErP Reference (page and/or table number)
Energy Escalation rate (energy price growth rate adjusted for inflation)	4%	Section 2.2, page 42; and Table 6, Page 56
Inflation Rate	2.1%	Figure 9, page 53; and Table 6, Page 56
Discount Rate (EU default)	4%	Table 6, Page 56
Interest Rate (domestic)	7.7%	Table 6, Page 56
Interest Rate (non-domestic)	6.5%	Table 6, Page 56
Industrial (non-domestic) electricity rates	0.11 € / kWh	Table 6, Page 56
Domestic electricity rates	0.18 € / kWh	Table 6, Page 56
VAT	20%	Table 6, Page 56

[76] http://www.bis.gov.uk/assets/foresight/docs/energy/energy%20final/wolfe%20paper-section%206.pdf

Two rates are provided for electricity, depending on whether it is for industrial or domestic use. The majority of UPS are used within commercial situations; therefore it is proposed that the industrial electricity rate will be used for the purposes of the life cycle costs assessment undertaken in Task 5.

It is anticipated that other parameters with generic cost information, for example gas and water rates, will not be required for assessing the life cycle costs of this product group. If this changes then reference will be made to the MEErP methodology and the appropriate rates used.

2.5.2 Product Specific Cost Information

In addition to the generic information to be used from the MEErP methodology, product specific cost information is also required to accurately assess the life cycle costs of UPS products. This includes information on the following:

- Installation costs (only for products that are installed),
- Acquisition costs i.e. product prices
- Repair and maintenance costs, for example consumables, spare parts, etc and disposal costs
- Disposal Costs

Installation Costs:

Limited information on installation costs has been identified. Most UPS/suppliers installers do not provide details in the public domain, for commercial reasons, and also because installation costs are likely to vary depending on specific circumstances. Prior to installation many suppliers offer a site survey, usually free of charge, to help assess the customer's requirements. Installation for hardwire systems will include electrical installation and commissioning.

For commissioning itself the information presented in Table 16 has been identified. It is important to note that this does not include electrical installation, for which no information has been identified. For smaller sized UPS, which have plug and socket connections, it is assumed there is no installation cost, as they will be installed by the end user themselves. For larger systems, the commissioning process can be more complex than simply switching the UPS on, and can include issues with peripherals, components, firmware matching, configuration and final set up and testing prior to switch on.

Table 16: Summary of commissioning costs[77]

UPS Rating	Normal Hours - Commissioning Charge (Euros[78])	Outside Normal Hours - Commissioning Charge Euros)
450 VA – 10 kVA	345	398
10 – 30 kVA	392	451
40 – 80 kVA	431	498
100 – 200 kVA	517	596
250 – 400 kVA	604	696
500 – 800 kVA	689	524

[77] http://www.criticalpowersupplies.co.uk/ups-services/ups-installation-commissioning

[78] Price in Euros calculated using exchange rate £1 = 1.23168 Euros

Additional information provided by a UPS supplier indicated installations costs of approximately €280 for 1-3kVA, €680 for 5-10kVA and €1220 of UPS's above 12 kVA. These are for installation during normal working hours, and an additional charge of €185 is made for out of hours.

Acquisition Costs (Product Prices):

Information regarding product prices for different sizes of UPS has been obtained during the sales and stock modelling, from on line retailers (Below 1.5 kVA, 1.5 – 5 kVA, 5.1 – 10 kVA) and stakeholder feedback (10.1 – 200 kVA and Above 200 kVA). This information is summarised in Table 17.

Table 17: Average prices for different sizes of UPS

	Below 1.5 kVA	1.5 – 5 kVA	5.1 – 00 kVA	10.1 – 200 kVA	Above 200 kVA
	Euros (excl VAT)	Euros (excl VAT)	Euros (excl VAT)	Euros (excl VAT)	Euros (excl VAT)
Price from stakeholder feedback	-	-	-	28,800.20	28,800.20
Price from on line retailer - Median	180	643	3502	-	-
Price from on line retailer - Highest	614	2780	12194	-	-
Price from on line retailer - Lowest	39	92	1237	-	-

Repair & Maintenance Costs (Consumables):

The main consumable for UPS is the battery. There are two cost elements to the replacement of batteries, the cost of the battery itself and the actual replacement of the battery, where this is done by a third party and not the end user. This is a service suppliers/installer of UPS can provide. As with installation, limited information regarding maintenance costs has been identified, and is summarised in Table 18.

Table 18: Summary of battery replacement costs

Service	Cost (Euros) of replacement battery (sealed lead acid) [79]	Battery Replacement Service , up to 10 kVA (Limited to up to 2 hours on site and a maximum of 100K of replacement batteries in one visit, excludes battery cost)[80]
Range	12 – 753 Euros	-
Median	382 Euros	-
Cost	-	345 Euros (normal Hours) 615 Euros (Outside Normal Hours)

Following the second stakeholder meeting further information was provided by industry in relation to repair and maintenance costs. It was highlighted that costs will vary between manufacturers, but indicative estimated costs for a replacement battery and its installation can be based on the following assumptions:

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[79] http://www.criticalpowersupplies.co.uk/ups-spares-kits/ups-batteries
[80] http://www.criticalpowersupplies.co.uk/ups-services/ups-battery-testing-replacement

- Below 1.5 kVA – No cost; batteries are not generally replaced in these UPS
- 1.5 to 5 kVA – From 40% (for 1.5 kVA) to 35% (for 5 kVA) of the corresponding product price
- 5.1 to 10 kVA – From 35% (for 5.1 kVA) to 30% (for 10 kVA) of the corresponding product price
- 10.1 to 200 kVA – From 30% (for 10.1 kVA) to 25% (for 200 kVA) of the corresponding product price

Other consumables include replacement fans. Stakeholder feedback indicates that replacement of components, other than batteries would never or very rarely occur for UPS below 10 kVA, because of their lifetimes. At the second stakeholder meeting, it was indicated that the cost of replacement parts, such as fans or capacitors is generally covered by service agreements for the larger UPS, see below.

Repair and Maintenance Costs (Other):

In addition to the replacement of consumables identified above, maintenance plans are popular, in particular for larger sized UPS. Depending on the scope of the contract these may cover preventative and corrective maintenance and emergency repairs. The cost of service plans are often not available, and may be specific to the system they apply to. Information regarding the extension of the manufacturer's warranty has been identified, with a one year extension costing approximately €34 and a three year extension €67[81].

Stakeholder feedback indicates that aside from the maintenance activities already highlighted, no typical repairs are generally required. Reliability is a key design criterion to ensure critical loads are protected, therefore product failures are seldom and subsequent repairs are usually case specific. Examples may include replacement of power modules, semiconductor components, PCBAs and associated wiring.

Additional feedback following the second stakeholder meeting indicated that service contracts are not typical on smaller UPS sizes e.g. below 5 kVA. The use of service contracts is marginal on 5.1 to 10 kVA products, and their cost can be estimated to be approximately 15% of the product price, service contracts are much more common on 10.1 to 200 kVA products where the replacement of parts other than batteries is more common. The cost of service contracts vary, but typically cost 15% of the product price for a 10 kVA UPS, down to 7% for a 200 kVA product.

Further information from a UPS supplier indicated the following approximate costs for service contracts depending on the level of cover required:

- 1 – 3 kVA: €185 to €240 per year
- 5 – 10 kVA: €310 to €365 per year
- Above 12 kVA: Priced on an individual basis, but average cost is €1170 to €1225 per year

Disposal Costs:

In general the disposal costs for replacement batteries and the UPS at the end of its life are limited, due to the value of the materials. For batteries it is often the case that the cost is limited to the postage required to send a battery to an appropriate recycler. Some suppliers offer battery disposal services, with one example costing approximately €10[82].

Often, through take back schemes, manufacturers and suppliers will offer discounts on the purchase of a new UPS in exchange for the old one, resulting in no disposal costs for the end user[83]. Larger UPS may need decommissioning/dismantling, which may incur additional costs; however information regarding this has not been identified.

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81 http://www.criticalpowersupplies.co.uk/ups-services/ups-maintenance-contracts
82 http://www.criticalpowersupplies.co.uk/ups-services/ups-battery-testing-replacement/Battery-Disposal-WEEE
83 http://www.criticalpowersupplies.co.uk/news/UPS-disposal-and-recycling

3 Task 3 – Consumer/user behaviour and local infrastructure

3.1 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. The analysis undertaken in this task has not resulted in a change to the product scope or definition, which was outlined in Task 1.

3.2 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.

3.2.1 UPS Efficiency and load profiles

UPS operation costs are an important consideration for 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 7). However, the curve is relatively flat with load levels higher than 50%.

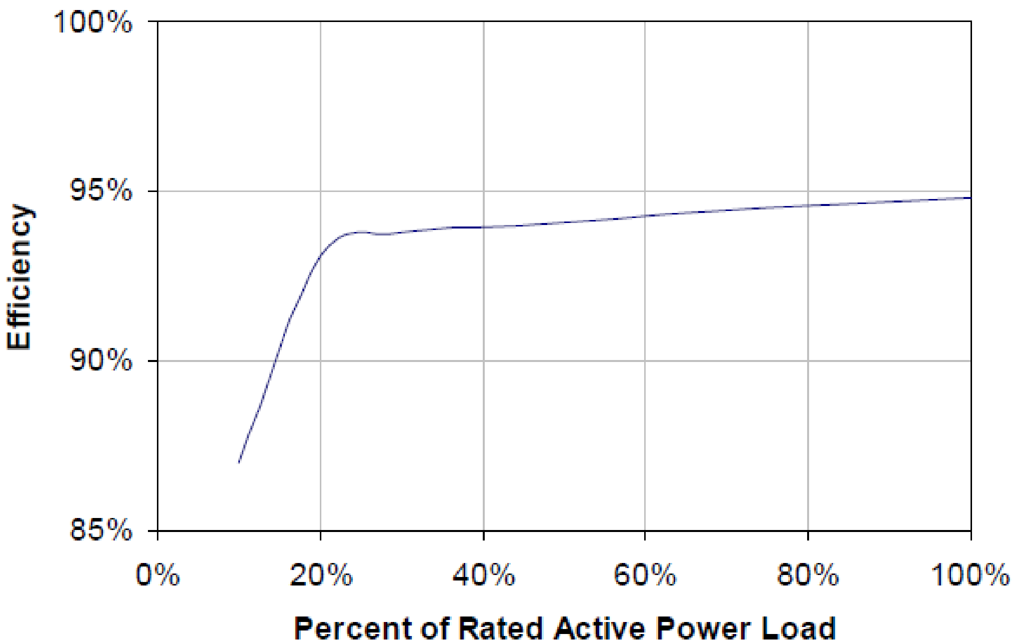


Figure 7: Typical UPS efficiency curve (PIER, 2008)[84]

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

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

and 30% (Sawyer, 2006)[85], which leads to a 4-17% reduction of efficiency (Figure 8). Therefore, knowing the efficiency with loads below 50% is very important to estimate the real efficiency.

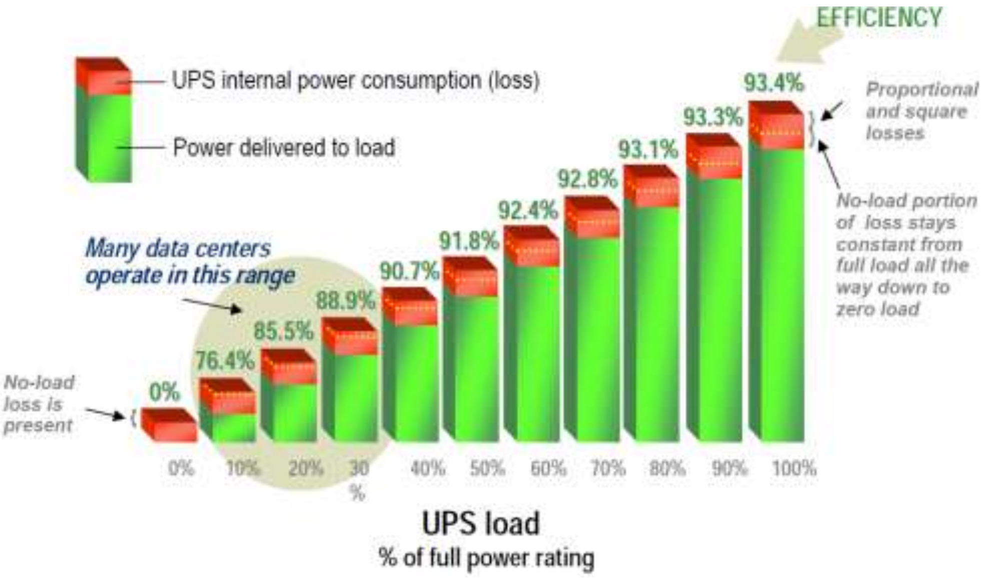


Figure 8: Breakdown of total UPS input power (Sawyer, 2006)[2]

This trend in efficiency of the UPS is due to the three types of UPS losses (Figure 9):

- “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).

Over the last decades the manufactures have focused on reducing the losses and mainly the "square" losses to tend to a pure proportional relation between load rating and losses which have a "flat energy efficiency curve". The new high frequency and tranformerless products have roughly the same efficiency from 20% to 100% load. The consequence is that efficiency sensitivity to load rating and linear/non-linear load is negligible. A secondary consequence is the reduction of sensitivity to power factor of the load.

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).

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

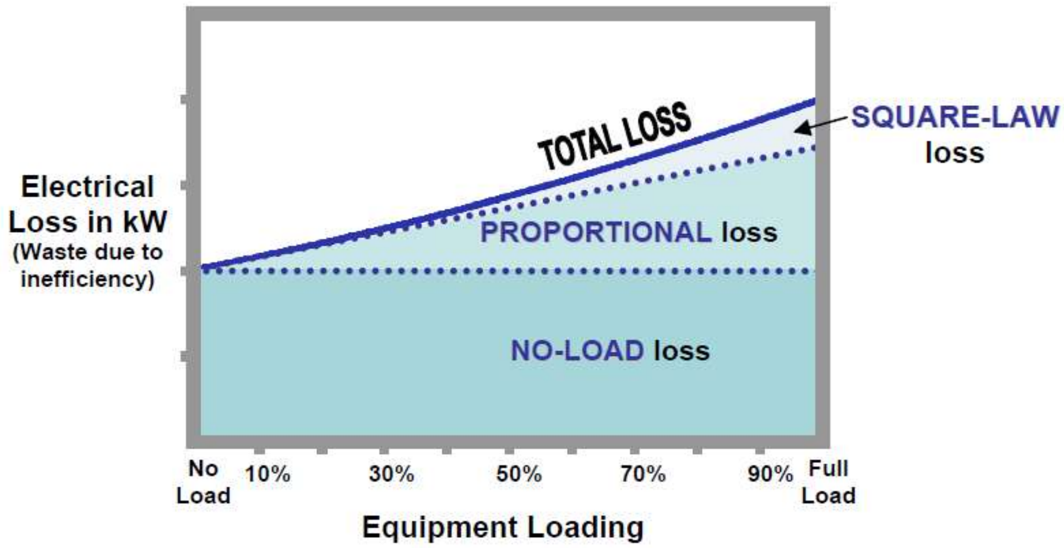


Figure 9: Power loss graph (Sawyer, 2006)[2]

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 10).

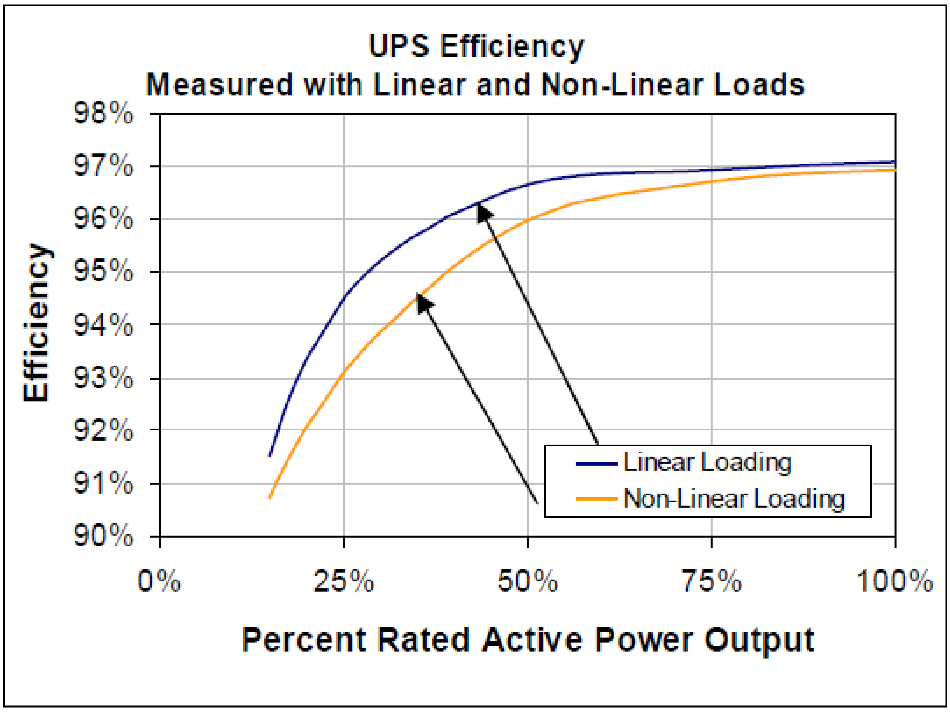


Figure 10: UPS efficiency with linear and non-linear loads (PIER, 2008)[86]

To increase the energy efficiency of UPSs, several technological improvements have been implemented, such as (CEMEP, 2009)[87]:

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

[86] PIER. "Uninterruptible Power Supplies, a Data Centre Efficiency Opportunity." Technical brief. California Energy Commission's Public Interest Energy Research (PIER) Program, 2008
[87] 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)[88];
- The transformer-less UPS reduces heat dissipation, thus allowing additional savings on power and cooling infrastructures.

To improve performance and minimize maintenance requirements other steps are widely used in the market place:

- Power monitoring and remote management (requiring an additional infrastructure of monitoring, communications and control) help minimise on-site service engineer intervention;
- Electronic systems for battery management increases battery lifetime by preventing over- and under-charging;
- UPS modularity brings adaptability (right size for the needs of newly purchased equipment) and scalability (capability to expand equipment without complete product replacement).
- High efficiency UPSs allow the use of smaller electrical network infrastructure (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)[89]. Energy Star is a joint programme 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 programme 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 19.

88 EMERSON, Capacitors Age and Capacitors Have an end of Life, 2008.
89 ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.

Table 19: Minimum average efficiency requirement to the Energy Star label (Energy Star, 2012)

Rated Output Power	Input Dependency Characteristic		
	VFD[90]	VI[91]	VFI[92]
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 programme 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 11) was designed to match the style of the existing EU labels for other electric appliances[93]. 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.

[90] VFD - Voltage and Frequency Dependent
[91] VI - Voltage Independent
[92] VFI - Voltage and Frequency Independent
[93] http://ec.europa.eu/energy/efficiency/labelling/labelling_en.htm

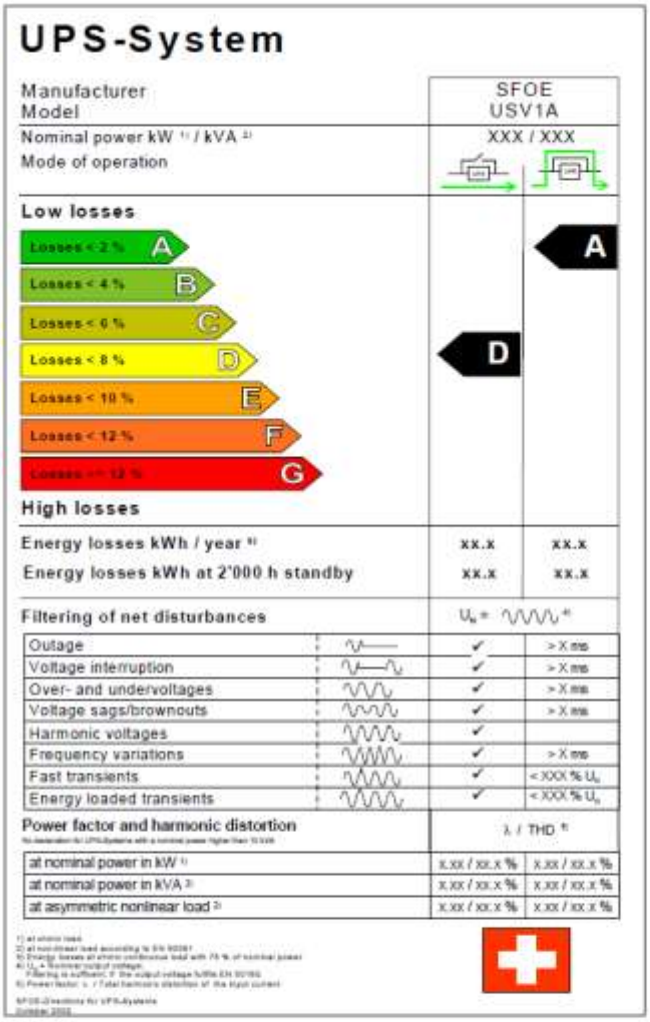


Figure 11: Label proposed by SFOE[94]

The Lawrence Berkeley National Laboratory (LBNL)[95] put forward a modified version of the above proposal for a label with the following changes (Figure 12):

- 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).

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

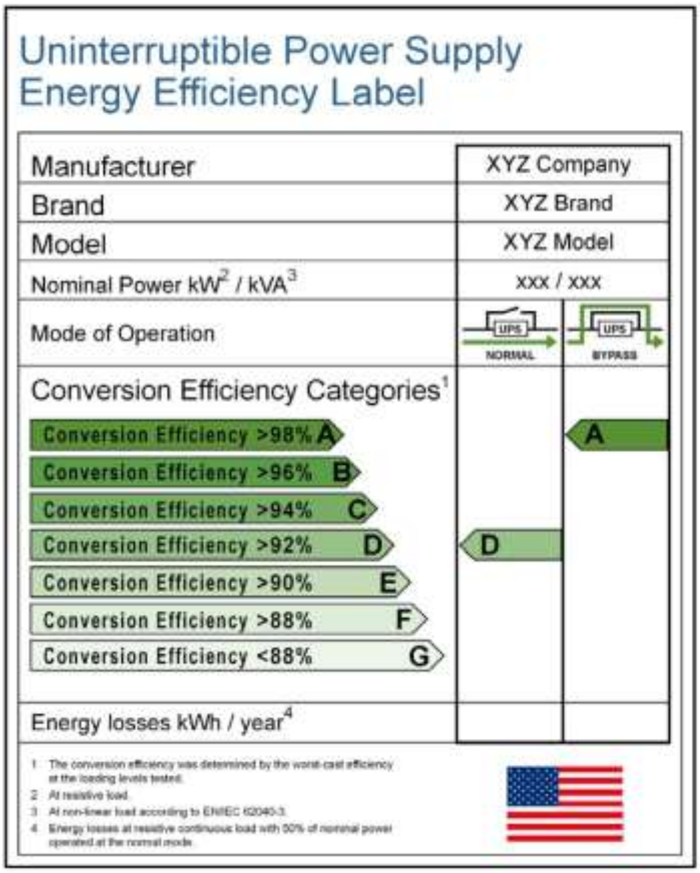


Figure 12: Label proposed by LBNL[96]

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)[97];
- 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.

An additional aspect of efficiency losses came into discussion via the requests of the Geer Blue Angel (UZ-182): The variation of the internal resistance of the battery cells has a serious impact on the lifetime of the whole battery pack as the weakest cell is stressed more than others. The variation at the same load level should not increase ± 30%.

3.2.2 UPS Efficiency and Load Profile Conclusions

UPS operation costs are 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 programme labels UPS equipment surpassing a minimum level of efficiency. However, more detailed labelling schemes have been

[96] LBNL, High Performance Buildings: Data Centers Uninterruptible Power Supplies (UPS), 2005
[97] The concept of the 2 modes as described i.e Normal or By-Pass is not used any more in the industry of UPS.

proposed by the Swiss Federal Office of Energy and 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. The Industry[98] supports the concept of a future Energy Efficiency label for UPS; however, it should include a clear differentiation between VI, VFD and VFI, as these different topologies provide various kinds of power qualities.

The key factors that must be considered regarding energy efficiency are the size of the UPS, in comparison to load, 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.[99] 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 maintaining correct operating temperatures and maintenance procedures. Battery packs with cells that provide a similar internal resistance could extend the lifetime of the battery packs as well.

3.2.3 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% [100]

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.

3.2.4 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[101]. 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

[98] Feedback from Industry on Task 3 report V1.
[99] Chris Loeffler, Which UPS is right for the job, Eaton, 2009
[100] http://www.northstarbattery.com/sitesolutions/sitestar/index.php
[101] http://www.apcdistributors.com/white-papers/Power/WP-30%20Battery%20Technology%20for%20Data%20Centers%20and%20Network%20Rooms%20-%20Lead-Acid%20Battery%20Options.pdf

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. As bespoke systems such installations are not in the scope of the study. 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 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 20.

Table 20 Stress factors and their impact on damage mechanisms (light blue: strong impact; yellow: medium impact; green: little impact) [102]

	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.

3.2.5 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

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

dependent on the actual condition of each battery. As all batteries age, it is necessary to 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 [103]. 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[104] 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[105].

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.

103 http://www.mpoweruk.com/shipping_regs.htm
104 http://powerquality.eaton.com/Where-to-buy/Reman-ups.asp
105 http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf

3.2.6 Usage Patterns Conclusion

Stable grids, long charging periods and only a few discharge situations were typical operating conditions for UPS systems. Changing grid conditions due to the growing number of small-scale power stations (photovoltaic, wind, mini hydro etc.) has impacted grid stability and increases the number of short power failures. For UPS this translates into an increased number of discharge/charge cycles of the UPS system batteries. Batteries need to handle these conditions To reduce air conditioning costs 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 battery life expectation but at the expense of higher air conditioning costs. The request of batteries that run at 40°C ambient temperature and last 10 years had no success yet.

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. Improvement options, for example concerning automatic testing, will be researched and discussed with stakeholder as part of subsequent tasks and potential proposals could include mandatory demands for optimised monitoring of small UPSs.

3.3 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)[106] - a guide to equipment eligible for Enhanced Capital Allowances", the Carbon Trust.
- ENERGY STAR Specification Development for Uninterruptible Power Supplies (UPSs)[107] 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.

3.3.1 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

106 http://etl.decc.gov.uk/NR/rdonlyres/7FA0B0D6-FDDC-4CB0-B1B6-C76C77B042A7/0/ECA778_UPS.pdf
107 http://www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies

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[108].
- Electrolytic DC capacitors: Life of DC capacitors varies from eight to 30 years[108].
- Oil-filled AC capacitors: Oil-filled capacitors life is about of 10 years[108]. 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[109]:

- 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.

3.3.2 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 [110].

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[111] operates recycling and take-back for UPS batteries in the UK[112]. Other WEEE operators offer battery recycling for UPS in the UK but not the UPS units. The manufacture,

108 Informed by discussion with stakeholders
109 As defined by IEC 60896-2
110 For example http://www.apc.com/site/company/index.cfm/company/environmental-and-community/recycling/, http://www.riello-ups.co.uk/ups-services/tradeups/
111 http://uk.simsmm.com/products-and-services/ups-battery-recycling
112 http://www.simsrecycling.co.uk/electronics-recycling/UPS-Battery-recycling

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.

3.3.3 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 casing the respective recycling scheme is handling the registration and organising the final recycling[113].

3.3.3.1 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 [114]. 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[115].

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.

113 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.
114 http://batterycouncil.org/?page=Battery_Recycling
115 http://batterycouncil.org/?page=Battery_Recycling and discussion with stakeholders

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%[116]. 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.

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.

3.3.4 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 3.3.5 below). Further checks will be made to determine any implications arising as a result of the WEEE Directive recast.

3.3.5 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 discrete 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.

116 SAFT mentioned this in the telephone conference.

UPS are not separately listed in Annex 1 of the WEEE Directive (covering the period 14 August 2012 to 14 August 2018)[117], 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.

3.3.6 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.

3.4 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.

3.4.1 Energy

Given the purpose of UPSs, 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

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

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%[118]
- 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 design, and could potentially reduce the engineering requirements for data centre design[119].

3.4.2 Water

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

3.4.3 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.

3.4.4 Installers

A number of UPS suppliers offer installation and start up services to ensure correct and optimal installation. Typically this could include the following[120], 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.

118 CEMEP UPS Guide
119 Cooling requirement report
120 CEMEP UPS guide and Schneider Electric 'Critical Power and Cooling' brochure

3.4.5 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[121] . UPS therefore tend to be installed in temperature controlled environments if optimum service life is to be achieved.

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.

121 CEMEP UPS Guide

4 Task 4 – Technical analysis of existing products

4.1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design working plan 2009-2011. This preparatory study is the starting point of a process to build an informed evidence base for informing possible ecodesign measures. It aims to identify the current market size and composition, technical solutions, potential future technology improvements and possible policy options.

The Preparatory Study will follow the Commission's established MEErP methodology[122] 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 of 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, a project specific website: www.ecoups.org caters for:

- Raising awareness and understanding of the project with product developers, manufacturers and other stakeholders
- Informing stakeholders about the procedures of the study and how they can provide input to the work
- 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 posted on the website for stakeholders who cannot attend workshops.

4.1.1 Task 4 – Objectives

The objectives of Task 4 are to present an overview of the current products available on the market and the type of technologies used. It addresses the technical analysis of existing products across the different life cycle phases, looking at production, distribution, in use, and end of life characteristics. The data gathered through Task 4 will be used to inform the inputs for the environmental impact analysis of UPS, which is undertaken using the EcoReport[123] tool as part of Task 5.

EcoReport is a simplified life cycle assessment tool, developed for use in Ecodesign preparatory studies to quantify the environmental impact of the product being investigated. In

[122] http://www.meerp.eu/
[123] For the purposes of this study we are using the EcoReport tool developed as part of the MEErP methodology - http://www.meerp.eu/

order to generate environmental impact analysis, EcoReport requires inputs relating to the materials used to make the product (a bill of materials), its use, and end of life management. The data for the bill of materials were gathered through the second questionnaire as well as dismantling trials conducted by the project team.

This section includes an initial overview of the different UPS typologies and key terms, before presenting more detailed information in relation to the different life cycle phases; production, distribution, use (both at a product and systems level) and end of life.

4.1.2 Overview UPS topologies and key terms

UPS are designed to act as an interface between the mains and particular applications, e.g. PCs and servers. They protect the application against power problems, such as power failures, power sags, power surges, under-/over-voltage, switching transients, line noise, frequency variation and harmonic distortion[124]. The UPS does this by supplying the load with continuous, high quality electrical power regardless of the status of the mains. The supply voltage delivered by the UPS is free from major disturbances, within specified tolerance levels[125].

In the case of power failure, the UPS will provide a supply for a given run time, typically 5-30 minutes[125], to allow a backup generator to be started or systems to be shut down properly.

There are three main typologies used in existing UPS products:

- Passive Standby (off-line) (output Voltage and Frequency Dependent from mains supply - VFD);
- Line Interactive (output Voltage Independent from mains supply - VI); and
- Double conversion (online) (output Voltage and Frequency Independent from main supply – VFI)

Each of these is summarised below[124, 125].

Passive Standby (VFD)

These types of UPS provide power to the application direct from the mains in normal load. Where there are power cuts or fluctuations (for example, outside of pre-set tolerances), then the UPS will deliver a stable supply via the battery/inverter. Figure 13 illustrates a passive standby operation. The battery is charged from the mains and will provide a stable supply for the designed run time, or until the mains input voltage returns to within the pre-set tolerances of the UPS, if this is sooner.

Passive standby UPS are relatively low cost and are typically used for protecting PCs or other similar equipment in the office environment. They can be used to protect against power problems such as power failure, sags and surges. They are however, unsuitable for applications where there are frequent disruptions or the supply has a low power quality.

[124] Eaton Powerware Series Product Catalogue 2012
[125] Uninterruptible Power Supplies, European Guide, CEMEP, February 2008: http://www.cemep.org/fileadmin/downloads/CEMEP_UPS_Guide.pdf

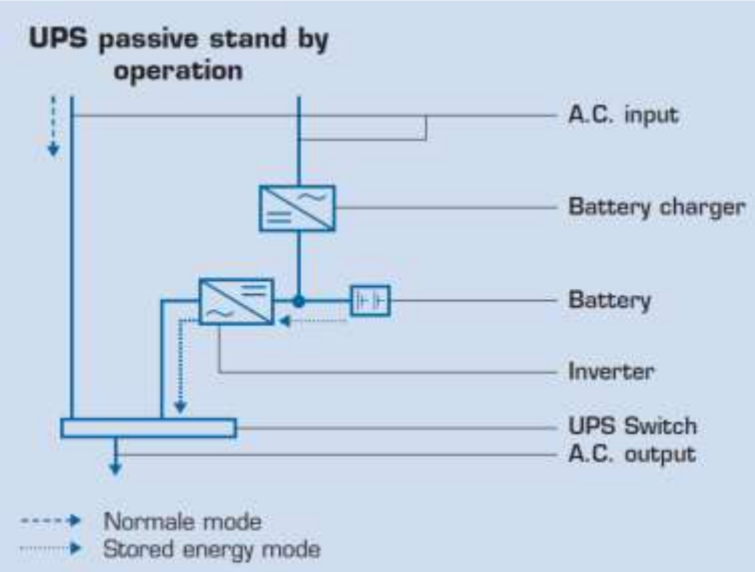


***Figure 13: Passive Standby Operation*[125]**

Line Interactive (VI)

These types of UPS are used to protect larger applications, such as enterprise networks and IT applications. In addition to power failure, sags and surges, line interactive UPS also protect against under-/over-voltage. The inverter provides output voltage conditioning in response to voltage fluctuations, for example outside pre-set tolerances. The output frequency is still dependent on the mains input frequency. Figure 14 illustrates a line interactive operation.

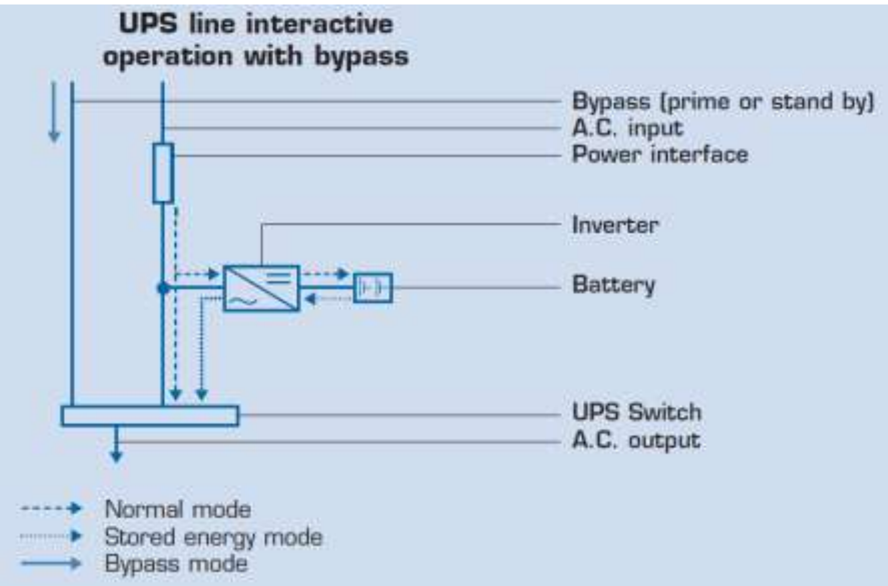


***Figure 14: Line Interactive Operation*[125]**

Double Conversion (VFI)

This UPS topology is designed to be used for the protection of critical applications, and will provide protection against a wide range of power problems, including power failure, power sag, power surge, under-/over-voltage, switching transient, line noise, frequency variation and harmonic distortion. These types of UPS provide a consistent power supply regardless of disturbances to the mains input. This is achieved by regenerating the output voltage by double conversion i.e. AC to DC conversion followed by DC to AC conversion. This creates a power supply without any electrical interference (Figure 15).

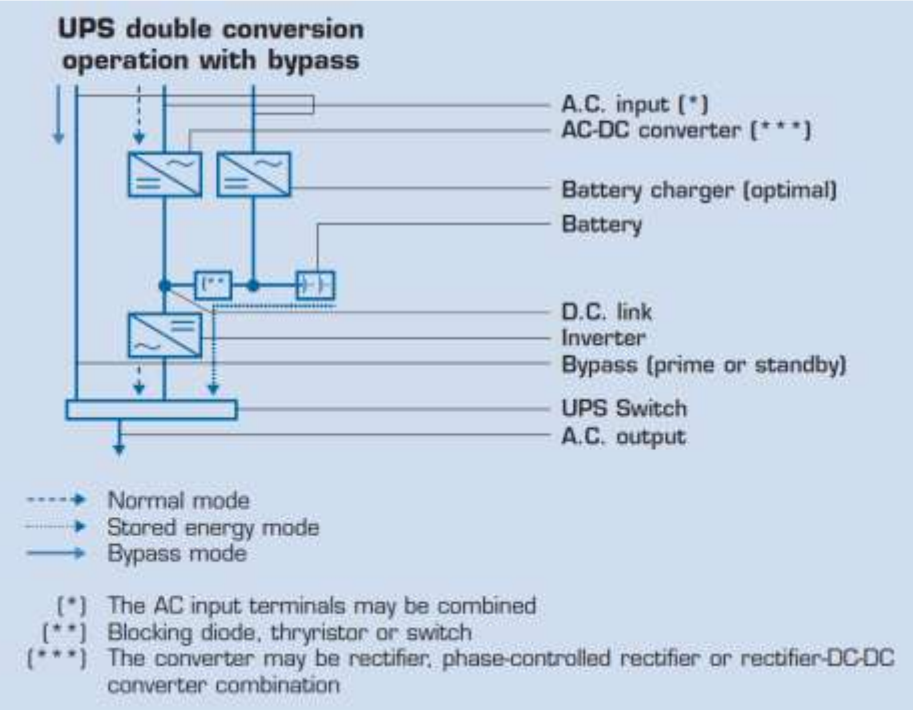


Figure 15: Double Conversion Operation[125]

A UPS can be used on its own, or where increased security and reliability of supply is required a number of UPS products can be used in parallel. This results in a level of redundancy within the system, which can have an effect on efficiency and energy consumption. This is discussed in detail in Section 4.4.

4.2 Subtask 4.1 – Production phase

Understanding the materials used in the production of UPSs is important. It provides a significant proportion of the input data required for Task 5 – Definition of Base Case enabling modelling of the product's environmental impacts and costs, for the production, distribution, and end of life phases.

The key UPS product typologies include standby, line interactive and double conversion (online). These typologies broadly align with different sizes/rating of UPS used for the segregation of the market data completed in Task 2 therefore the technical analysis of products has been completed on this basis.

Information on the materials used for the production of a UPS (bill of materials – BoM) was sought from stakeholders as part of the second questionnaire, and additional information was obtained through dismantling trials undertaken by the project team.

The BoM information relating to the production phase has been dealt with in three distinct sections:

- UPS
- Packaging
- Batteries

4.2.1 UPS

The Project team's experience and information from stakeholders suggests that the design and components of different sized UPS above 1.5 kVA do not vary significantly, with the main change being the weight of the materials. For UPS below 1.5kVA a different mix of materials is used, as discussed below.

For each of the four UPS size categories, information on representative products has been obtained through the second questionnaire and dismantling trials as follows:

- Below 1.5 kVA – based on measurements from dismantling of a typical 0.6 kVA UPS;
- 1.5 to 5 kVA – based on the average of four BoMs received from UPS manufacturing industry stakeholders covering this size range and the key topologies;
- 5.1 to 10 kVA – based on the average of two BoMs provided by UPS manufacturing industry stakeholders covering this size range and the key topologies; and
- 10.1 kVA to 200 kVA – based on the average of two BoMs provided by UPS manufacturing industry stakeholders and from dismantling of an 11kVA UPS.

Some of the product and BoM information provided to us was made available on a confidential basis, we have therefore withheld identities. The BoM information for different sizes of UPS is summarised in Table 21. In terms of the broad material categories that make up UPS, Table 22 provides a summary indicating the percentage of the different materials used in UPSs of different sizes. Broadly the trends are similar for the three largest UPSs, with metal dominating. For the smallest UPS there is a higher proportion of plastic due to its increased use in the casing.

Table 21: UPS bill of material inputs

	Base Cases - Weights in g			
EcoReport Material Codes	**Below 1.5kVA**	**1.5 to 5 kVA**	**5.1 to 10 kVA**	**10.1 to 200 kVA**
1-LDPE				80.0
2-HDPE				1 333.3
8-PVC	85.0	261.6	241.8	6 000.0
11-ABS	1 216.0	547.7	662.5	5 197.3
12-PA6		19.9	57.5	73.3
13-PC		74.3	5.5	41.0
14-PMMA				10.0
15-Epoxy	10.0	19.4	44.5	66.7
18-Talcum filler		0.7		
19-E glass fibre		13.9	17.3	3.3
20-Aramid fibre				1 666.7
22-St sheet galv		5 089.8		157 083.3
23-St tube/profile		7.5	15106.0	
24-Cast iron	1 123.0	1 277.8	125.7	32 000.0
25-Ferrite	91.0	303.2	955.5	18 790.0
26-Stainless 18/8 coil	25.0			
27-Al sheet/extrusion	117.0	657.1	1712.0	21 526.7
28-Cu winding wire	480.0	482.5		21 768.3
30-Cu wire	232.0	428.3	1022.6	24 650.0
31-Cu tube/sheet		4.5		19 733.3
32-CuZn38 cast		103.9	183.4	2 916.7

40-powder coating		20.7	12.5	1 500.3
43-lcd per m2 scrn		11.3		0.3
45-big caps & coils	15.0	259.7	933.5	17 340.0
46-slots . Ext. Ports	250.0		275.0	650.0
47-Ics avg 5% Si, Au	3.0	2.4	10.3	6.7
48-IC's avg 1% Si	7.0	29.1	89.0	16.7
49-SMD/LEDs avg	39.5	237.8	561.0	383.3
50-PWB 1/2 lay 3.75kg/m^2	108.0	538.3	1302.1	1 993.3
51-PWB 6 lay 4.5 kg/m^2		87.5		
53-Solder SnAg4Cu0.5	70.0	158.2	66.8	140.0
TOTAL	**3 871.5**	**10 637.0**	**23 384.4**	**33 4970.7**

Table 22: Contribution of material categories

Materials	Below 1.5kVA	1.5 to 5 kVA	5.1 to 10 kVA	10.1 to 200 kVA
Plastics	34%	9%	4%	4%
Metals	53%	79%	82%	89%
Electronics	13%	12%	14%	6%
Total	100%	100%	100%	100%

4.2.2 Packaging

Information on packaging for different UPSs was provided by stakeholders and dismantling trials undertaken by the project team. Based on the information relevant to each product category an average bill of materials for packaging has been calculated as in Table 23.

Table 23: Detailed packaging bill of material inputs

	Weights in g			
EcoReport Material Codes	**Below 1.5 kVA**	**1.5 to 5 kVA**	**5.1 to 10 kVA**	**10.1 to 200 kVA**
1-LDPE		558	2 350	
2-HDPE	36			12
4-PP		34	160	167
6-EPS	78	108		290
8-PVC				500
57-Cardboard	535	946	3520	8 850
58-Office paper	77	150		
Total weight (g)	**726**	**1 796**	**6 030**	**9 819**

Packaging is generally consistent between the different product categories, and is mainly card/paper, with some plastic, as Table 24 shows. This is as expected, and similar to other electrical products.

Table 24: Material categories used in packaging

	Below 1.5 kVA	1.5 to 5 kVA	5.1 to 10 kVA	10.1 to 200 kVA
Plastic	16%	39%	42%	10%
Card/paper	84%	61%	58%	90%
Total	100%	100%	100%	100%

4.2.3 Batteries

Research and stakeholder feedback indicates that the main battery technology for existing UPS products is lead acid. This is typically a sealed, valve regulated lead acid battery. For the smaller sizes UPS products, the battery is often incorporated within the casing of the UPS. For larger UPS products or where longer runtimes are required batteries are more likely to be external, for example rack mounted.

In terms of the bill of materials for lead acid batteries, recent research[126] indicates that the following composition is typical[127]:

- Lead / Lead Oxides – 60%
- Polypropylene – 10%
- Sulphuric acid – 10%
- Water – 16%
- Glass – 2%
- Antimony – 1%

A review of material safety data sheets for lead acid batteries confirms this is a reasonable breakdown of the materials used in the manufacture of lead acid batteries.

The value of lead means that there is a high level of lead recycling within the battery industry, and therefore not all of the lead used in the battery will be primary lead, a proportion will be secondary/recycled lead. The literature indicates that a new lead acid battery contains 60 to 80% recycled lead and plastic[128]. This will be taken into account in Task 5 when calculating the EcoReport inputs for the different base cases.

The weight of the battery varies between the different sizes of UPS. Feedback from stakeholders and information from dismantling trials undertaken by the project team has allowed an average battery weight of 6.23 kg per kW output to be calculated. This information, together with the typical composition above will be used in Task 5 to calculate the specific EcoReport inputs relating to the battery for the different sizes of UPS products.

4.2.4 Manufacturing

The majority of the inputs relating to manufacturing in EcoReport are fixed and cannot be altered, however the percentage of scrap sheet metal produced from the manufacturing processes needs to be assessed.

Detailed information, specific to UPS has not been identified during the research; however, the EcoReport guidance indicates the following:

'As a default, if no specific values are used, one can assume 25-30% cutting losses for average deep-drawing, cutting and stamping. For folded sheet in e.g. fridge housings, losses are much less (default 10%)'

The casing shapes cut for UPS are relatively simple, and should therefore minimise the losses/scrap production. It is therefore proposed to use a value of 10% for the amount of scrap sheet metal produced from the manufacturing process.

4.3 Subtask 4.2 - Distribution phase

In addition to the weight and composition of the packaging identified in Subtask 4.1, the volume of the packaged product has also been obtained from stakeholder feedback and

[126] A Review of battery Life-Cycle Analysis: State of Knowledge and Critical Needs, Argonne National Laboratory, 2010
[127] It is noted that the percentage total is 99%, and is assumed this is due to rounding in the source document, the additional 1% is not attributed to any materials when entering the weight of the battery materials in EcoReport – see Task 5.
[128] http://batterycouncil.org/?page=Battery_Recycling

dismantling trials. This information is required to enable EcoReport to calculate distribution impacts of the product. Table 25 summarises the volume of packaged product information for the different UPS categories.

Table 25: Volume of packaged product

	Product Category			
Parameter	**Below 1.5 kVA**	**1.5 to 5 kVA**	**5.1 to 10 kVA**	**10.1 to 200 kVA**
Volume of packaged final product (m^3)	0.022	0.022	0.041	1.48

4.4 Subtask 4.3 - Use phase (product)

The purpose of subtask 4.3 is to identify the annual resource consumption associated with UPS equipment use throughout its lifetime. This is in fact electricity consumption. Such consumption is strongly influenced by the load level, the load type and the effect of the requirement for additional resilience in the security of the uninterruptible power source. Another factor influencing the lifetime electricity consumption of more recent UPS designs is the ability of a single UPS to work in automatically selected multi-modes ranging from a standby (eco) mode to full double conversion mode. These issues are discussed in the subsequent sections.

4.4.1 Impact of Load on UPS Efficiency

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%[129], which leads to a 4-17% reduction of efficiency. The load type also has a strong influence on the achieved efficiency. The UPS's 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[130] and high total harmonic distortion[131]). The low power factor will require a higher peak current from the UPS, decreasing its efficiency. Therefore, in order to assess the conversion efficiency it is important to have tests with different load levels (typically 25, 50, 75 and 100%) and with different load types (R – resistive, RL – inductive and RCD – capacitive). Table 26 provides information about the energy performance and consumption in the use phase of 5 typical products with different power, considering different load levels.

Table 26: Energy consumption parameters for each product[132]

Parameters	**Standby (VFD) 0-1.5 KvA**	**Line Interactive (VI) UPS 1.5-5kVA**	**On Line (VFI) UPS 1.5-5kVA**	**On Line (VFI) UPS 5-10 kVA**	**On Line (VFI) UPS above 10kVA**
Active Power (kW)	0.24	0.9	2.7	4.2	200
Apparent Power (kVA)	0.4	1.5	3	6	200
Tested load levels (%)	25, 50, 75, 100				

[129] Richard L. Sawyer, "Making Large UPS Systems More Efficient", 2006
[130] The power factor of a load, which may be a single power-consuming item, or a number of items (for example an entire installation), is given by the ratio of P/S i.e. kW divided by kVA at any given moment. The value of a power factor will range from 0 to 1. If currents and voltages are perfectly sinusoidal signals, power factor equals cos φ. A power factor close to unity means that the reactive energy is small compared with the active energy, while a low value of power factor indicates the opposite condition.
[131] The total harmonic distortion, or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. THD is used to characterize the linearity of audio systems and the power quality
[132] CEMEP responses to the Second Stakeholder Questionnaire

Conversion efficiency (%)	Always 96%	always 95% fully charged battery	Table 27	Table 28	93, 94.7, 95, 95 - without battery charging
Energy losses associated with active power at 50% of nominal power (kWh/year)	87	190	1 183	2 024	46 000

Table 27 and Table 28 provide more details on the different achieved conversion efficiencies with different load levels, load types and modes of operation. As can be seen the efficiency with lower load levels and with non-resistive loads is lower. Furthermore, with the ECO Modes a much higher efficiency can be achieved to the same load levels and load types.

Table 27: Efficiency chart for On Line (VFI) UPS 1.5-5kVA[132]

Load	R	RL	RCD
25%	0.87	0.87	0.84
50%	0.91	0.92	0.89
75%	0.91	0.93	0.90
100%	0.91	0.93	0.91

Table 28: Efficiency chart for On Line (VFI) UPS 5-10 kVA[132]

Load	Normal Mode			ECO Mode		
	R	RL	RCD	R	RL	RCD
25%	0.88	0.91	0.88	0.96	0.96	0.95
50%	0.89	0.93	0.89	0.97	0.97	0.97
75%	0.91	0.93	0.91	0.98	0.98	0.98
100%	0.905	0.93	0.91	0.97	0.98	0.98

Since conversion efficiency changes with the load levels, it is also important to know the average time spent in each load level. Table 29 extracted from Version 1.0 of the US EPA's Energy Star Product Specification for UPSs[133] (widely approved by manufacturers) shows the breakdown of the average time spent at specified proportion of the rated load and for each rated output power categories.

Table 29: AC-output UPS Loading Assumptions for Calculating Average Efficiency[133]

Rated Output Power, P, in watts (W)	Input Dependency Characteristic	Proportion of Time Spent at Specified Proportion of Reference Test Load, $t_{n\%}$			
		25%	50%	75%	100%
P ≤ 1500 W	VFD[134]	0.2	0.2	0.3	0.3
	VI[135] or VFI[136]	0	0.3	0.4	0.3
1500 W < P ≤ 10,000 W	VFD, VI, or VFI	0	0.3	0.4	0.3
P > 10,000 W	VFD, VI, or VFI	0.25	0.5	0.25	0

[133] ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.
[134] VFD - Voltage and Frequency Dependent
[135] VI - Voltage Independent
[136] VFI - Voltage and Frequency Independent

The conversion efficiency of UPS systems has been improving in the last few years, mainly due to the new typologies (conversion mode, Eco-mode), the newly-developed low resistance IGBTs (Insulated-Gate Bipolar Transistor) and rectifiers and the use of transformer-less UPS[137]. Another very important factor which is leading to a higher conversion efficiency of the products put out on the market are voluntary agreements on minimum levels of efficiency that have been developed.

For new products put out on the market post 1 January 2011, the minimum level of the conversion efficiency for UPS is defined in the UPS Code of Conduct 2011 from JRC[138] (widely adhered to by manufacturers). Signatories for the Code of Conduct include the main manufacturers supplying products to the EU market[139]. Therefore, it can be assumed that the majority of the small size UPS which have a short life time are already compliant or will be within the next 3-4 years. For the mid-range and larger UPS the renewal cycle is longer (typically 8 and 12 years respectively), so while new products will meet the latest code of conduct requirements, older products will meet the requirements of the first code of conduct, which is discussed further below. The efficiency is specified according to the load level for each rated output power categories and type of UPSs.

The following tables present the conversion efficiency from the current code of conduct for UPS double conversion in the basic configuration with the classification “VFI – S…" (Table 30 and Table 31), for all VI and VFI UPS, except “VFI – S…” (Table 32 and Table 33), and for all VFD UPS (Table 34 and Table 35).

Table 30: Efficiency for UPS rated from 0.3kVA to < 10KVA with classification “VFI – S…[140](from 1-1-2011 to 31-12-2014)[138]

Voltage V	Load %	UPS rating (kVA)				
		≥0.3 to <0.8	≥0.8 to <1.5	≥1.5 to <3.5	≥3.5 to <5.0	≥5.0 to <10.0
230/400	25	73.0%	73.0%	78.0%	82.0%	82.5%
	50	74.0%	80.0%	83.0%	84.0 %	85.0%
	75	78.0%	82.0%	83.0%	86.0%	87.0%
	100	80.0%	82.0%	84.0%	86.0%	87.0%

Table 31: Efficiency for UPS rated from 10kVA to ≥ 200kVA with classification “VFI – S…" (from 1-1-2013 to 31-12-2014)[138]

Mode[141]	UPS range 10 – < 20 kVA	UPS range 20 – < 40 kVA	UPS range 40 – < 200 kVA	UPS range ≥ 200 kVA
25 % of nominal power	86.5%	87.5%	89.0%	90.0%
50 % of nominal power	91.0%	91.5%	92.0%	92.5%
75 % of nominal power	92.0%	92.5%	93.0%	93.5%
100 % of nominal power	92.0%	92.5%	93.0%	93.5%

[137] CEMEP, Environmental Considerations, Focus on UPS, 2009.
[138] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011
[139] Current list of participants for the code of conduct are available here: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/ac-uninterruptible-power-systems
[140] S - output with sinusoidal waveform
[141] Normal mode Minimum efficiency measured according to EN 62040-3 Annex AA

Table 32: Efficiency for UPS rated from 0.3kVA to < 10kVA with classification VI and VFI, except "VFI – S…" (from 1-1-2011 to 31-12-2014)[138]

Voltage V	Load %	UPS rating (kVA)				
		≥0.3 to <0.8	≥0.8 to <1.5	≥1.5 to <3.5	≥3.5 to <5.0	≥5.0 to <10.0
230/400	25	80.0%	85.0%	85.0%	85.0%	85.5%
	50	87.0%	88.0%	89.0%	91.0%	91.5%
	75	87.5%	88.5%	89.9%	92.0%	92.5%
	100	88.0%	89.0%	90.0%	92.0%	92.5%

Table 33: Efficiency for UPS rated from 10kVA to ≥ 200kVA with classification VI and VFI, except "VFI – S…" (from 1-1-2013 to 31-12-2014)[138]

Mode[141]	UPS range 10 – < 20 kVA	UPS range 20 – < 40 kVA	UPS range 40 – < 200 kVA	UPS range ≥ 200 kVA
25 % of nominal power	90.0%	91.0%	91.5%	93.0%
50 % of nominal power	93.0%	93.5%	94.0%	95.5%
75 % of nominal power	93.5%	94.0%	94.5%	96.0%
100 % of nominal power	93.5%	94.0%	94.5%	96.0%

Table 34: Efficiency for UPS rated from 0,3kVA to <10kVA with classification VFD (from 1.1.2011 to 31.12.2014)[138]

Voltage V	Load %	UPS rating (kVA)				
		≥0.3 to <0.8	≥0.8 to <1.5	≥1.5 to <3.5	≥3.5 to <5.0	≥5.0 to <10.0
230/400	25	86.0%	87.8%	89.0%	90.0%	90.0%
	50	87.0%	88.8%	92.0%	93.0%	93.0%
	75	88.0%	89.8%	93.0%	94.0%	94.0%
	100	89.0%	90.8%	93.0%	94.0%	94.0%

Table 35: Efficiency for UPS rated from 10kVA to ≥ 200kVA with classification VFD (1-1-2013 to 31-12-2014)[138]

Mode[141]	UPS range 10 – < 20 kVA	UPS range 20 – < 40 kVA	UPS range 40 – < 200 kVA	UPS range ≥ 200 kVA
25 % of nominal power	94.0%	94.5%	95.0%	95.5%
50 % of nominal power	96.0%	96.5%	97.0%	97.5%
75 % of nominal power	96.5%	97.0%	97.5%	98.0%
100 % of nominal power	96.5%	97.0%	97.5%	98.0%

As highlighted above, mid-range and larger UPS have longer lifetimes and therefore renewal cycles. The majority of installed products will not therefore meet the requirements of the current code of conduct and are likely to have lower conversion efficiency, for example in line with the first version of the code of conduct, published in 2008[142].

[142] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, 2008

Although only published in 2008, stakeholder feedback indicates that the first code of conduct will provide a good indication of the level of efficiency found in existing products above 10 kVA. This is due to updating of the UPS when IT applications are updated, which is done more frequently than the lifetime of the UPS. In addition, since 2008 the demand for larger UPS has increased due to the increase in datacentres and cloud servers. Although there are some pre-2008 UPS in operation it is considered these are low in number. Hence post-2008 stock dominates. This stock exceeds the 2008 code of conduct requirements meaning the minimum conversion efficiency level used in the Code of Conduct version 1 can be used to characterise existing installed products above 10 kVA.

The following tables present the conversion efficiency for UPS double conversion in the basic configuration with the classification “VFI – S..." (Table 36), for all VI and VFI UPS, except “VFI – S…” (Table 37) and for all VFD UPS (Table 38) used in the first version of the Code of Conduct[142].

Table 36: Efficiency for UPS double conversion in the basic configuration with the classification “VFI – S..." (from 1-1-2008 to 31-12-2009)[142]

Mode[141]	UPS range 10 – < 20 kVA	UPS range 20 – < 40 kVA	UPS range 40 – < 200 kVA	UPS range ≥ 200 kVA
25 % of nominal power	83.0%	84.0%	86.5%	89.0%
50 % of nominal power	89.0%	89.5%	90.5%	92.0%
75 % of nominal power	90.5%	91.0%	92.0%	93.0%
100 % of nominal power	91.0%	91.5	92.0%	93.0%

Table 37: Efficiency for UPS with classification VI and VFI, except "VFI – S…” (from 1-1-2008 to 31-12-2009)[142]

Mode[141]	UPS range 10 – < 20 kVA	UPS range 20 – < 40 kVA	UPS range 40 – < 200 kVA	UPS range ≥ 200 kVA
25 % of nominal power	88.0%	88.5%	89.0%	91.5%
50 % of nominal power	92.0%	92.5%	93.0%	94.5%
75 % of nominal power	92.5%	93.0%	93.5%	94.5%
100 % of nominal power	92.5%	93.0%	93.5%	94.5%

Table 38: Efficiency for UPS with classification VFD (from 1-1-2008 to 31-12-2009)[142]

Mode[141]	UPS range 10 – < 20 kVA	UPS range 20 – < 40 kVA	UPS range 40 – < 200 kVA	UPS range ≥ 200 kVA
25 % of nominal power	93.0%	93.5%	94.0%	95.0%
50 % of nominal power	95.0%	95.5%	96.0%	97.0%
75 % of nominal power	95.7%	96.3%	96.7%	97.7%
100 % of nominal power	96.0%	96.5%	97.0%	98.0%

Table 39, Table 40 and Table 41 provide a comparison between the conversion efficiencies defined in the 2008 and 2011 versions of the Code of Conduct. As can be seen the increase on the minimum efficiency level ranges from 0 to 3.5%, with higher improvements on smaller UPS and lower load levels.

Table 39: Efficiency for UPS double conversion in the basic configuration with the classification "VFI – S..."

Mode	UPS range 10 – < 20 kVA			UPS range 20 – < 40 kVA			UPS range 40 – < 200 kVA			UPS range ≥ 200 kVA		
	2008	2013	Δ	2008	2013	Δ	2008	2013	Δ	2008	2013	Δ
25%	83.0%	86.5%	***3.5%***	84.0%	87.5%	***3.5%***	86.5%	89.0%	***2.5%***	89.0%	90.0%	***1.0%***
50%	89.0%	91.0%	***2.0%***	89.5%	91.5%	***2.0%***	90.5%	92.0%	***1.5%***	92.0%	92.5%	***0.5%***
75%	90.5%	92.0%	***1.5%***	91.0%	92.5%	***1.5%***	92.0%	93.0%	***1.0%***	93.0%	93.5%	***0.5%***
100%	91.0%	92.0%	***1.0%***	91.5	92.5%	***1.0%***	92.0%	93.0%	***1.0%***	93.0%	93.5%	***0.5%***

Table 40: Efficiency for UPS with classification VI and VFI, except "VFI – S..."

Mode	UPS range 10 – < 20 kVA			UPS range 20 – < 40 kVA			UPS range 40 – < 200 kVA			UPS range ≥ 200 kVA		
	2008	2013	Δ	2008	2013	Δ	2008	2013	Δ	2008	2013	Δ
25%	88.0%	90.0%	***2.0%***	88.5%	91.0%	***2.5%***	89.0%	91.5%	***2.5%***	91.5%	93.0%	***1.5%***
50%	92.0%	93.0%	***1.0%***	92.5%	93.5%	***1.0%***	93.0%	94.0%	***1.0%***	94.5%	95.5%	***1.0%***
75%	92.5%	93.5%	***1.0%***	93.0%	94.0%	***1.0%***	93.5%	94.5%	***1.0%***	94.5%	96.0%	***1.5%***
100%	92.5%	93.5%	***1.0%***	93.0%	94.0%	***1.0%***	93.5%	94.5%	***1.0%***	94.5%	96.0%	***1.5%***

Table 41: Efficiency for UPS with classification VFD

Mode	UPS range 10 – < 20 kVA			UPS range 20 – < 40 kVA			UPS range 40 – < 200 kVA			UPS range ≥ 200 kVA		
	2008	2013	Δ	2008	2013	Δ	2008	2013	Δ	2008	2013	Δ
25%	93.0%	94.0%	***1.0%***	93.5%	94.5%	***1.0%***	94.0%	95.0%	***1.0%***	95.0%	95.5%	***0.5%***
50%	95.0%	96.0%	***1.0%***	95.5%	96.5%	***1.0%***	96.0%	97.0%	***1.0%***	97.0%	97.5%	***0.5%***
75%	95.7%	96.5%	***0.8%***	96.3%	97.0%	***0.7%***	96.7%	97.5%	***0.8%***	97.7%	98.0%	***0.3%***
100%	96.0%	96.5%	***0.5%***	96.5%	97.0%	***0.5%***	97.0%	97.5%	***0.5%***	98.0%	98.0%	***0.0%***

4.4.2 Multi-Mode operation of UPS

In critical applications where a high degree of power supply resilience is required, such as data centres for financial institutions, the best choice of UPS has always been considered to be the double conversion topology. This topology protects critical IT loads from virtually all types of disturbance in the main electrical network supply to the data centre. The double conversion topology is, in basic application, the least efficient UPS topology.

Developments in digital signal processing (DSP) applied to UPS design have been the catalyst for intelligent multi-mode double conversion UPS. In these designs the UPS automatically discriminates between different types of disturbances and supplies power to the load in control and treatment modes that range from direct from the mains distribution to full double conversion.

■ **Maximum energy saving mode (eco-mode)**

This mode is automatically activated when the UPS detects that the incoming mains supply is within acceptable limits of voltage, frequency, and distortion and effectively supplies the load directly through a bypass line, as shown in Figure 16. A power transfer efficiency of up to 99% can be achieved in this mode.

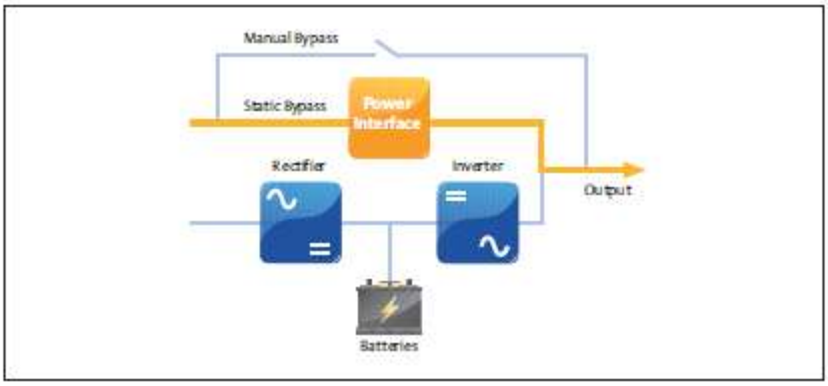


Figure 16: UPS In Eco Mode (power transfer route in yellow)[143]

■ **Power conditioning mode**

This mode is activated when the load power factor (PF) and the total harmonic distortion (THDi) from incoming mains and load exceeds specified limits. The energy required to correct these disturbances is through the use of the inverter section as an active, filter and power factor corrector, see Figure 17.

A power transfer efficiency of between 97% and 98.5% may be achieved in this mode depending on the linearity of the load and the condition of the incoming mains.[144]

[143] Emerson Network Power
[144] Emerson Network Power

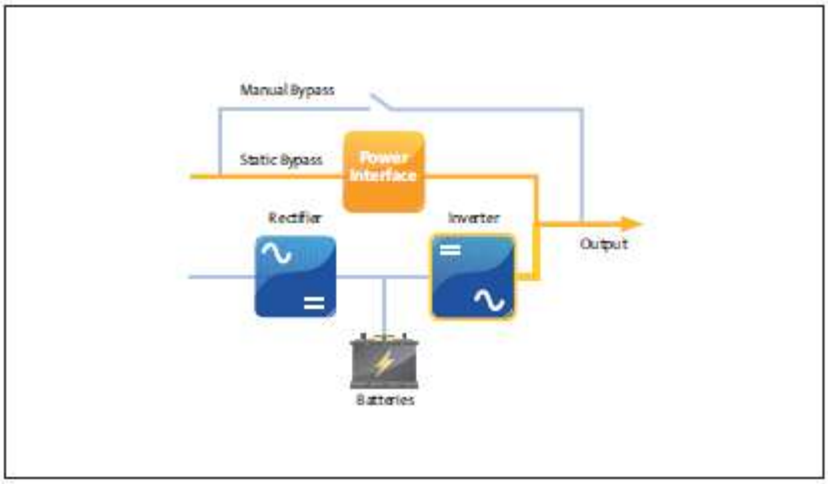


Figure 17: UPS in Power Conditioning mode (power transfer route and active conditioning load in yellow)[145]

■ Maximum power conditioning and control mode

This mode is automatically activated when the condition of the incoming mains is unacceptable for the load. It provides protection against all electrical disturbances through double conversion (Figure 18). At full load the power transfer efficiency of this mode is over 95%[146] (transformer-free topology).

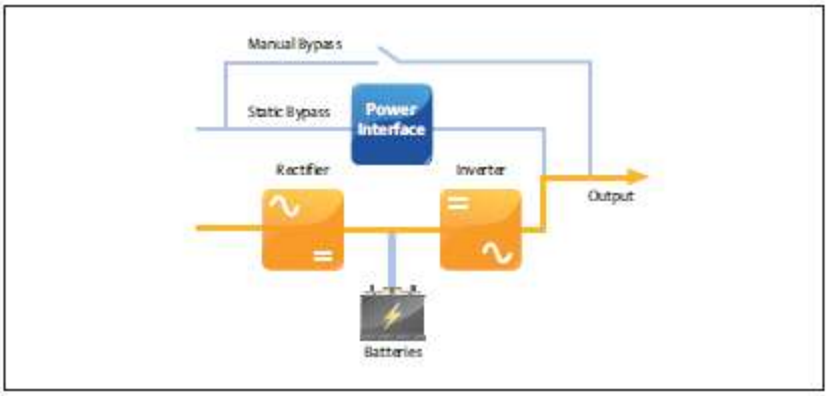


Figure 18: UPS in maximum power conditioning and control mode[147]

Any of the modes described above are selected automatically by the UPS control circuitry to optimise operating efficiency in a given combination of load and incoming mains conditions. The multi-mode UPS may also be controlled by an external control programme to operate in a mode suitable for the level of supply reliability required at given times (e.g. maximum energy saving mode could be selected during known IT load standby periods).

4.4.3 UPS Availability, Reliability and Redundancy

This section discusses UPS system availability, reliability and UPS redundancy to meet various levels of supply security and resilience.

An indicator of the reliability of a UPS system is termed the mean time between failure (MTBF). This is the average operating time (normally measured in hours) between the powering up of the UPS system and the shutdown of the UPS system due to failure. In the European UPS industry the MTBF of a UPS system, in a failure condition, where the load is

[145] Emerson Network Power
[146] Emerson Network Power
[147] Emerson Network Power

supplied only by the incoming AC mains supply is assumed in CEMEP UPS industry calculations to be 50 hours.

UPS system availability is a different measure to reliability since it takes into account the mean time to repair (MTTR) of a UPS system fault. The availability level is measured in "nines" and calculated using the formula:

Availability % = (1- (MTTR ÷ MTBF)) X 100

Table 42 shows the availability related to the "nines" level and projected downtime of the UPS installation system per year.

***Table 42**: Availability of UPS system related to "nines" level and downtime*

Availability	Level ("nines")	System downtime per year (100-availability)*secs per annum)
99.9999%	Six nines	32 seconds
99.999%	Five nines	5 minutes 35 seconds
99.99%	Four nines	52 minutes 33 seconds
99.9%	Three nines	8 hours 46 minutes
99%	Two nines	87 hours 36 minutes
90%	One nine	36 days 12 hours.

The topology of a UPS installation system is usually described using the letter "N". A single or group of UPS exactly providing the power capacity required to meet the needs of a load would be a basic "N" system. Apart from bypass to the incoming mains supply there would be no back-up for the failure of a UPS module or for maintenance. From CEMEP data on installed UPS the calculated average MTBF of an "N" UPS installation system is 250,000 hours. This MTBF figure presumes that early failures due to manufacturing or component faults are eliminated at the testing stage of an installation system. The projected lifetime availability level of an "N" system is four nines (99.99%). A MTBF of 250,000 hours is the equivalent of 28 years operation without failure. This MTBF is far in excess of the design lifetime of a UPS installation and certainly that of the protected loads.

Where UPS are configured in a system installation topology to allow redundancy of one of the UPS for maintenance or failure but still meet the needs of the full load, the system is usually described as an N+1 UPS system topology and generically as a parallel redundant UPS system (Figure 19). Such a system has a projected MTBF of 950,000 hours and a projected lifetime availability level of five nines (99.999%). In this system installation topology the failure of one UPS or its removal for maintenance is covered by the remaining UPS.

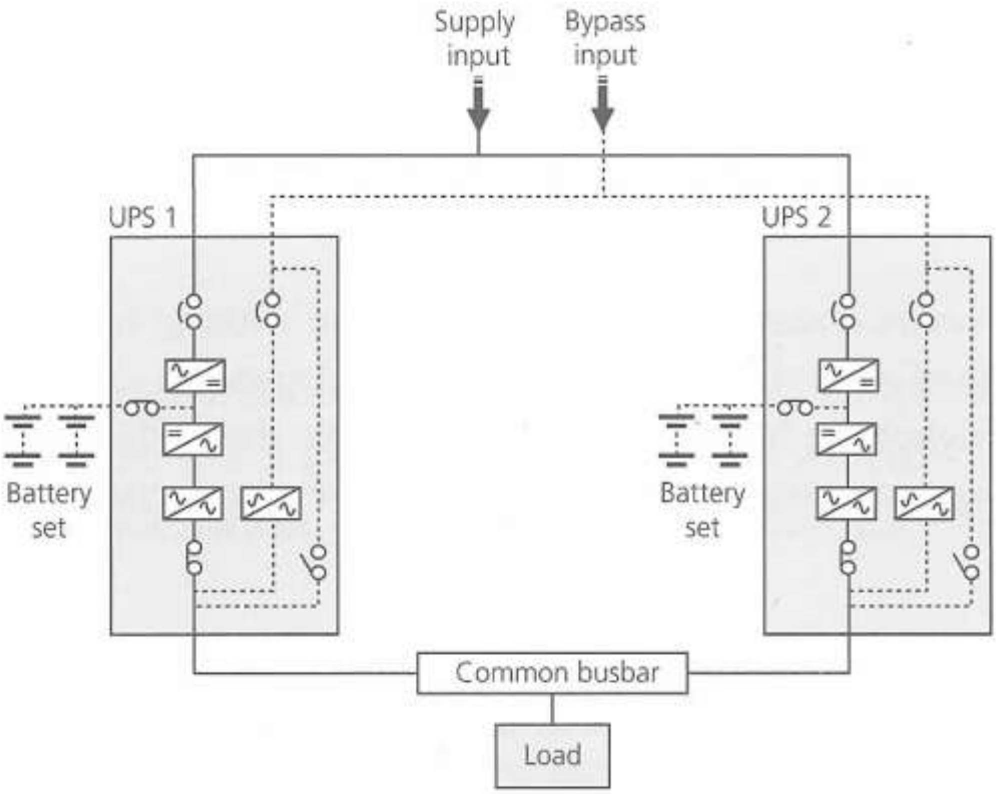


Figure 19: Parallel Redundant UPS (N+1)[148]

Where the N+1 system is duplicated to supply the load e.g. in a parallel- redundant UPS group the system is termed a 2N or 2 (N+1) system. A 2(N+1) installation system is shown in Figure 20). This solution has a projected MTBF of 2,500,000 hours and an availability level of six nines (99.9999%). In this installation topology a parallel systems joiner (PSJ) is used to connect the outputs from two parallel redundant (N+ 1) systems to the protected loads. All system functions are redundant, even during maintenance and the system is capable of handling high overload currents.

[148] Rielllo UPS power protection guide Stillwater Publications.

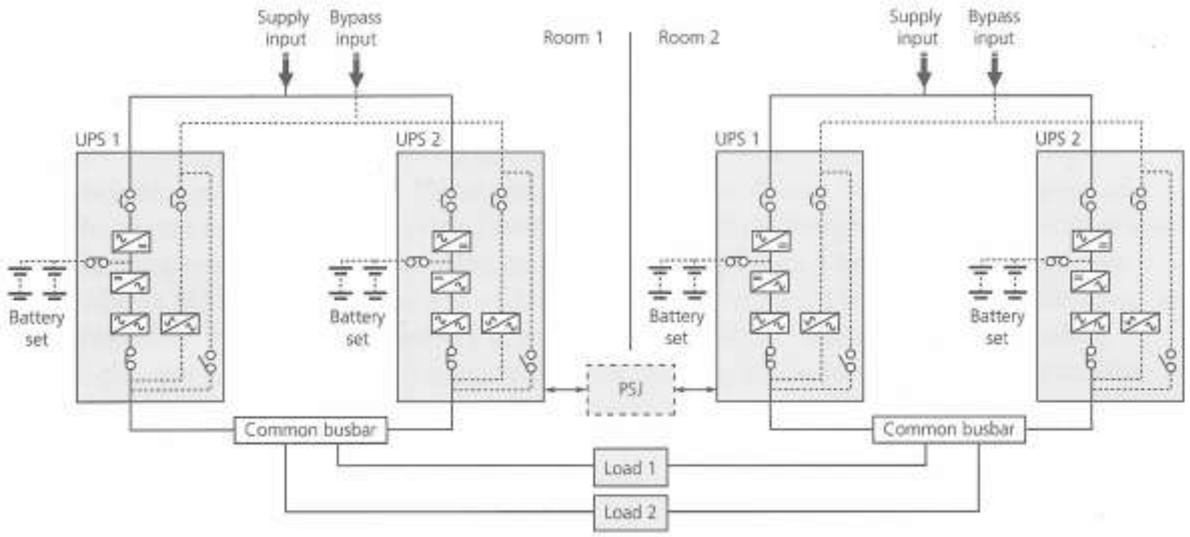


Figure 20: Parallel Redundant UPS (2N+1)[149]

In N+1, 2N and 2 N+1 systems the no load losses of the additional UPS modules impact adversely on the overall power transfer efficiency of the system.

Care has to be taken to ensure that the shared load configuration of each UPS module is not causing the UPS to work at a low load and therefore a poor efficiency level for most of its operating cycle.

The total load on a UPS unit is an important consideration where non modular centralised UPS are installed in new data centre designs with a high level of power redundancy to allow for future load expansion. In such designs large UPS have been known to work at less than 10% load for significant periods in the first two or three years of operation from new. No UPS system can achieve a power transfer efficiency of more than 80% at load levels of around 10% of optimum performance design load.[150]

In addition to power transfer efficiency considerations in parallel redundant installation topologies there is an obvious increase in the life cycle resource impact to consider through the use of multiple UPS modules.

Informed industry sources estimate that for the data centre market 10% of the installation typologies would have an "N" UPS system, 70% an N+1 topology and 20% a 2N topology.

The comparative resilience and UPS availability in an N+1system is 10 times better than an N system. For a 2N system the factor is 100 times better than an N system.

Table 43 summarises the key characteristics of availability, reliability and redundancy of the installation systems discussed in this section.

***Table 43**: Summary of Installation system topology specifications*

Installation System Topology	Number of UPS Units for a given load	MTBF of UPS System (hours)	MTBF during maintenance (hours)	Redundancy during Maintenance	Availability
N	1	250,000	50	No	99.998%
N+1	2	950,000	250,000	No	99.9997%
2(N+1)	4	2,500,000	750,000	Yes	99.9999%

149 Riello UPS Power Protection Guide, Stillwater publications
150 Efficiency and load data consultation Prof. Ian Bitterling Emerson Network Power Systems

4.4.4 Battery Technology

Batteries represent one of the main components of a UPS. Of the many available battery types, UPS systems generally use lead-acid, with other battery types, for example nickel-cadmium (NiCd) batteries a niche market.

Lead-acid batteries can be divided in valve regulated batteries and vented batteries, which are constructed with the liquid electrolyte completely covering the closely spaced plates. The different types present the following main characteristics[151].

- Valve Regulated Lead-Acid battery - less involved maintenance; no specific room requirements; no topping up operations; high energy density; extremely low gas emission; reduced demands on the ventilation; more sensitive to high temperatures; require good voltage stabilization chargers; no possibility to check or to see internally the cell; limited shelf life.
- Vented Lead-Acid Battery - easy to determine the state of a cell due to transparent container; possibility to test the electrolyte density; long storage periods are possible for dry charge cells; long life; installation in dedicated rooms; need of filling; limited energy density; gas emission.
- Nickel- Cadmium - Possibility to test the electrolyte density; long storage periods; higher life; less sensitive to higher temperature; installation in dedicated rooms; need of filling; gas emission.
- Lithium Ion batteries are starting to enter the UPS market, but are currently a niche market. An advantage is the high energy density that results in smaller battery cases; however recycling is more costly than for lead acid batteries and it is not standard at present.

During the last few years, batteries' efficiency and performance have improved, mainly due to the research effort to increase the autonomy of electric vehicles. Such improvements have had positive impact on the efficiency batteries used within UPS systems. However, the new types of batteries, with higher efficiency and performance, still have very high costs to be used in most of UPS systems.

Battery operation

During initial operation, the battery requires charging. The battery charger should provide the initial charge, replenish the local losses to maintain the battery capacity, equalize the individual cells state-of-charge, and recharge the battery following discharge. In stationary applications such as static UPS systems, the battery is continually connected to the charger and the load and the battery is float charged[152].

Therefore, to characterize the performance during the use phase it is also important to have information about the battery recharge and use. Table 44 provides information about the batteries used in each product.

Table 44: Battery parameters for each product

Parameters	Standby (VFD) 0-1.5 KvA	Line Interactive (VI) UPS 1.5-5kVA	On Line (VFI) UPS 1.5-5kVA	On Line (VFI) UPS 5-10 kVA	On Line (VFI) UPS above 10kVA
Battery runtime (half and full load - minutes)	8 and 3 minutes	13 and 4 minutes	11 and 4 minutes	10 and 4 minutes	NA
Battery recharge time (hours)	2 to 4 hours	12 hours	3 hours to 90%	3 hours to 90%	NA
Battery recharge frequency	depends on usage	3-4 time/year			NA

[151] CEMEP, Uninterruptible Power Supplies EUROPEAN GUIDE, 2008
[152] US Department of Army, Uninterruptible Power Supply System Selection and Maintenance for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance Facilities, 2007

4.4.5 Consumer use behaviour

UPS efficiency and expected lifetime are both greatly impacted by how consumers/users actually use a UPS. Most of the small scale UPS-products e.g. below 1.5 kVA are operated in a purchase-and-forget-mode. Their batteries are charged permanently without any discharge for the lifetime of the product. They are seldom maintained or tested, which increases the risk of UPS failure/break down if left for a number of years. As products sold between 50 and 100 Euros are manufactured at a level of 15 – 20 % of this price, manufacturers avoid any cost possible. As a result these devices do not usually have a fan and most are tightly packed in casing with limited air circulation. This means the temperature inside the cabinet could increase up to a level that shortens the lifetime of the batteries.

For larger devices the situation is better as these products are more likely to be covered by a service contract, or include software alerts that highlight the status of the battery.

Battery lifetime is dependent on the respective load cycles and the ambient temperature. Standby devices work at lower temperatures than online devices equipped with a transformer. Nevertheless cooling of the batteries is essential which operate best at an ambient temperature of 20°C.

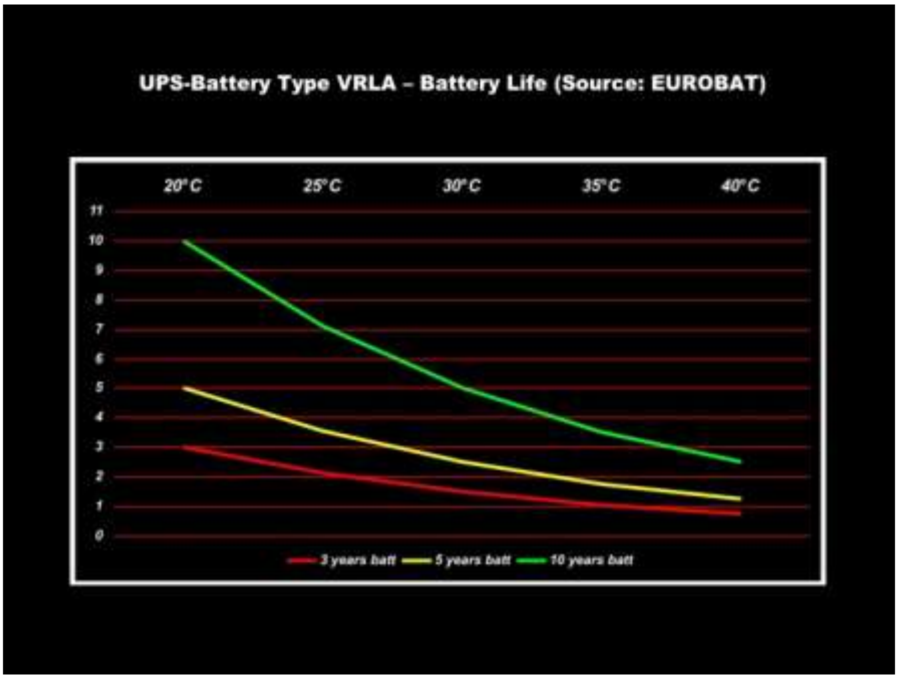


Figure 21: battery lifetime and local temperature[153]

Some poor batteries in cheap UPS devices with a nominal lifespan of 3 years are not operational after 10 – 15 months. This is due to bad cooling and higher ambient temperatures (Figure 21).

Battery lifetime is dependent on the actual environment of the devices. One of the main issues is the maintenance routine of the UPS's electronics. Small devices provide no alert but shut down finally after some seconds. Some batteries heat up when discharged with high current. Batteries for UPS should be certified for high current.

Professional maintenance for small devices is not common and costs per annum would be higher than the price for a new device. For maintenance purposes automatic procedures would provide the only solution available. Testing small UPSs is a main issue. A test routine every 3 to 6 months including a discharge by 30% could be useful. After 30% discharge

[153] Graph by Reveman Energy Academy

there is still 60% of the stored power available (assuming a charging level of 90%). The testing routine does not prevent the UPS from operation during the testing process.

Warranty for UPS

UPS systems are backed by comprehensive warranties. Stakeholder feedback indicates that most UPS products hold a two-year warranty while batteries are treated as consumable parts and are covered by a one-year warranty. Larger UPS products can be covered by a service contract. Some of the contracts include the batteries and some not. Service contracts that exclude the batteries transfer the risk of battery failure and replacement costs to the customer. Service contracts including the battery replacement risks may charge higher margins. Finally the customer has to pay for the replacement batteries in each scheme.

Some manufacturers extend the warranty for their products to 3 years or up to 5 years with an additional warranty contract. In such warranty schemes batteries could be included, if the UPS's integrated electronics detect them as faulty.

In the event of failure, the unit will be exchanged free of charge provided that the unit is accompanied by a proof-of-purchase. For smaller UPS units, the customer must return defective products to the respective stores boxed for replacement or repair during the standard warranty period.

Warranties do not include any labour, carriage or shipping costs and the supplier has the right to test and, if necessary, charge for the replacement if the faults are due to misuse.

4.5 Subtask 4.4 – Use phase (system)

4.5.1 Different markets and energy use

A system in the context of UPS is constituted by UPSs, transformers, harmonic filters and the loads which are supplied by the UPS.

UPSs are used in three main markets (industry and infrastructure; data centres; residential and small business). Despite their growing importance, UPSs only represent a small part of the total energy consumption in these various markets[154].

In industry and infrastructure appliances, the UPS systems are used to ensure the service continuity of industrial processes to prevent production losses. In such market UPSs represent 1.5% of the energy consumption (Figure 22), which is about 0.465% of the total EU consumption. The figure presents only the electricity consumption which is 30% of the total energy consumption in industry.

[154] CEMEP, Environmental Considerations, Focus on UPS, 2009.

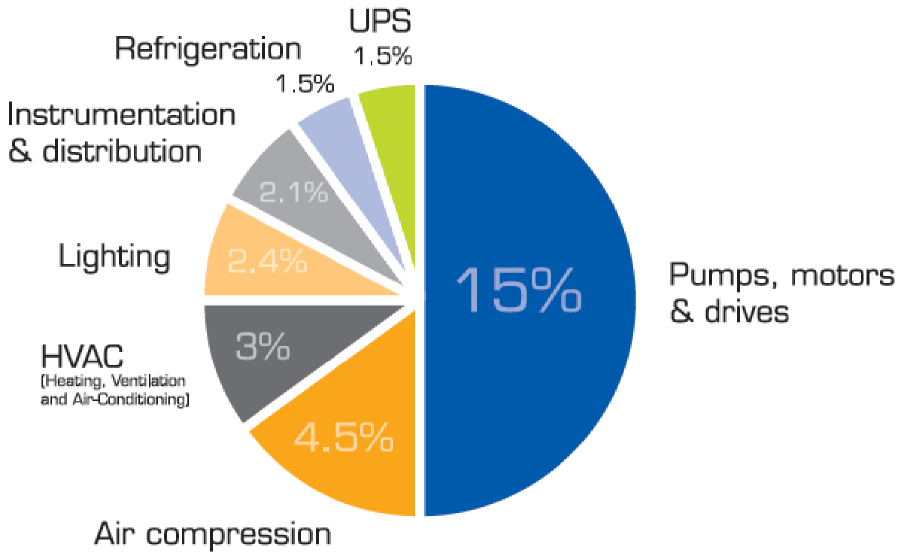


Figure 22: Electricity consumption in industry and infrastructures in EU[154]

In data centres, the UPS systems are used to ensure the service continuity of information and communication technologies to protect it from risk of halts in processing. In such a market UPSs represent 7% of the energy consumption (Figure 23). However, it represents just 0.14% of the total EU consumption.

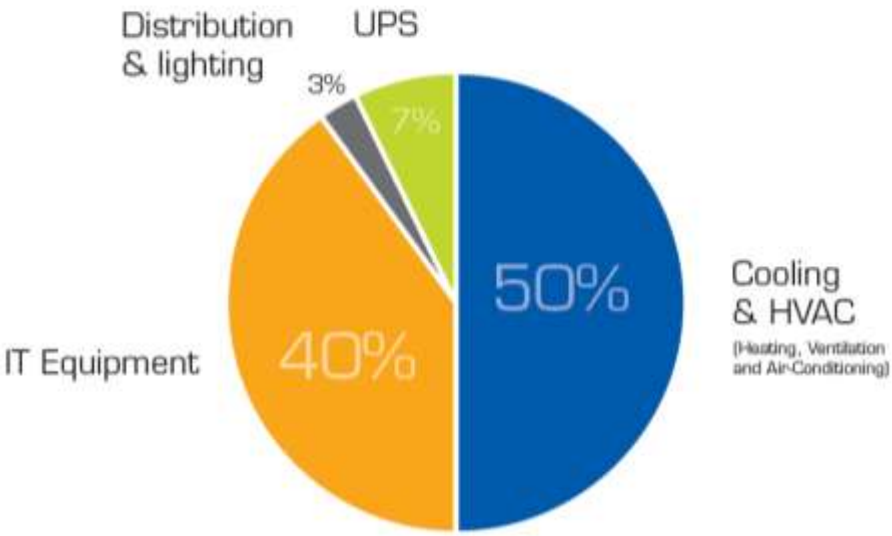


Figure 23: Energy consumption in data centres in EU[154]

In residential buildings and small business appliances, the UPS systems are used mainly to ensure the service continuity and power quality of electronic devices, representing only 0.02% of the energy consumption in such market (Figure 24), which is just 0.004% of the total EU consumption.

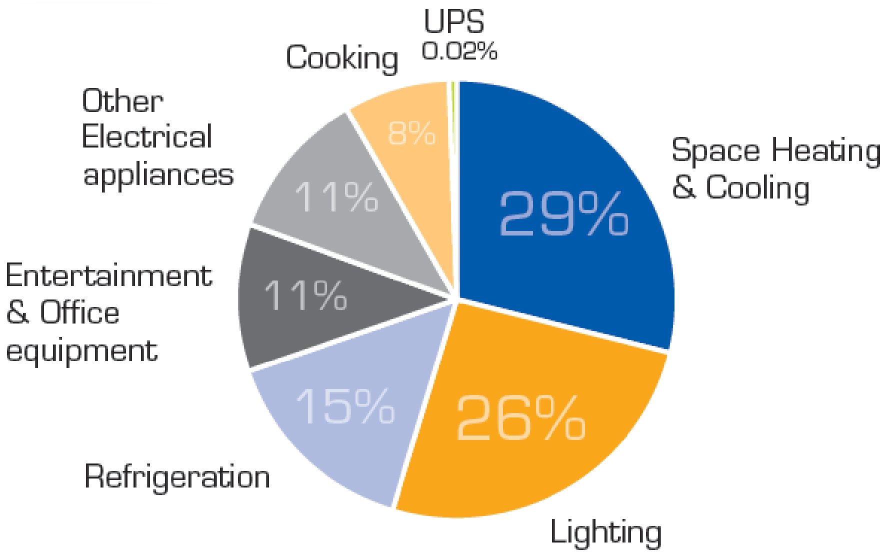


Figure 24: Energy consumption in residential and small business in EU[154]

The UPS systems can also include other equipment, such as isolation transformers or harmonic current filters added on to the UPS in the basic configuration. Those additional components are also responsible for energy losses.

The maximum losses per device are also defined in the UPS Code of Conduct 2011 from JRC[138]. Table 45 presents UPS efficiency allowances for input or output isolation transformer. Table 46 presents the UPS efficiency allowances for input harmonic current filtering (additional or embedded harmonic correcting device connected at the inlet or outlet in the normal power path).

Table 45: UPS efficiency allowances for input or output isolation transformer[138]

UPS Load (% of rated)	UPS rating (kVA)									
	0.3 to < 10		10 to < 40		40 to <200		200 to < 500		500	
	Duty	Stand -by	Duty	Stand -by	Duty	Stand -by	Duty	Stand -by	Duty	Stand -by
25	6.0%	5.5%	6.0%	5.5%	4.0%	3.5%	2.8%	2.3%	1.9%	1.4%
50	3.9%	2.7%	3.9%	2.7%	2.9%	1.7%	2.2%	1.1%	1.5%	0.7%
75	3.5%	1.8%	3.5%	1.8%	2.9%	1.2%	2.4%	0.8%	1.7%	0.5%
100	3.6%	1.4%	3.6%	1.4%	3.2%	0.9%	2.7%	0.6%	2.0%	0.4%

Table 46: UPS efficiency allowances for input harmonic current filtering[138]

UPS Load (% of rated)	UPS rating (kVA)									
	0.3 to < 10		10 to < 20		20 to <40		40 to < 200		200	
	Duty	Stand -by	Duty	Stand -by	Duty	Stand -by	Duty	Stand -by	Duty	Stand -by
25	2.5%	2.3%	2.5%	2.3%	2.3%	2.1%	2.1%	1.7%	1.9%	1.5%
50	1.6%	1.1%	1.6%	1.1%	1.5%	1.0%	1.5%	0.9%	1.4%	0.8%
75	1.4%	0.8%	1.4%	0.8%	1.3%	0.7%	1.3%	0.6%	1.2%	0.5%
100	1.4%	0.6%	1.4%	0.6%	1.3%	0.5%	1.3%	0.4%	1.2%	0.4%

4.5.2 Power supply failure and UPS Systems

Establishing the number of times UPSs are used annually and the duration of use at any one time (condition of the equipment when used) is challenging.

To provide relevant data concerning how much a UPS is used annually, use of grid failure statistics for the European power grids are helpful as the consumer/users operate their UPS in parallel to their electricity using products. As the grid structures in the EU member states vary and the grid operator's structure are different as well, the data concerning grid failures within the EU is not available for all national grids.

The statistics in some EU member states mention only power failures longer than 3 minutes. There are various problems with the existing statistics. As can be seen from Table 47, in some EU member states short time interruptions are not even covered by the definition:

"... about half of the countries make no distinction between long and short interruptions. Additionally, few countries differentiate between interruptions lasting less than one second (or similar values), known as transient interruptions, and those lasting longer than 1 second and less than 3 minutes."[155]

The German association, VIK indicates power failures mentioned in the statistics represent less than 10% of all power interruptions relevant for the customers or 90% of the relevant grid failures in Germany are not mentioned in the statistics. Concerning the short time supply interruption there was a 61% increase in the German national grid from 2006 to 2011. The increase of the number of small renewable sources could raise the number of extremely short power failures as well. The situation will be similar in all countries that shift from large central power station to small decentralised power plants.

Table 47: 5th CEER Benchmarking Report on the Quality of Electricity Supply 2011[156]

TABLE 2.1 Definitions of long, short and transient interruptions

Country	Transient interruption	Short interruption	Long interruption
AUSTRIA	Not defined	Not defined	T>3 min
BULGARIA	T<1 sec	T<3 min	T>3 min
CYPRUS	It is not distinguished for the moment	It is not distinguished for the moment	It is not distinguished for the moment
CZECH REPUBLIC	20 ms <T≤ 1 sec	1 sec <T≤3 min	T>3 min
DENMARK	No specific definition	No specific definition	All interruptions lasting 1 minute or more are monitored
ESTONIA	Not defined	Not defined	T>3 min
FINLAND	Not defined	T<3 min	T≥3 min
FRANCE	T<1 sec	1 sec ≤T≤3 min	T>3 min(1)
GERMANY	Not defined	Not defined	T>3 min
GREAT BRITAIN	Same as short interruptions	T<3 min	T≥3 min(2)
GREECE	Not defined	T≤3 min	T>3 min
HUNGARY	T≤1 sec	1sec <T≤3 min	T>3 min
IRELAND	Not defined	Not defined	T≥3 min(3)
ITALY	T≤1 sec	1 sec <T≤3 min	T>3 min
LATVIA	Not defined	T≤3 min	T>3 min
LITHUANIA	T<3 min	T<3 min	T≥3 min
LUXEMBOURG	Not defined	T≤3 min	T>3 min
THE NETHERLANDS	No separate definition	No separate definition	No distinction. An interruption has a duration of at least 5 seconds
NORWAY	Not used (short interruptions start at zero)	T ≤ 3 min	T>3 min
POLAND	Not defined	T≤3 min	T>3 min
PORTUGAL	Not defined	T ≤ 3 min	T>3 min
ROMANIA	T≤1 sec	1sec <T≤3 min	T>3 min
SLOVAK REPUBLIC	Not defined	T<3 min	T>3 min
SLOVENIA	Not yet. If classified (per NRA request) the guideline from EN 50160:2010 ("very Short Interruption") would be used	T≤3 min	T>3 min
SPAIN	No definition in our regulation	T≤3 min	T>3 min
SWEDEN	Not defined	100 msec <T≤3 min	T>3 min

(1) Until 2010 it was T≥3 min.
(2) This excludes re-interruptions to customers that have already been interrupted during the same incident.
(3) Up to and including 2010, this was defined as greater than or equal to 1 minute (T≥1 min).

[155] 5th CEER Benchmarking Report Page 28 (http://issuu.com/ceer/docs/ceer_benchmarking_report)
[156] http://www.energy-regulators.eu/portal/page/portal/EER_HOME/CEER_5thBenchmarking_Report.pdf

As Table 48 shows there are no common procedures for an identification of network users affected by power failures. This makes it difficult to estimate the number of power failures that needs to be covered by a UPS system in Europe.

Table 48: Measurement techniques for long and short interruptions

TABLE 2.5 Measurement techniques for long and short interruptions

Country	Identification of network users affected	Automatic identification	Automatic logging
AUSTRIA	No common rules.	No	No
BULGARIA	There is no automatic identification of affected customers.	No	No
CYPRUS	Yes there is a rule for estimating the customers affected. (Assumption is 1 customer for every 2 kVA).	Yes	No
CZECH REPUBLIC			No
DENMARK	No common rules.	No	No
ESTONIA	Automatic identification of customers affected for interruptions on MV level, on basis of messages from customers on LV level via GIS (geographic information system).	Yes	Yes
FINLAND	Customers are identified only by sorting them into different voltage levels.	No	No
FRANCE	On the transmission network, each customer's substation feeding is individually monitored. On both transmission and distribution systems, network system and commercial system are connected.	Yes	Yes
GERMANY	There is no standardised way of identifying the customers affected. The way of estimating differs from network operator to network operator.	No	No
GREAT BRITAIN	Ofgem collects data at a system level for each of the 14 licensed electricity distribution businesses. Ofgem also collects disaggregated data for each MV circuit so that comparisons can be made across the distribution businesses.	Yes	Yes
GREECE	For interruptions originating at MV, the number of customers affected is estimated through the interrupted MV/LV transformer installed power. For interruptions originating at LV, the number of customers affected is estimated through the rated current of the interrupted LV line fuse.	Yes	No
HUNGARY	The practice to date has been to estimate the number of customers affected. But the NRA is issuing a decision on determination of number of customers affected, which will lay down the rules for estimation from 1 January 2012.	No	No
IRELAND	This level of detail is not specified by the NRA.		
ITALY	For transmission, the sources of data/info include: the remote control system, the SCADA, the log of the remote control system, other recording systems, registrations by EHV-HV users, registrations by the distribution network operators. For distribution: the remote control system or other systems (for the MV network); various options are allowed for recording LV customers affected (the simplest refer to average number of customers, the most complex involves the single LV smart meters).	Yes	Yes
LATVIA		No	No

LUXEMBOURG	HV, MV: Details in DSOs system. LV: Currently average number per transformer.	Yes	Yes
THE NETHERLANDS	Identification of affected customers mostly occurs through well-established and documented methods of estimation, which are part of a national system for the registration of interruptions.	Yes	Yes
NORWAY	The standardised system for reporting interruption data (FASIT) uses data from the Customer Information System regarding exactly how many customers are connected to each of the distribution transformers affected by an interruption. The customers are divided into 36 different end-user groups, and two sub-groups (extended from 27 to 36+2 from 2008), and the interruptions are monitored for all the 36+2 end-user groups. (The 36+2 end-user groups are distributed on the 6 different customer categories.), TSO/DSO network areas, counties and the country as a whole.	Yes	Yes
POLAND	The customers at LV level are estimated and at the other higher levels are all identified.	No	No
PORTUGAL	The customers at a higher level than LV are all identified. The customers at LV are all identified if the fault affects all phases. If the fault affects only 1 or two phases, only the customers that claim are identified.	No	No
ROMANIA	An automatic system of calculation is in progress, until end of 2012, in order to record the interruptions for the customers of HV and MV level.		Yes
SLOVAK REPUBLIC	No common rules.	No	No
SLOVENIA	Identification is performed by the automatic binding of the number of affected customers through the entity properties in SCADA (i.e. substation, feeder properties etc.). This applies on the EHV, HV and MV levels. For LV (not yet covered) Slovenia is planning to use either the call-centres or AMI (SmartGrids) services. Exemptions: some cases have been identified where the meta data in SCADA is not complete or not up-to-date. In such cases, the operator performs manual mapping in post-processing phase (applying the data from external source).	No	Yes
SPAIN	Each customer is associated to a transformation centre or element in the distribution network. Each interruption in this element is associated with the customer.		Yes
SWEDEN	Connectivity model is used. Yearly interruption reported at single customer level.	Yes (for >90% of network users)	Yes (for >90% of network users)

Sources in the manufacturing industry suggest a voltage failure of less than 1 second could result in a production interruption of 10 hours in the paper industry[157]. In chemical factories a voltage reduction of less than 20% for 0.35 seconds could result in costs of more than 200,000 € for the interruption of the production plus costs for repair of the manufacturing units. For European UPS industry, calculations of the resilience (ability to power the load) of a UPS system as installed, it is assumed that 50 hours is the average mean time between failure (MTBF) of any UPS system that has reverted to relying on a mains power source to ensure powering of the load. This direct reliance on the mains power source can be triggered by UPS component and battery faults or UPS bypass for routine maintenance.

[157] Dr. Christoph Bier, VIK, Essen: Versorgungsqualität - Die Sicht der industriellen Stromverbraucher

4.6 Subtask 4.5 - End-of-life phase

End of Life for UPS products is not currently covered by the current categories under the WEEE Directive; however this is set to change from 2018 following the recast of the WEEE Directive (See Task 1 for further details of the WEEE Directive).

UPS are not separately listed in any of the 10 above categories, but UPS are very often used in conjunction with products in several of the current WEEE 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. This means the UPS products are often treated in the same manner as this other electrical and electronic equipment at the end of life phase.

4.6.1 Small devices - mass market devices for home and office

For small UPS, at the end of their lifetime they are dealt with other similar electronic waste. The end of life (EoL) of the small UPS boxes can arise after 1 or 2 power failures. After months of continuous charging cheap batteries they could reach their EoL within 1 or 2 discharging periods and stop working without any advance warning. A repair is impossible. Proprietary form factors of the batteries in small devices reduce the availability of specific replacement batteries. In addition, the low purchase cost of smaller UPS products means replacing batteries integrated within the product isn't generally costs effective. No potential refurbisher could guarantee for such a product as new devices of this size would be available for less than €100.

As a result of the present situation with almost all small UPSs made in China there are take back schemes organised by some brands. The treatment of the products taken back is similar to the other devices that are given to electric recycling organised by the local authorities. For the small UPS products that are sold in millions at prices below €100 there is no refurbishment or re-use possible. At the end of the devices' lifetime the batteries are taken out of the box and the electronics is recycled with other electronics. Recycling of those components is equivalent to the electronics recycling and depending on the market development for secondary material.

4.6.2 Standard devices beyond the mass market for home and office

There is a second hand market for UPS systems up to 6 KVA within the EU. This market is supplied by independent SMEs that test and replace fans, capacitors and batteries. Stakeholder feedback indicates up to 15% of used equipment is refurbished this way.

For the market segment above 6 kVA there exists a second hand market only for 2nd generation transformer-less UPS. This specific market is located in some of the eastern EU member states and in Eastern Europe outside the EU. Stakeholder feedback indicates up to 25% of the 6-12 year old UPS systems are sold second hand.

The remaining systems are not refurbished but recycled as metal scrap or plastic granulates.

4.6.3 Battery re-use or recycling at end of life

For the batteries it depends on the type of the battery. Directive 2006/66/EC requires schemes for the collecting and recycling of batteries to be established. Specialised recyclers recycle lead/acid/gel batteries by almost 100%. The price paid for secondary lead from recycling is sufficient to cover the costs of the recycling process. For Lithium based batteries the price paid for the recycled material doesn't cover the costs of the recycling. Stakeholder feedback indicates an additional cost of approximately €1/kg is required to cover the recycling processing costs. Discussions with stakeholders indicates approximately 53% of the material of lithium based batteries is recycled using existing technologies, with the remainder sent for incineration.

In some member states non-recyclable parts are disposed of in landfills in others all non-hazardous waste is incinerated.

4.7 Subtask 4.6 – Recommendation for mandates

A key qualification of UPS efficiency lies in the determination of the optimum operational configuration of the UPS for the power resilience and power quality requirements of the load. Software control of the UPS operating mode (Subtask 4.2) can allow the UPS to automatically determine the optimum operating mode to meet the load power quality

Power resilience is also qualified by the chosen UPS monitoring and remote control system allowing on-site or remote networked monitoring and control of the UPSs in an installation system.

Both remote mode control and monitoring systems are currently UPS manufacturer specific and there is little or no Industry standardisation allowing the mixed use of UPS products from different manufacturers in a system installation.

Current UPS rarely provide automatic operating mode control software for UPS below 60kVA because of the relatively high cost impact of the additional design and software development. Standardisation of software control protocols and control circuit topology could quickly lead to system on chip (SOC) hardware solutions providing a cost effective solution to the automatic mode control of UPS down to 10kVA.

Work for subtask 1.2 and informed CEMEP stakeholder input has indicated that there is no International Standardisation activity (e.g. IEC Standards working group) for the standardisation of control and monitoring software protocols for UPS.

The catalysing of such activity in Europe through the process of a CEN CENELEC harmonised standard EC mandate should be an important priority. In addition to the normative standardisation of software protocols in a new standard, informative annexes should include guidance on the optimising UPS installation systems in terms of required power resilience and ecodesign efficiency.

5 Task 5 – Definition of base cases

5.1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design working plan 2009-2011. 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 Commission's 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.

5.1.1 Task 5 - Objectives

Task 5 of a Preparatory Study involves undertaking an environmental assessment of UPS using the EcoReport Tool. The EcoReport tool developed as part of the Methodology for the EcoDesign of Energy Related Products (MEErP)[158] is used in all Ecodesign Preparatory Studies and provides a streamlined life cycle assessment of the product, together with a life cycle cost assessment. The purpose of this assessment is to provide an indication of the representative environmental impacts for a typical product across the different life cycle phases. This allows the importance of non-energy environmental impacts to be understood alongside the environmental impacts associated with in use energy consumption. The EcoReport tool includes set parameters and calculations and uses the product specific inputs described in this report to generate the environmental and cost assessment outputs.

[158] http://www.meerp.eu/ - This website provide further information about the MEErP methodology, including a copy of the EcoReport tool.

In order to undertake the assessment of UPS using EcoReport, a number of key steps are required. Firstly base cases need to be defined based on 'typical products' reflecting different UPS sizes. These were agreed with stakeholders at the second stakeholder meeting, held in May 2013.

Once the base cases have been defined (See Section 5.1.2), their characteristics are used to generate the input parameters for EcoReport. This includes a bill of materials (a list of materials and their weight fractions) for different sizes of UPS in order to assess the extraction, production, and manufacturing phases of the life cycle. Stakeholders helped inform this part of the study via their responses to the second questionnaire. Dismantling trials undertaken by the project team and a review of existing literature completed the information gathering activity. It is important to note that the information from the literature, stakeholder feedback and dismantling trials are used to provide EcoReport inputs for an average product, therefore there may be some differences between these and products actually available on the market.

In addition, the in use energy consumption has been calculated for each base case using information from existing standards, in particular the UPS Code of Conduct[159], the Energy Star specification for UPS[160], and stakeholder feedback.

This section presents the results from Task 5, outlining the approach used to select the base cases, the product specific inputs that have been used for the EcoReport analysis, and the results of the environmental assessment for the base cases. The base case life cycle costs are presented, which have been assessed, using information from the literature and stakeholder feedback. Finally the EU-27 impacts have been calculated based on the EcoReport analysis, and the stock and market data presented in Task 2.

5.1.2 Definition of Base Cases

In order to undertake the environmental impact assessment of UPS using EcoReport, typical products need to be defined. Based on the research from earlier tasks, and feedback from stakeholders, the bases cases have been selected on the basis of different UPS sizes, which align with different typologies. For example, above 10 kVA products are typically three phase as opposed to single phase hence using 10 kVA as the lower boundary for Base Case 4.The selected sizes for the base cases are also consistent with the IEC 62040 standard. There was consensus at the second stakeholder meeting held in May 2013, that the base cases summarised in Table 49 are the most appropriate:

Table 49: Summary of base cases

Base Case	UPS size	Main topology	EU-27 Stock – Million Units (2011)*	EU-27 Sales – Million Units (2011)*
1	Below 1.5 kVA	Standby	3.98	0.99
2	1.5 to 5.0 kVA	Line Interactive	3.06	0.40
3	5.1 to 10 kVA	Double Conversion (Online)	0.24	0.03
4	10.1 to 200 kVA	Double Conversion (Online)	0.14	0.01

*The stock and sales figures were calculated in Task 2.

159 JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011
160 ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.

These base cases cover the majority of sales (based on units), which are highest in the smaller UPS sizes, and the main UPS typologies. A base case has not been selected for products above 200 kVA, as these are generally bespoke and cannot be represented by a typical bill of materials. Stakeholders agreed with this rational for products above 200 kVA.

The inputs required for EcoReport in order to assess the environmental impacts and cost impacts at the product and EU-27 total level differ between the base cases. These inputs are outlined in Section 5.2, with the results of the assessments described in Sections 5.3, 5.4 and 5.5.

5.2 Subtask 5.1 – Product-specific inputs

Product specific inputs are required for each base case for the different life cycle phases in order to complete the environmental assessment using EcoReport. This section outlines the inputs for each base case, and the assumptions used to calculate them.

5.2.1 Material Extraction and Production

As part of Task 4, existing products have been assessed, and an average product bill of materials for the different sizes of UPS developed, which are used for the extraction and production inputs for EcoReport.

As discussed in the Task 4 report, the bill of material for each UPS base case consists of the following elements:

- UPS;
- Packaging; and
- Battery.

The BoM for the UPS and packaging are detailed fully in Task 4 and are summarised below:

Table 50: UPS bill of material inputs

	Base Cases - Weights in g			
EcoReport Material Codes	**Below 1.5kVA**	**1.5 to 5 kVA**	**5.1 to 10 kVA**	**10.1 to 200 kVA**
1-LDPE				80.0
2-HDPE				1333.3
8-PVC	85.0	261.6	241.8	6000.0
11-ABS	1216.0	547.7	662.5	5197.3
12-PA6		19.9	57.5	73.3
13-PC		74.3	5.5	41.0
14-PMMA				10.0
15-Epoxy	10.0	19.4	44.5	66.7
18-Talcum filler		0.7		
19-E glass fibre		13.9	17.3	3.3
20-Aramid fibre				1666.7
22-St sheet galv		5089.8		157083.3
23-St tube/profile		7.5	15106.0	
24-Cast iron	1123.0	1277.8	125.7	32000.0
25-Ferrite	91.0	303.2	955.5	18790.0
26-Stainless 18/8 coil	25.0			
27-Al sheet/extrusion	117.0	657.1	1712.0	21526.7
28-Cu winding wire	480.0	482.5		21768.3

30-Cu wire	232.0	428.3	1022.6	24650.0
31-Cu tube/sheet		4.5		19733.3
32-CuZn38 cast		103.9	183.4	2916.7
40-powder coating		20.7	12.5	1500.3
43-lcd per m^2 scrn		11.3		0.3
45-big caps & coils	15.0	259.7	933.5	17340.0
46-slots . Ext. Ports	250.0		275.0	650.0
47-Ics avg 5% Si, Au	3.0	2.4	10.3	6.7
48-IC's avg 1% Si	7.0	29.1	89.0	16.7
49-SMD/LEDs avg	39.5	237.8	561.0	383.3
50-PWB 1/2 lay 3.75kg/m^2	108.0	538.3	1302.1	1993.3
51-PWB 6 lay 4.5 kg/m^2		87.5		
53-Solder SnAg4Cu0.5	70.0	158.2	66.8	140.0
TOTAL	**3871.5**	**10637.0**	**23384.4**	**334970.7**

Table 51: Packaging bill of material inputs

	Base Cases - Weights in g			
EcoReport Material Codes	**Below 1.5 kVA**	**1.5 to 5 kVA**	**5.1 to 10 kVA**	**10.1 to 200 kVA**
1-LDPE		558	2350	
2-HDPE	36			12
4-PP		34	160	167
6-EPS	78	108		290
8-PVC				500
57-Cardboard	535	946	3520	8850
58-Office paper	77	150		
Total weight (g)	**726**	**1795**	**6030**	**9818**

For batteries, Task 4 identifies that the majority of existing products use lead acid batteries, and the typical composition of a lead acid battery was identified from the literature[161], as follows[162]:

- Lead / Lead Oxides – 60%
- Polypropylene – 10%
- Sulphuric acid – 10%
- Water – 16%
- Glass – 2%
- Antimony – 1%

The majority of the materials used to make up a typical lead acid battery are not included as standard materials in EcoReport and the size of the battery for the base cases will vary, depending on the capacity of the UPS. Therefore the steps described below have been undertaken to calculate the required product specific inputs for batteries.

The latest version of EcoReport, developed in 2011, enables the user to enter impact assessment data for other materials. For the lead acid battery composition the following

[161] A Review of battery Life-Cycle Analysis: State of Knowledge and Critical Needs, Argonne National Laboratory, 2010
[162] It is noted that the percentage total is 99%, and is assumed this is due to rounding in the source document, the additional 1% is not attributed to any materials when entering the weight of the battery materials in EcoReport.

materials have been added to EcoReport: primary lead, secondary lead, sulphuric acid, water and antimony. Data from SimaPro has been used to calculate the impacts across the different environmental indicators for these materials (See Appendix 5).

The weight of the battery varies between the different sizes of UPS. Feedback from stakeholders and information from dismantling trials has allowed an average battery weight of 6.23kg per kW output to be calculated.

Using this and the average kW output for each base case (see Section 5.2.3 below for details of how this has been calculated), an average battery weight for each base case has been calculated. This information is summarised in Table 52.

Table 52: Battery weight for each base case

Base Case	Battery Weight per kW (g)	kW rating (See Section 5.2.3)	Single battery weight for base case (g)
Below 1.5 kVA	6,229	0.54	3,364
1.5 to 5.0 kVA		2.87	17,878
5.1 to 10 kVA		6.25	38,932
10.1 to 200 kVA		94.50	588,650

The above composition for the lead acid battery is then applied to the calculated battery weight to generate the battery bill of materials for each base case. Battery replacement has been identified as a key maintenance procedure during the lifetime of the UPS. The following assumptions have therefore been made:

- Below 1.5kVA – No battery replacement; typically these products do not have their battery replaced during their lifetime
- 1.5 to 5 kVA, 5.1 to 10 kVA and 10.1 to 200 kVA – Based on the lifetime of these UPSs and batteries, it is assumed that the batteries are replaced once during the lifetime for these three base cases

Lead/lead oxides represent 60% of the battery weight. The commercial value of lead means there is a high level of lead recycling within the battery industry, and therefore not all of the lead used in the battery will be primary lead, a proportion will be secondary/recycled lead. For the purposes of our bases cases, it is assumed that the lead is split 40:60 between primary and secondary (recycled) lead[163].

Table 53 summarises the EcoReport inputs for the battery component of the different base cases, taking into account the assumptions outlined above.

[163] http://batterycouncil.org/?page=Battery_Recycling - The typical new lead-acid battery contains 60 to 80% recycled lead and plastic

Table 53: Battery bill of materials

			Battery weight input for each base case (g)			
	EcoReport material Code	**Composition (%)**	**Below 1.5 kVA (1 battery)**	**1.5 to 5 kVA (2 batteries)**	**5.1 to 10 kVA (2 batteries)**	**10.1 to 200 kVA (2 batteries)**
Lead/lead oxides - total	-	0.60	2 018	21 453	46 718	706 380
Primary lead (40% of lead content)	Extra		807	8 581	18 687	282 552
Secondary lead (60% of lead content)	Extra		1 211	12 872	28 031	423 828
Polypropylene	4 - PP	0.10	336	3 576	7 786	117 730
Sulphuric acid	Extra	0.10	336	3 576	7 786	117 730
Water	Extra	0.16	538	5 721	12 458	188 368
Glass	55 – Glass for lamps (see note)	0.02	67	715	1 557	23 546
Antimony	Extra	0.01	34	358	779	11 773
Total	-	0.99	3 330	35 397	77 085	1 165 527

Note: The Product Cases report[164] written by the developers of EcoReport indicates "55 – Glass for lamps" has been used to represent glass in other product groups, such as shelves and lighting equipment, and is considered an appropriate proxy in this instance, given the relatively small amount of glass used.

164 http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm

5.2.2 Manufacturing and Distribution

The EcoReport tool calculates manufacturing impacts mainly on the basis of the bill of material inputs, outlined in Section 5.2.1, with limited user defined parameters. The one parameter that can be altered is the percentage of scrap sheet metal produced from the manufacturing process.

This parameter is set at a default of 25%. Limited information regarding scrap production during the UPS manufacturing process has been identified; however, the EcoReport guidance indicates the following:

'As a default, if no specific values are used, one can assume 25-30% cutting losses for average deep-drawing, cutting and stamping. For folded sheet in e.g. fridge housings, losses are much less (default 10%)'

It is therefore proposed to use a value of 10%, as the casing shapes cut for UPS are relatively simple, and should therefore minimise the losses/scrap production.

For the distribution phase, EcoReport requires yes/no answers to three key questions regarding the product type, installation and volume of the packaged product. Table 54 summarises the inputs for each of the bases cases for the distribution phase. The volume of the packaged product is based on feedback from stakeholders and the packaged product volume for the products dismantled by the project team.

Table 54: Distribution Inputs

	Base Case / Input Response			
Distribution Parameter	**Below 1.5 kVA**	**1.5 to 5 kVA**	**5.1 to 10 kVA**	**10.1 to 200 kVA**
Is it an ICT or consumer electronic product less than 15 kg? Yes or No	Yes – product weight less than 15 kg and sold to consumers and businesses	No – product weight more than 15 kg	No – product weight more than 15 kg	No – product weight more than 15 kg
Is it an installed appliance? Yes or No	No – assumed these are mostly plug and play, with no installation required	Yes – assumed some level of installation is required.	Yes – assumed some level of installation is required.	Yes – assumed some level of installation is required.
Volume of packaged final product (m^3)	0.02	0.02	0.04	1.5

5.2.3 Use Phase

The key EcoReport parameter in the use phase is energy consumption. In order to calculate the energy consumption for the bases cases, a number of steps, including data requirements and assumptions have been identified. These are summarised below.

5.2.3.1 Data Requirements:

Table 55 summarises the key data requirements for the in use energy calculations.

Table 55: Summary of data requirements for in use energy calculations

Data Requirement	Abbreviation	Units	Note / Assumption
Nominal active power	P	kW	Average data collected from datasheets
Tested load levels	l	%	25, 50, 75, 100%
Conversion efficiency at each load level	Ef_l	%	Minimum levels of conversion efficiency defined in the UPS Code of Conduct from JRC, using version 1[165] for products above 10 kVA and version 2[166] for products below 10 kVA. For products above 10 kVA, the transformer losses (Trans.L) from version 2 of the code of conduct are taken into consideration[167].
Proportion of time spent at each load level	t_l	%	Loading assumptions extracted from the version 1 of the Energy Star product specification for UPSs[168].

5.2.3.2 Calculation Steps:

Step 1

Power with each load level (P_l in kW)

$$P_l = P \times l$$

Step 2[169]

Yearly energy input with each load level (Ei_l in kWh)

$$Ei_l = P_l \times t_l \times 8760$$

Step 3

Yearly energy input (Ei in kWh)

$$Ei = \sum Ei_l$$

This is the input of energy (E_i), but such energy is mainly transferred to the load (E_o) and therefore should be considered as a consumption of the load, since such energy is consumed with or without the use of UPS (Figure 25). The energy consumed by the UPS is the difference between the input of energy (E_i) and the output of energy (E_o), which is the energy spent due to the UPS losses. This is the approach that was also used for the assessment of energy consumption with transformers[170].

[165] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, 2006
[166] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011
[167] Transformer losses are taken into account for larger UPS, as these generally have an internal transformer. The transformer losses in Version 1 of the code of conduct appear to be incorrect; therefore those from Version 2 have been used. The transformer losses from Version 2 of the code of conduct are consistent at different load levels as those identified in the Impact Assessment for ENTR Lot 2 Power, Distribution and Small Transformers i.e. the losses decrease from 0-40% load and then increase from 40-100% load.
[168] ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.
[169] 8760" is the number of annual operating hours
[170] ISR-UC, Ricardo-AEA, PE, RPA, Implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign Requirements for Power, Distribution and Small Transformers, 2013.

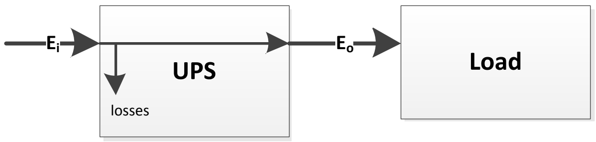


Figure 25: Energy flow in a UPS system

Step 4

Yearly energy consumption with each load level (Ec_l), in kWh

$$Ec_l = Ei_l \times (1 - Ef_l)$$

Step 5

Yearly energy consumption (Ec), in kWh

$$Ec = \sum Ec_l$$

The detailed calculations for each base case using the above equations are presented in Appendix 6, with the key EcoReport inputs for each base case summarised in Table 56.

Table 56: In use phase energy consumption inputs

Base Case	Average kW rating	UPS in use phase energy consumption kWh
Below 1.5 kVA	0.54	377.70
1.5 to 5 kVA	2.87	1 929.40
5.1 to 10 kVA	6.25	3 120.75
10.1 to 200 kVA	94.50	42 839.69

The in use energy consumption is classified as a direct energy related product impact, and therefore no use phase inputs have been included in EcoReport for indirect energy related product impacts.

In addition to the in use energy consumption, other parameters required for the in use phase include lifetime and the number of kilometres over the product life for maintenance, repairs and service. The lifetimes used for this analysis (Table 57) have been discussed with stakeholders and are considered to be appropriate for the different base cases. The lifetimes are consistent with those used in Task 2 to calculate the stock and sales data.

Table 57: Base Case Lifetimes for EcoReport

Base Case	Lifetime (Years)
Below 1 kVA	4
1.1 to 5 kVA	8
5.1 to 20 kVA	10
20.1 to 200 kVA	12

Limited information is available regarding the distance travelled for maintenance, service and repair; this has therefore been set to zero across all base cases. Assuming maintenance will be undertaken by local contractors, sensitivity analysis shows that adding 50km to this value does not affect the overall results.

5.2.4 End of Life Phase

For the End of Life phase, EcoReport requires inputs for the following parameters:

- The fraction of materials, as % of total mass in products, still to reach their end of life.
- The routes for different materials at the end of life of the product.
- End of life recyclability

For the first parameter, it is assumed the fraction of materials is the same as the base case products, as no significant changes in the materials used for UPS have been identified in the last 4-12 years.

For the second parameter, research has been undertaken to identify the different routes for the key material groups at the end of life stage. Table 58 summarises the values used in the EcoReport modelling. The values for metals are set as a default, and cannot be altered. For other materials, in particular plastics, electronics, miscellaneous (mainly cardboard/paper for packaging) and extra materials (i.e. those added in relation to the lead acid battery), the values have been amended to reflect practices relating to UPS as far as they are known.

Specific information regarding plastics from UPSs at the end of life phase has not been identified, but information on plastics in general has been identified[171]. This indicates that approximately 59% of plastics were recovered, with approximately 25% recycled and 34% sent for energy recovery. The remaining amount (approximately 40%) is disposed of, assumed to landfill. Allowing for a small reuse percentage, these figures from the plastic industry have been used to inform the EcoReport inputs for the end of life phase for plastic from UPS.

Limited information regarding the percentage of electronics recovered at the end of life has been identified. Therefore, it has been assumed 50% are recycled and the remaining 49% (allowing for a small percentage of reuse) are incinerated without energy recovery. These values were presented during the second stakeholder meeting, during which there was no objection to their use.

Miscellaneous materials consist mainly of cardboard and paper used for the packaging of the UPS. The default values from EcoReport have been used.

Extra materials relates to the extra materials added to EcoReport in order to enable the lead acid battery component to be included. Lead acid batteries experience a high level of recycling[172], due to the high value of lead. We assume that 95% of the extra materials are recycled, and the remaining 4% (after allowing for a small percentage of reuse, which EcoReport assumes is the same across all material categories – see Table 58) of extra materials are incinerated without energy recovery, following feedback from stakeholders.

For the base cases, the EoL recyclability parameter is set to average, in line with the EcoReport guidance.

[171] http://www.plasticseurope.org/Document/plastics-the-facts-2012.aspx?Page=DOCUMENT&FolID=2
[172] http://batterycouncil.org/?page=Battery_Recycling

Table 58: End of life EcoReport inputs

Per fraction (post-consumer)	1	2	3	4	5	6	7a	7b	7c	8	9
	Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc. , excluding refrigant & Hg	refrigerant	Hg (mercury), in mg/unit	Extra	Auxiliaries
EoL mass fraction to re-use, in %	1%										5%
EoL mass fraction to (materials) recycling, in %	25%		94%			50%	64%	30%	39%	95%	30%
EoL mass fraction to (heat) recovery, in %	34%		0%			0%	1%	0%	0%	0%	10%
EoL mass fraction to non-recov. incineration, in %	0%		0%			49%	5%	5%	5%	4%	10%
EoL mass fraction to landfill/missing/fugitive, in %	40%		5%			0%	29%	64%	55%	0%	45%
TOTAL	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
EoL recyclability	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**

5.3 Subtask 5.2 – Base Case Environmental Impact Assessment

5.3.1 Introduction

The EcoReport tool has been used to generate an environmental impact assessment for the four base cases:

- Base Case 1: Below 1.5 kVA
- Base Case 2: 1.5 to 5 kVA
- Base Case 3: 5.1 to 10 kVA
- Base Case 4: 10.1 to 200 kVA

This calculates the impacts for the environmental indicators shown in Table 59 across the different life cycle phases; production, distribution, use and end of life. It is important to note that EcoReport uses different units to show the impact for the different individual impact categories.

Table 59: Environmental Indicators covered by EcoReport

Parameter		Unit
Other Resources & Waste	Total Energy (GER)	MJ
	of which, electricity (in primary MJ)	MJ
	Water (process)	ltr
	Water (cooling)	ltr
	Waste, non-haz./ landfill	g
	Waste, hazardous/ incinerated	g
Emissions (Air)	Greenhouse Gases in GWP100	kg CO_2 eq.
	Acidification, emissions	g SO_2 eq.
	Volatile Organic Compounds (VOC)	g
	Persistent Organic Pollutants (POP)	ng i-Teq
	Heavy Metals	mg Ni eq.
	PAHs	mg Ni eq.
	Particulate Matter (PM, dust)	g
Emissions (Water)	Heavy Metals	mg Hg/20
	Eutrophication	g PO_4

Section 5.3.2 presents the outputs from the EcoReport modelling for each of the base cases, together with a discussion of the results, and the implications for the preparatory study going forward. This includes identification of the key environmental impacts, which life cycle phase they occur in and which elements of the UPS are driving the main impacts.

The results from the EcoReport analysis at this stage enable the identification at which phase of the product life cycle environmental impacts occur, at which phase are they the highest and whether these are consistent for all base cases or not.

The identification of the key impacts is important, as it will inform the key areas on which to focus when considering the improvement potential and possible policy options in Tasks 7 and 8 of the project.

In order to address points raised by stakeholders, sensitivity analysis has been undertaken with regards the number of battery replacements and replacement of spare parts. The results of this are presented in Section 5.3.3.

5.3.2 EcoReport Outputs and Discussion of Results

Using the product specific inputs described in Section 5.2, EcoReport has been used to generate an environmental life cycle assessment for each of the four base cases. The outputs from EcoReport can be presented in different ways to help their interpretation and understanding whether results are consistent for the different base cases. This includes:

- Absolute results
- Standardisation of results using common parameters e.g. kW and lifetime
- Relative (percentage) importance of impacts for the different life cycle phases

A high level snapshot is provided in Figure 26, which shows the absolute results across the lifetime of the different base cases for each of the environmental indicators. This clearly shows that Base Case 4 has the highest impact across all categories. This is to be expected, as this base case has a significantly higher product weight, longer lifetime and capacity (energy use) compared to the other three base cases.

Figure 26: Results for each base case for the environmental impact indicators (totals across lifetime)

In order to make the interpretation of the results easier, they can be normalised on the basis of common parameters. The purchase of a particular UPS is driven by the size of the load that is to be protected and the lifetime of the products varies, therefore the results have been normalised on a kW rating and lifetime basis. The different base cases should not be seen as alternatives to one another, as they represent different UPS size groups. For example Base Case 1 would not be suitable for a very high load, for example represented by Base Case 4.

Figure 27 shows the normalised results for each of the environmental indicators. Broadly this shows that the impacts are much more even across the different base cases, with impacts reducing as the size and lifetime of the products increases. The key drivers for the various impacts are discussed in more detail below, but are due to factors such as product weight, the bill of materials and assumptions regarding aspects such as replacement of batteries.

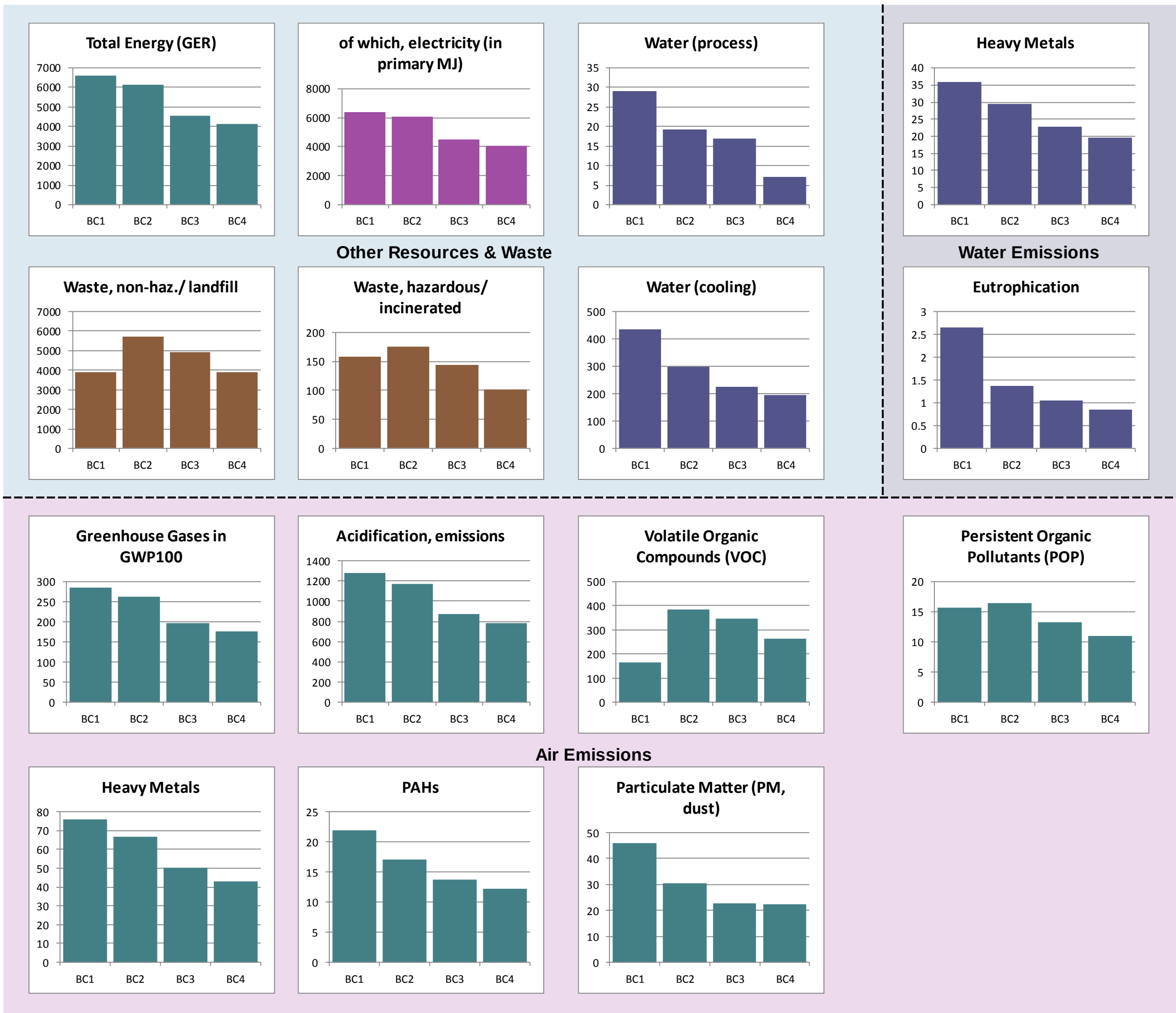


Figure 27: Results for each base case across the different environmental impact indicators (normalised by lifetime and kW)

While it is useful to note overall trends, it is important to understand the key drivers of the impacts. In order to do this, the relative importance of the different life cycle phases, production, distribution, use and end of life need to be assessed.

Figure 28 shows a diagram for each base case indicating the life cycle phases that are important for each environmental indicator, with further details provided in Table 60. These indicate that the majority of the environmental indicators are driven by the in use phase energy consumption. The EcoReport outputs (absolute results) on which the diagrams in Figure 28 and Table 60 are based are provided in Appendix 7.

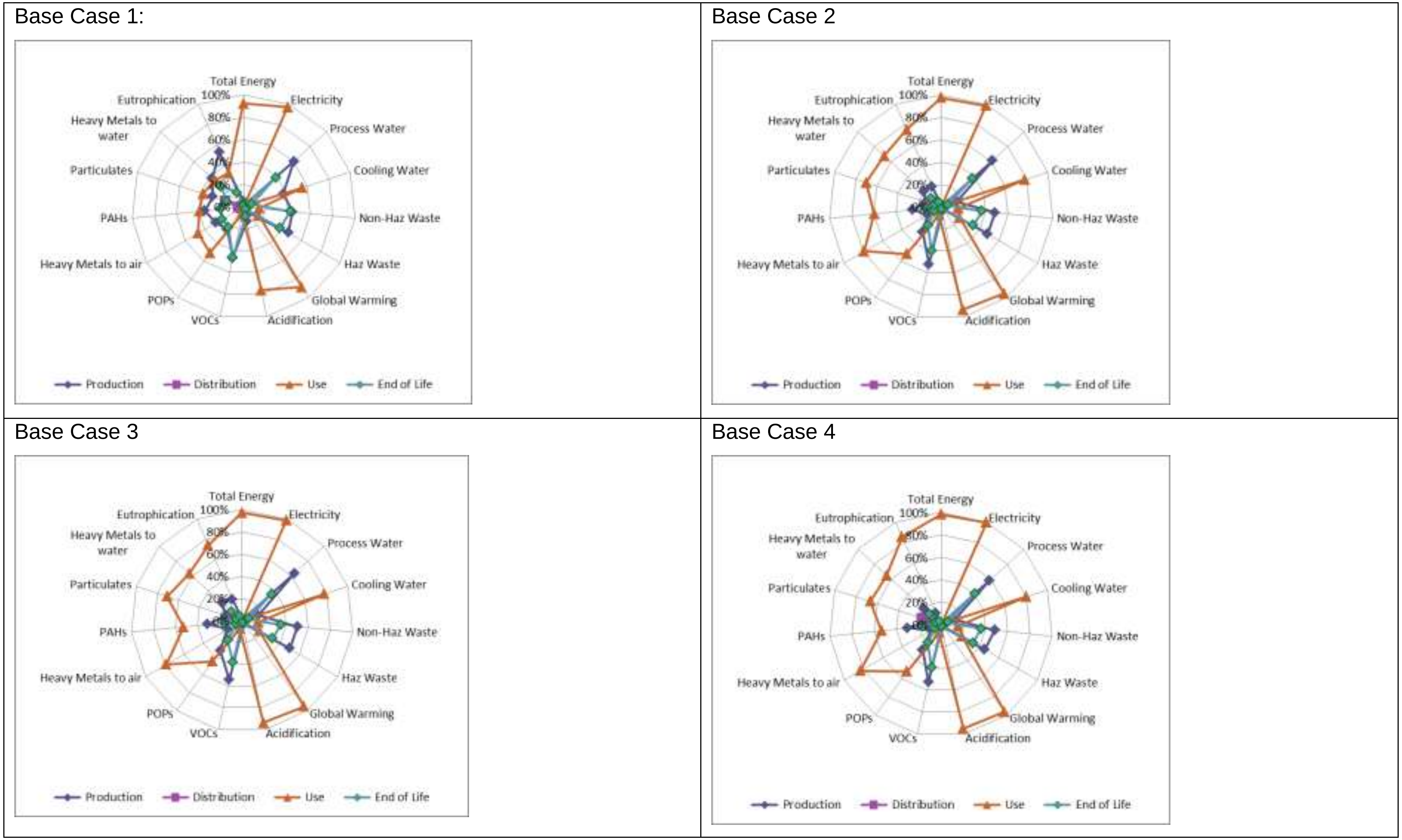


Figure 28: Radar plot showing the relative importance of the different life cycle phases for the environmental indicators

Table 60: Impacts / Benefits for each parameter across the different life cycle phases for BC1-4

		Base Case 1 Below 1.5 kVA				Base Case 2 1.5 to 5 kVA				Base Case 3 5.1 to 10 kVA				Base Case 4 10.1 to 200 kVA			
		Production	Distribution	Use	End of Life	Production	Distribution	Use	End of Life	Production	Distribution	Use	End of Life	Production	Distribution	Use	End of Life
Other Resources & Waste	**Units**																
Total Energy (GER)	MJ	5%	1%	92%	2%	2%	0%	98%	1%	2%	0%	97%	1%	1%	0%	98%	0%
of which, electricity (in primary MJ)	MJ	2%	0%	97%	1%	1%	0%	99%	0%	1%	0%	99%	0%	0%	0%	100 %	0%
Water (process)	ltr	61%	0%	1%	39%	62%	0%	1%	38%	64%	0%	1%	36%	59%	0%	1%	41%
Water (cooling)	ltr	37%	0%	55%	8%	15%	0%	79%	6%	16%	0%	78%	6%	13%	0%	80%	7%
Waste, non-haz./ landfill	g	44%	0%	14%	42%	48%	0%	15%	37%	50%	0%	14%	35%	48%	0%	15%	36%
Waste, hazardous/ incinerated	g	46%	0%	16%	38%	48%	0%	19%	33%	50%	0%	18%	32%	45%	0%	22%	33%
Emissions (Air)																	
Greenhouse Gases in GWP100	kg CO_2 eq.	6%	2%	89%	3%	3%	0%	96%	1%	3%	0%	95%	1%	2%	0%	97%	1%
Acidification, emissions	g SO_2 eq.	13%	1%	76%	9%	4%	0%	94%	2%	4%	0%	94%	2%	3%	0%	95%	2%
Volatile Organic Compounds (VOC)	g	47%	0%	7%	46%	52%	0%	7%	40%	54%	0%	7%	38%	53%	0%	8%	40%
Persistent Organic Pollutants (POP)	ng i-Teq	25%	1%	51%	23%	28%	0%	52%	20%	33%	0%	45%	22%	28%	0%	52%	20%
Heavy Metals	mg Ni eq.	28%	2%	47%	22%	14%	0%	79%	7%	15%	0%	79%	6%	10%	0%	83%	7%
PAHs	mg Ni eq.	35%	5%	40%	21%	26%	1%	60%	14%	31%	0%	53%	16%	30%	0%	53%	16%
Particulate Matter (PM, dust)	g	29%	17%	38%	16%	14%	10%	70%	6%	15%	9%	71%	5%	11%	18%	66%	5%
Emissions (Water)																	
Heavy Metals	mg Hg/20	38%	0%	35%	27%	20%	0%	68%	12%	24%	0%	64%	13%	21%	0%	65%	14%
Eutrophication	g PO_4	53%	0%	33%	14%	20%	0%	75%	5%	21%	0%	74%	4%	11%	0%	86%	3%

Note: *The sign of contribution (impact or benefit) is ignored in the colours and percentages, which just reflect relative magnitude. For production, distribution, and use phases the contributions are impacts, for end of life phase the contributions are benefits.*

Overview of the environmental impacts' of the base cases

It is clear from Figure 28 and Table 60 that the life cycle phases driving the environmental impacts for Base Cases 2, 3 and 4 are very similar, with the radar plots for these three base cases showing similar profiles.

Base Case 1 has a different profile, with the main difference being the level to which the use phase dominates particular environmental impact indicators and dominance of the production phase for two of the environmental indicators, which are dominated by the use phase for the other three base cases.

The outputs from the EcoReport analysis are discussed in more detail below.

Discussion of results

For Base Cases 2, 3 and 4, the in use phase, driven by in use energy consumption dominates the impacts for eleven of the fifteen environmental indicators:

- **Resources and Waste**
    - Total Energy
    - Electricity
    - Water (Cooling)
- **Emissions to Air**
    - Greenhouse gases (Global warming potential)
    - Acidification
    - Persistent Organic Pollutants (POPs)
    - Heavy metals
    - PAHs
    - Particulate Matter (PM)
- **Emission to Water**
    - Heavy Metals
    - Eutrophication

For all these indicators the use phase contributes between 45 to 100% of the impact depending on the base case and parameter. Clearly this indicates the use phase, on account of in use energy consumption, is a key factor in driving the majority of the impacts of UPS.

For Base Cases 2, 3 and 4 the impacts for the remaining four indicators are driven by the production phase:

- **Resources and Waste**
    - Water (process)
    - Waste non-haz/landfill
    - Waste, hazardous/incinerated
- **Emissions to Air**
    - Volatile Organic Compounds (VOCs)

The production phase impacts are driven by the materials used in the production and manufacture of the UPS. The impacts for these four indicators are the result of using different materials, details of which are summarised below.

Water (Process)

The production impacts for Water (Process) are driven by the following:

- Base Case 1: Approximately 46% electronic components in the UPS and 36% from battery materials (lead, sulphuric acid and antimony).
- Base Case 2: Approximately 34% electronic components in the UPS and 59% from battery materials (lead, sulphuric acid and antimony).
- Base Case 3: Approximately 34% electronic components in the UPS and 59% from battery materials (lead, sulphuric acid and antimony).

- Base Case 4: Approximately 84% from battery materials (lead, sulphuric acid and antimony).

There is a credit at the end of life phase associated with recycling against the Water (Process) indicator, which means the net impact is relatively small, for example when compared to Water (Cooling), which is mainly a result of in use phase energy consumption.

Waste non-haz/landfill

The production impacts for Waste non/haz/landfill are driven by the following:

- Base Case1: 73% Antimony and 21% primary lead
- Base Case 2: 74% Antimony and 21% primary lead
- Base Case 3: 73% Antimony and 20% primary lead
- Base Case 4: 74% Antimony and 21% primary lead

As with the Water (process) indicator, there is a credit at end of life phase in relation to the waste non-haz/landfill indicator, which reduces the magnitude of the net environmental impact over the whole life cycle.

Waste hazardous/incinerated

The production impacts for Waste hazardous/incinerated are driven by the following:

- Base Case 1: 30% electronics and 64% related to primary/secondary lead in the batteries
- Base Case 2: 19% electronics and 77% related to primary/secondary lead in the batteries
- Base Case 3: 18% electronics and 78% related to primary/secondary lead in the batteries
- Base Case 4: 94% related to primary/secondary lead in batteries

As with the Water (process) and waste non-haz/landfill indicators, there is a credit at end of life phase in relation to the waste hazardous/incinerated indicator, which reduces the magnitude of the net environmental impact over the whole life cycle.

Volatile Organic Compounds (VOCs)

The production impacts for VOCs are driven by the following:

- Base Case 1: 71% primary/secondary lead and 28% antimony
- Base Case 2: 71% primary/secondary lead and 28% antimony
- Base Case 3: 71% primary/secondary lead and 28% antimony
- Base Case 4: 71% primary/secondary lead and 28% antimony

As identified above, the VOC levels for UPS are associated with the primary/secondary lead and antimony used in the lead acid batteries. In the 2010 study 'A Review of Battery Life-Cycle Analysis: State of Knowledge and Critical Needs' average VOC emissions associated with the production phase were identified as 0.7 g/kg of lead acid battery (with a minimum and maximum of 0.11 and 2.2 g/kg of battery). Modelling 1 kg of lead acid battery using the impact factors from SimaPro for the materials added to EcoReport provides a similar result of 0.65g/kg of lead acid battery for the production phase. As with the Water (process) and the two waste indicators, there is a credit at end of life phase in relation to the waste hazardous/incinerated indicator, which reduces the magnitude of the net environmental impact over the whole life cycle to 0.17g/kg of lead acid battery.

Base Case 1 has a different profile to Base Cases 2, 3 and 4. While the use phase, as a result of in use energy consumption, contributes the highest to the following environmental indicators, the dominance of the use phase is not a significant as the other three base cases.

- **Resources and Waste**
    - Total Energy
    - Electricity

  - Water (Cooling)
- **Emissions to Air**
  - Greenhouse gases (Global warming potential)
  - Acidification
  - Persistent Organic Pollutants (POPs)
  - Heavy metals
  - PAHs
  - Particulate Matter (PM)

A number of reasons have been identified for this. Firstly, the product weight, output and lifetime for Base Case 1 means that weight of materials per kWh output over the lifetime of the product is higher for Base Case 1 than for Base Cases 2, 3 and 4. For Base Case 1 there is approximately 5g of material per kWh of output compared to approximately 3g for Base Cases 2, 3 and 4. This higher weight to kWh output means that proportionally the production impacts are greater when compared to use phase energy consumption.

To demonstrate this further, increasing the lifetime of Base Case 1 to 7 years and therefore reducing the material weight per kWh output to approximately 3g, results in the radar plot shown in Figure 29, which is increasingly similar to those shown in Figure 28 for Base Cases 2, 3 and 4.

A further factor to consider is the materials used in the manufacture of Base Case 1. There is a higher proportion of plastic compared to metals in Base Case 1 compared to Base Cases 2, 3 and 4. This will influence the balance between the various impact indicators.

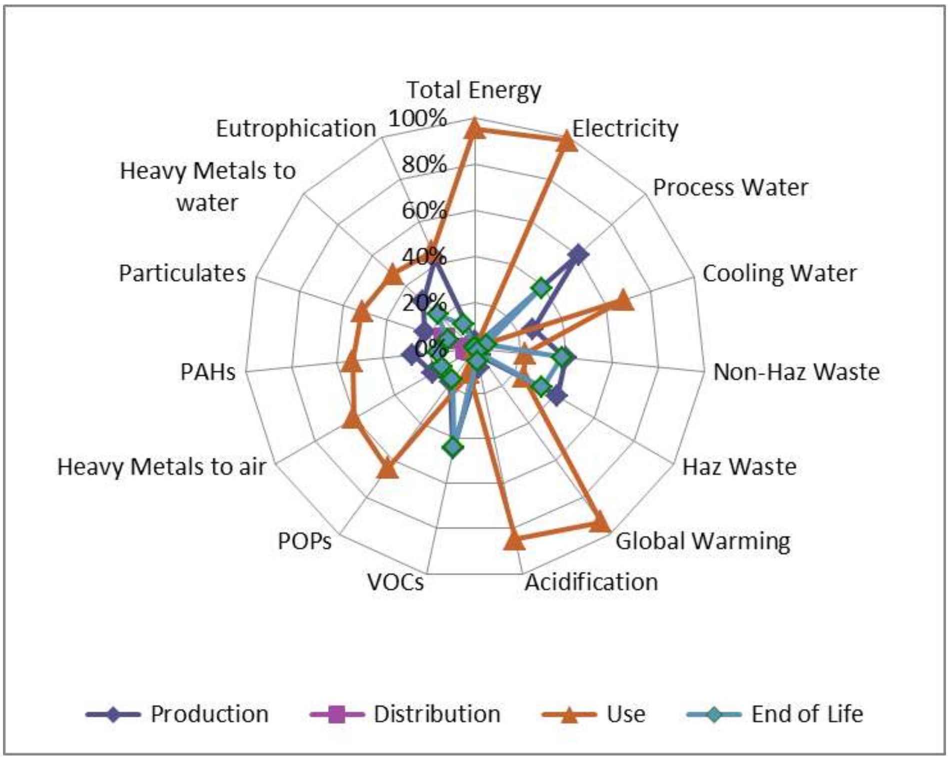


Figure 29: Radar plot for Base Case 1 with a 7 year lifetime

Impact indicators that are dominated by the use phase for Base Cases 2, 3 and 4, but are dominated by the production phase for Base Case 1 are:

- **Emission to Water**
  - Heavy Metals
  - Eutrophication

For Base Case 1, heavy metal emissions to water are driven by copper wire and electronic components, the relatively low lifetime and energy consumption mean there is a more equal balance between the production and in use phases. In addition, the absolute impacts per unit are relatively small compared to the other base cases. As Figure 29 above shows, if lifetime increases, then in use phase would be the main cause of the impacts for Heavy metal emissions to water.

For Base Case 1, eutrophication impacts are mainly as a result of electronic components and ABS plastic. Changing the ratio by increasing lifetime (Figure 29), shows the use phase proportion of eutrophication increases, again indicating it is the balance between material and energy use that affects the importance of different life cycle phases.

5.3.3 Sensitivity Analysis – Materials

Stakeholder feedback suggests that the replacement of spare parts during the lifetime of a UPS could affect the materials (non-energy) driven impacts. Two areas in particular have been highlighted, reduced battery lifetimes and the replacement of other spare parts. In order to determine whether these are worth further consideration in Task 7 as potential improvement options, an initial sensitivity analysis has been undertaken.

5.3.3.1 Battery lifetimes

Stakeholder feedback indicates that batteries are typically replaced once during the lifetime of the UPS for Base Cases 2, 3 and 4. The batteries make up a significant part of the overall product weight and therefore there is the potential to reduce impacts associated with reduced battery use. One means of reducing the impact of materials from battery use is to extend the lifetime of the batteries. Criteria in relation to this is included in other standards, for example the Blue Angel ecolabel criteria[173], published in February 2013.

Sensitivity analysis has been undertaken to assess the magnitude of potential impact reductions, should battery lifetime be extended. This analysis assumes that there is no battery replacement for Base Cases 2, 3 and 4 and that the original battery will last for the lifetime of the product.

The results indicate no significant changes to the importance of the different life cycle phases in relation to the environmental indicators calculated for the original base cases (Table 60). Full details of the results are provided in Appendix 8. The only indicator for which the dominant life cycle phase changes as a result of no battery change is waste non/haz/landfill and waste hazardous/incinerated for Base Case 4, which are now dominated by the use phase instead of the production phase, although the split is very even.

The four indicators whose impacts are driven by the battery materials are affected the most by eliminating the need to change the battery of the UPS during its lifetime, as would be expected:

- Water (process)
- Waste non-hazardous/landfill
- Waste hazardous/incinerated
- Volatile Organic Compounds (VOCs)

Table 61 shows the difference between the base case and sensitivity analysis scenarios for these indicators.

[173] http://www.blauer-engel.de/en/products_brands/search_products/produkttyp.php?id=718

Table 61: Reduction between base cases and sensitivity analysis scenario for no battery replacement for selected indicators

Indicator	Base Case 2		Base Case 3		Base Case 4	
	Absolute Reduction	Percentage Change	Absolute Reduction	Percentage Change	Absolute Reduction	Percentage Change
Water (process) (ltr)	91	21	242	23	3 144	40
Waste non-haz/landfill (g)	27 435	21	73 904	24	947 242	22
Waste hazardous/incinerated (g)	564	14	1 516	17	19 438	17
VOCs (mg)	2 825	32	7 714	36	98 718	33

This analysis indicates that there is some potential to reduce the environmental impacts of these indicators by eliminating the need to replace batteries during the lifetime of the UPS, at the product level.

5.3.3.2 Replacement of other spare parts

In addition to replacement batteries, fans and capacitors may need to be replaced during the lifetime of an UPS. Stakeholder feedback indicates that in general parts are not replaced in the smaller sized products (Base Cases 1 and 2). However for Base Cases 3 or 4 repair is more likely, especially for Base Case 4, which generally have a service contract including cover for replacement parts.

Feedback from stakeholders on the weight of materials for the largest UPS (Base Case 4) has allowed the following percentages for the amount of material replaced to be calculated:

- 10-ABS – 48%
- 24-Ferrite – 2.7%
- 28-Winding wire – 2.0%
- 44-big caps and coils – 34.6%

For Base Case 4 it is assumed fans and capacitors are replaced twice during an UPS's lifetime, and once for Base Case 3. These assumptions have been applied to Base Cases 3 and 4 and result in the additional extra material weight for the bill of materials over the product lifetime, summarised in Table 62.

Table 62: Additional material inputs and assumptions for spare parts

Base Case	Component	EcoReport Material Code	Additional material weight for EcoReport input for single replacement (grams)	Additional material weight for EcoReport input for two replacements (grams)	Assumptions
BC3	Fans	10-ABS	318	N/A	Assume fans are replaced once during lifetime
		24-Ferrite	26	N/A	
		28-Winding	10	N/A	

		wire			
	Capacitors	44-big caps and coils	323	N/A	Assume capacitors are replaced once during lifetime
BC4	Fans	10-ABS	2 495	4 989	Assume fans are replaced twice during lifetime
		24-Ferrite	507	1 015	
		28-Winding wire	435	8 71	
	Capacitors	44-big caps and coils	6 000	11 999	Assume capacitors are replaced twice during lifetime

Energy consumption in the use phase remains unchanged, as per the original base cases, with only additional materials related to the spare parts added. The results indicate no significant changes to the importance of the different life cycle phases in relation to the environmental indicators calculated for the original base cases (Table 60). Full details are in Appendix 8, but there are only between 1-6% changes in terms of the relative importance of the different life cycle for PAHs, particulate matter, heavy metals emissions to water and eutrophication for Base Case 3 and water (cooling), heavy metal emissions to air, PAHs, particulate matter, heavy metals emissions to water and eutrophication for Base Case 4, with the rest remaining the same.

Therefore the inclusion of spare parts that might reasonably be expected to be replaced during the product's lifetime does not alter the overall conclusions one would draw from the EcoReport analysis.

5.3.4 Observations / Conclusions

The environmental impact assessment undertaken using EcoReport for each of the four base cases indicates that the use phase, driven by energy consumption, is the most significant life cycle phase for the majority of the impact indicators, including:

- **Resources and Waste**
  - Total Energy
  - Electricity
  - Water (Cooling)
- **Emissions to Air**
  - Greenhouse gases (Global warming potential)
  - Acidification
  - Persistent Organic Pollutants (POPs)
  - Heavy metals
  - PAHs
  - Particulate Matter (PM)
- **Emission to Water**
  - Heavy Metals
  - Eutrophication

The production phase dominates the impacts for the following:

- **Resources and Waste**
  - Water (process)
  - Waste non-haz/landfill

  - Waste, hazardous/incinerated
- **Emissions to Air**
  - Volatile Organic Compounds (VOCs)

There is some variation for Base Case 1, for example emission to water are also dominated by the production phase, due to the shorter lifetime and slightly different materials for this base case compared to the others.

The sensitivity analysis has indicated that the impact of replacement parts (other than batteries) does not materially alter the analysis and the conclusions one would draw. Eliminating the need for the replacement of batteries indicates there is some potential for environmental improvement, however it does not affect the overall results of the analysis, which indicates the use phase dominates the majority of the impacts.

The analysis therefore indicates that Task 7 on improvement potential should focus on:

- Reducing in use energy consumption
- Reducing materials associated with minimising battery replacement and hence material use.

5.4 Subtask 5.3 – Base Case Life Cycle Costs

5.4.1 Life Cycle Cost Inputs

In order to calculate the life cycle costs for each base case, a number of cost inputs are required for EcoReport. This includes:

- Product price;
- Installation costs;
- Electricity rates; and
- Repair and maintenance.

The inputs, summarised in Table 63 have been developed using information collected as part of Task 2 and subsequent stakeholder feedback. The key assumptions used are as follows:

- Product price: Average based on on-line research, manufacturer's product literature, and stakeholder feedback in Task 2.
- Installation costs: Average based on on-line sources and feedback from stakeholders in Task 2. For Base Case 4 the installation costs can vary due to the range of sizes covered by this base case. Sensitivity analysis has been under taken to consider this. It is assumed no installation costs are incurred for Base Case 1, as these are generally installed by the user.
- Electricity Rate: The majority of UPS are used within commercial situations; therefore it is proposed that the industrial electricity rate will be used for the purposes of the life cycle cost assessment. Sensitivity analysis has been under undertaken for Base Case 1 using the domestic rate for electricity, as some of these products may be used in domestic circumstances. The rates used are those provided in MEErP.
- Repair and maintenance costs – These have been calculated using general rules, provide by CEMEP, associated with product price for the cost of battery replacement and service contracts. It is assumed there is no battery replacement for Base Case 1, and no service contracts for Base Cases 1, 2 and 3.

Table 63: Summary of life cycle cost inputs

Cost Parameter	Base Case 1 Below 1.5 kVA	Base Case 2 1.5 to 5 kVA	Base Case 3 5.1 to 10 kVA	Base Case 4 10.1 to 200 kVA
Product Price (€)	180	643	3 502	28 800
Installation Costs (€)	N/A	308	503	1 220 (632 for alternative scenario)
Electricity Rate (€/kWh)	0.11 (0.18 for alternative scenario)	0.11	0.11	0.11
Discount Rate	4%	4%	4%	4%
Escalation Rate	4%	4%	4%	4%
Repair and Maintenance Costs				
Replacement battery cost - includes battery and installation (€)	N/A	241 (37.5% of product price)	1 138 (32.5% of product price)	7 920 (27.5% of product price)
Annual Service contract costs - includes replacement of other parts e.g. fans and capacitors, but excludes battery replacement (€)	N/A	N/A – very low number of units under contract	N/A – very low number of units under contract	3168 (annually) (11% of product price) 38,016 (over 12 year lifetime)

5.4.2 Life Cycle Cost Outputs

Table 64 summarises the life cycle costs for the four base cases, using the rates and prices outlined in Table 63.

The key trends noted from the life cycle cost analysis for new products, as shown in Figure 30 are as follows:

- Product purchase costs range from 52% for Base Case 1 to 22% for Base Cases 2 and 4 of total costs.
- Installation costs range from 0% for Base Case 1 to 11% for Base Case 2 of total costs.
- Electricity costs range from 40% for Base Case 3 to 59% for Base Case 2 of total costs.
- Repair and maintenance costs range from 0% for Base Case 1 to 34% for Base Case 4 of total costs.

Similar trends are also seen for the EU27 totals, see Section 5.5.2.

Table 64: Summary of new product base case life cycle costs

Base Case	Base Case 1: Below 1.5 kVA	Base Case 2 1.5 to 5 kVA	Base Case 3 5.1 to 10 kVA	Base Case 4 10.1 to 200 kVA
	New product (€)	New product (€)	New product (€)	New product (€)
Purchase price	180	643	3 502	28 800
Installation cost	0	308	503	1 220[2]
Electricity	166[1]	1 698	3 433	56 548
Repair & maintenance	0	241	1 138	45 936
Total	346	2 890	8 576	132 504

Notes: [1] Using the domestic electricity rate for Base Case 1 increases product life cycle costs to €452 and EU-27 total costs to €449m. [2] €1 220 represents an average installation cost for what is a wide range of UPS for Base Case 4. Other information indicates installation costs could be lower, for example approximately half, at €632. Using this lower figure decreases product life cycle costs to €131 916 and EU-27 total costs to €2 422m. This is insignificant in terms of the total life cycle costs, which are driven mainly by electricity costs.

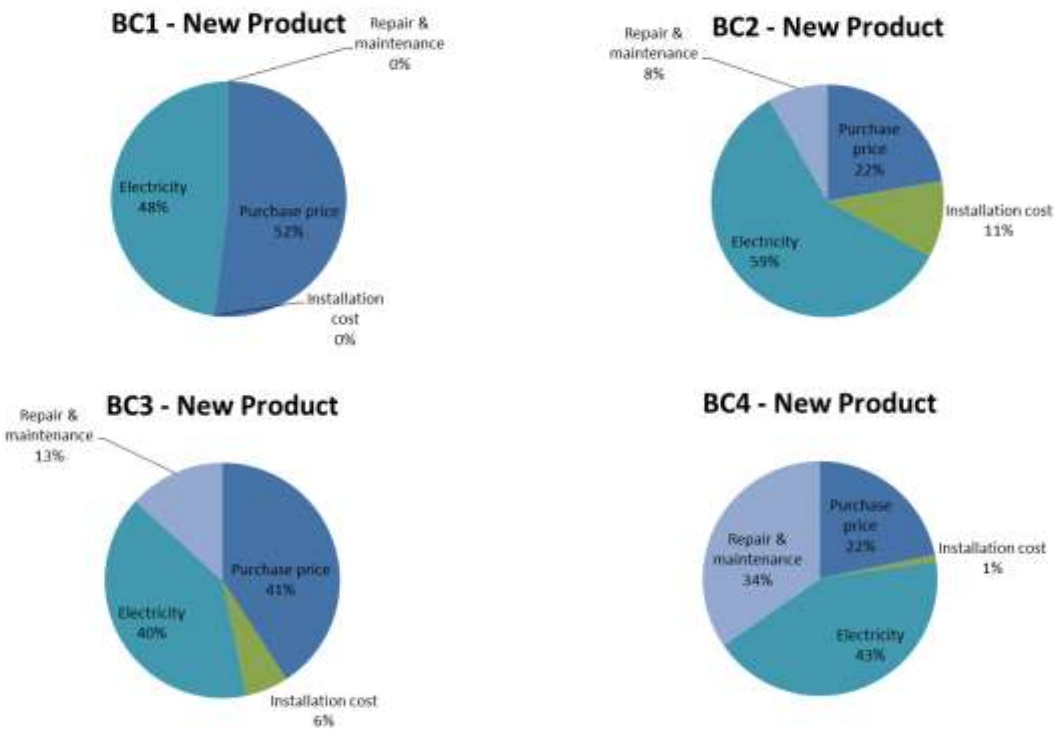


Figure 30: Proportion of different life cycle cost elements (new products) for each base case

5.5 Subtask 5.4 – EU-27 Totals

5.5.1 EU-27 Environmental Impact

This section presents the EU-27 total environmental impacts for each of the four base cases for 2011. This is calculated in EcoReport by multiplying the individual product environmental impacts of a particular base case with the 2011 EU-27 stock figures for that base case, which were calculated in Task 2. Table 65 summaries the total EU-27 environmental impacts for each of the four base cases.

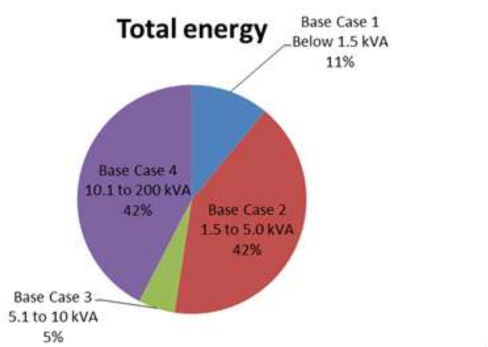
Table 65: Summary Environmental Impacts EU-Stock 2011, UPS products

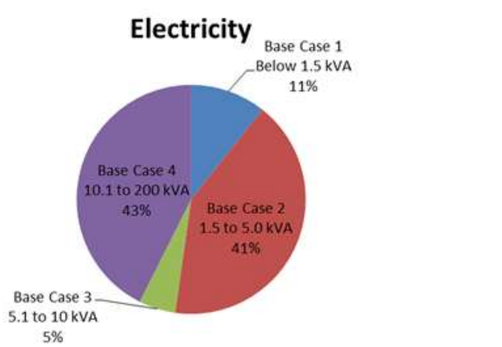
		Base Case 1 Below 1.5 kVA	Base Case 2 1.5 to 5.0 kVA	Base Case 3 5.1 to 10 kVA	Base Case 4 10.1 to 200 kVA
Main life cycle indicators	unit	value	value	value	value
Materials					
Plastics	Mt	0.002	0.002	0.000	0.002
Ferrous metals	Mt	0.001	0.003	0.000	0.003
Non-ferrous metals	Mt	0.001	0.001	0.000	0.001
Other resources & waste					
Total Energy (GER)	PJ	14	54	7	56
of which, electricity	TWh	2	6	1	6
Water (process)*	mln.m3	0	0	0	0
Waste, non-haz./ landfill*	Mt	0.03	0.12	0.02	0.13
Waste, hazardous/ incinerated*	kton	0.00	0.00	0.00	0.00
Emissions (Air)					
Greenhouse Gases in GWP100	mt	1	2	0	2
Acidifying agents (AP)	kt SO2eq.	3	11	1	11
Volatile Org. Compounds (VOC)	kt	3	11	1	11
Persistent Org. Pollutants (POP)	g i-Teq.	0	0	0	0
Heavy Metals (HM)	ton Ni eq.	0	1	0	1
PAHs	ton Ni eq.	0	0	0	0
Particulate Matter (PM, dust)	kt	0	0	0	0
Emissions (Water)					
Heavy Metals (HM)	ton Hg/20	0	0	0	0
Eutrophication (EP)	kt PO4	0	0	0	0

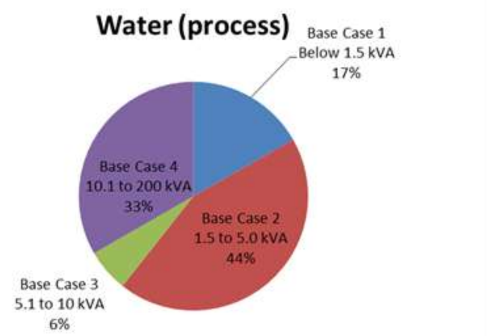
A summary of the total environmental impacts of the four base cases as a percentage of total impact are presented in Figure 31. The proportion of total 2011 stock for each base case is summarised in

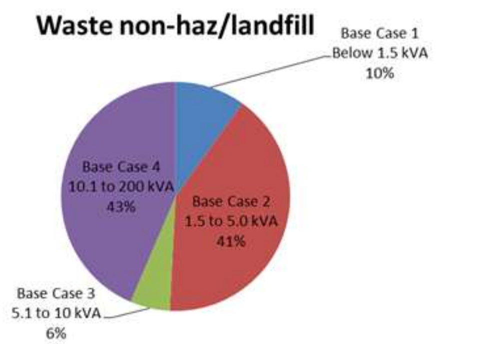
Table 66: Summary of 2011 Stock for base cases

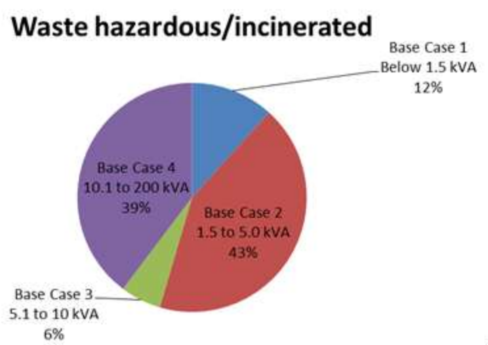
Base Case	2011 Stock (million units)	% of total 2011 stock
Base Case 1 – Below 1.5 kVA	3.98	54
Base Case 2 – 1.5 to 5.0 kVA	3.06	41
Base Case 3 – 5.1 to 10 kVA	0.24	3
Base Case 4 – 10.1 to 200 kVA	0.14	2
Total	7.42	100

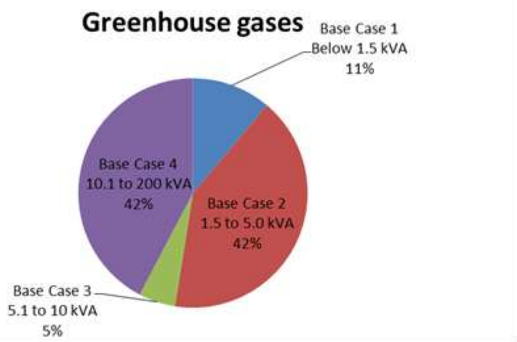

Total energy
Base Case 1
Below 1.5 kVA
11%
Base Case 2
1.5 to 5.0 kVA
42%
Base Case 3
5.1 to 10 kVA
5%
Base Case 4
10.1 to 200 kVA
42%

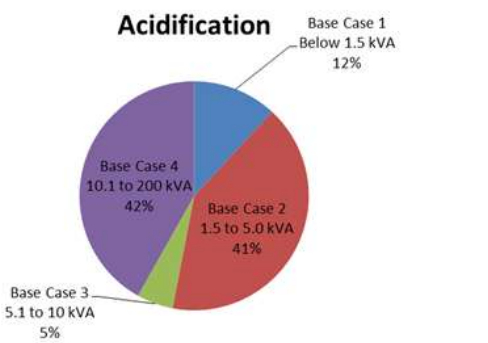

Electricity
Base Case 1
Below 1.5 kVA
11%
Base Case 2
1.5 to 5.0 kVA
41%
Base Case 3
5.1 to 10 kVA
5%
Base Case 4
10.1 to 200 kVA
43%

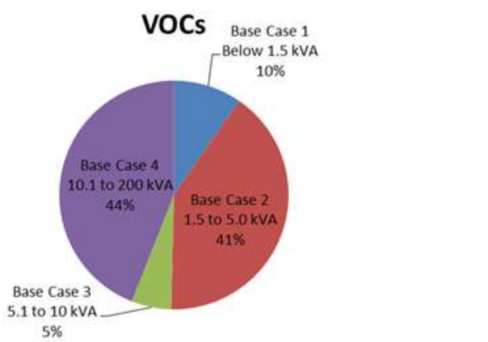

Water (process)
Base Case 1
Below 1.5 kVA
17%
Base Case 2
1.5 to 5.0 kVA
44%
Base Case 3
5.1 to 10 kVA
6%
Base Case 4
10.1 to 200 kVA
33%


Waste non-haz/landfill
Base Case 1
Below 1.5 kVA
10%
Base Case 2
1.5 to 5.0 kVA
41%
Base Case 3
5.1 to 10 kVA
6%
Base Case 4
10.1 to 200 kVA
43%


Waste hazardous/incinerated
Base Case 1
Below 1.5 kVA
12%
Base Case 2
1.5 to 5.0 kVA
43%
Base Case 3
5.1 to 10 kVA
6%
Base Case 4
10.1 to 200 kVA
39%


Greenhouse gases
Base Case 1
Below 1.5 kVA
11%
Base Case 2
1.5 to 5.0 kVA
42%
Base Case 3
5.1 to 10 kVA
5%
Base Case 4
10.1 to 200 kVA
42%


Acidification
Base Case 1
Below 1.5 kVA
12%
Base Case 2
1.5 to 5.0 kVA
41%
Base Case 3
5.1 to 10 kVA
5%
Base Case 4
10.1 to 200 kVA
42%


VOCs
Base Case 1
Below 1.5 kVA
10%
Base Case 2
1.5 to 5.0 kVA
41%
Base Case 3
5.1 to 10 kVA
5%
Base Case 4
10.1 to 200 kVA
44%

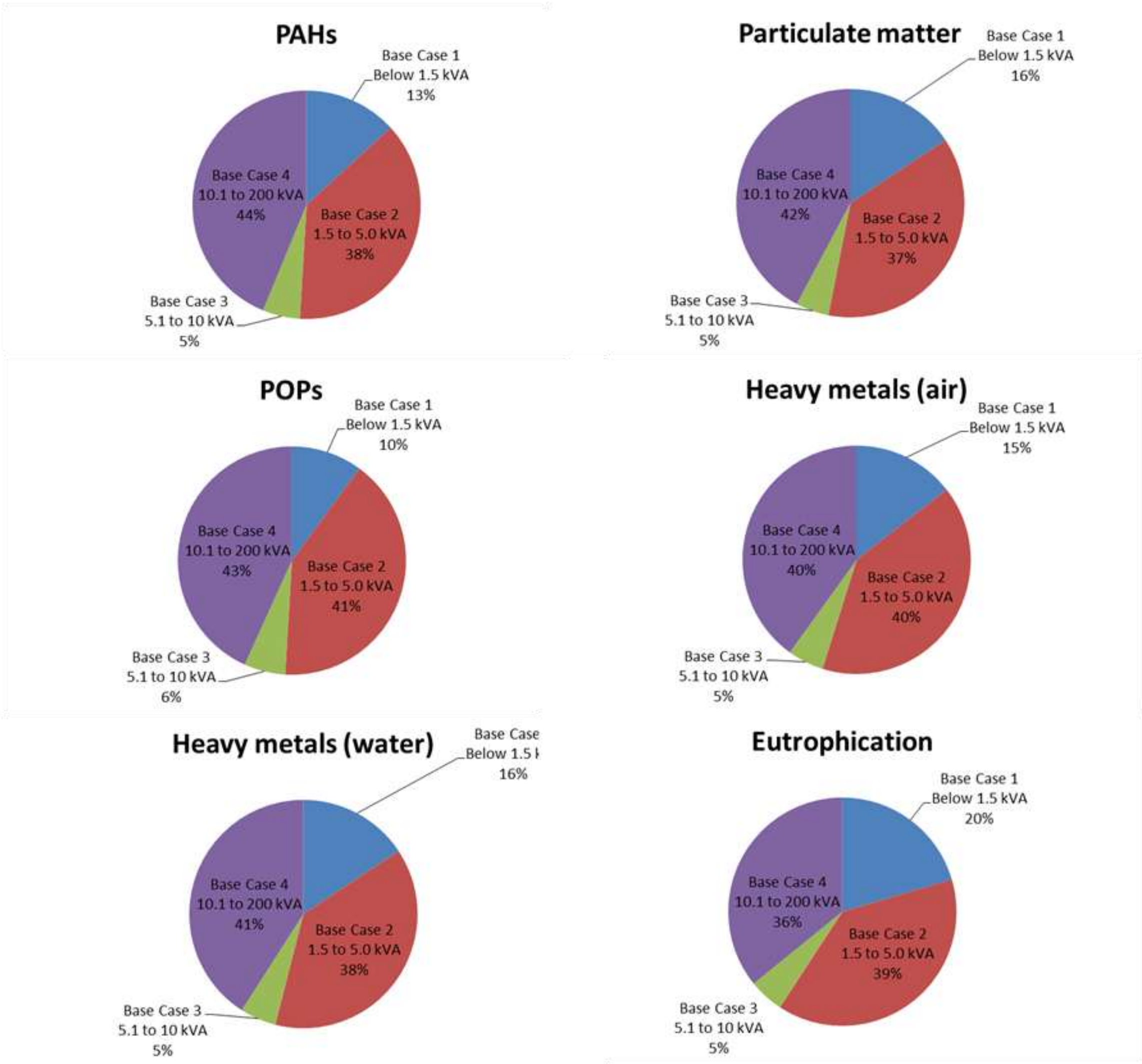


Figure 31: Share of environmental impacts by base case (2011 stock)

As Figure 31 shows, UPS above 10.1 kVA (Base Case 4) have the largest or equal largest total environmental impacts for all but three of the environmental indicators, while representing just 2% of the 2011 stock. For the indicators that Base Case 4 dominates, the share of the impact is similar, ranging from 40% for heavy metals (air) to 44% for PAHs and VOCs. The environmental indicators that Base Case 4 does not dominate are water (process), waste hazardous/incinerated and eutrophication where Base Case 4 is second only to Base Case 2. In all other parameters, Base Case 2 has the second highest impact, at approximately 40% for each indicator. Base Case 2 has a significantly higher proportion of the 2011 stock at 41%.

Compared to Base Cases 4 and 2, 1 and 3 have relatively small shares of the total environmental impact. The share of impacts for Base Case 1 varies between 10 to 20%, with 54% of the 2011 stock. Finally, Base Case 3 has the lowest share of environmental impacts, ranging from 5 to 6%, and just 3% of 2011 stock.

5.5.2 EU-27 Life Cycle Costs

Table 67 summarises the EU-27 life cycle costs for each of the Base Cases, providing an indication of total consumer expenditure in the EU-27 for 2011.

Table 67: Summary of EU-27 total life cycle costs

Base Case	Base Case 1: Below 1.5 kVA	Base Case 2 1.5 to 5 kVA	Base Case 3 5.1 to 10 kVA	Base Case 4 10.1 to 200 kVA	EU 27 Total	Share of annual consumer expenditure
	Total annual consumer cost – EU27 (M€)	Total annual consumer cost – EU27 (M€)	Total annual consumer cost – EU27 (M€)	Total annual consumer cost – EU27 (M€)	Total annual consumer cost – EU27 (M€)	%
Purchase price	179	257	89	379	**904**	**28**
Installation cost	0	123	13	16	**152**	**5**
Electricity	165	650	81	670	**1 566**	**48**
Repair & maintenance	0	92	27	505	**663**	**20**
Total	**344**	**1 122**	**210**	**1 609**	**3 285**	**100**

For the EU-27 as a whole total consumer expenditure is 3 285 M€ for all UPS products covered by the four base cases. Overall this is dominated by expenditure on electricity, which accounts for 48% of total consumer expenditure, with purchase price expenditure accounting for 28% and repair and maintenance 20%. Installation is the most insignificant cost element, accounting for just 5% of total consumer expenditure. There is some variation in EU-27 totals for the individual base cases, as shown in Figure 32, with trends broadly reflecting those outlined in Section 5.4.2 for new products.

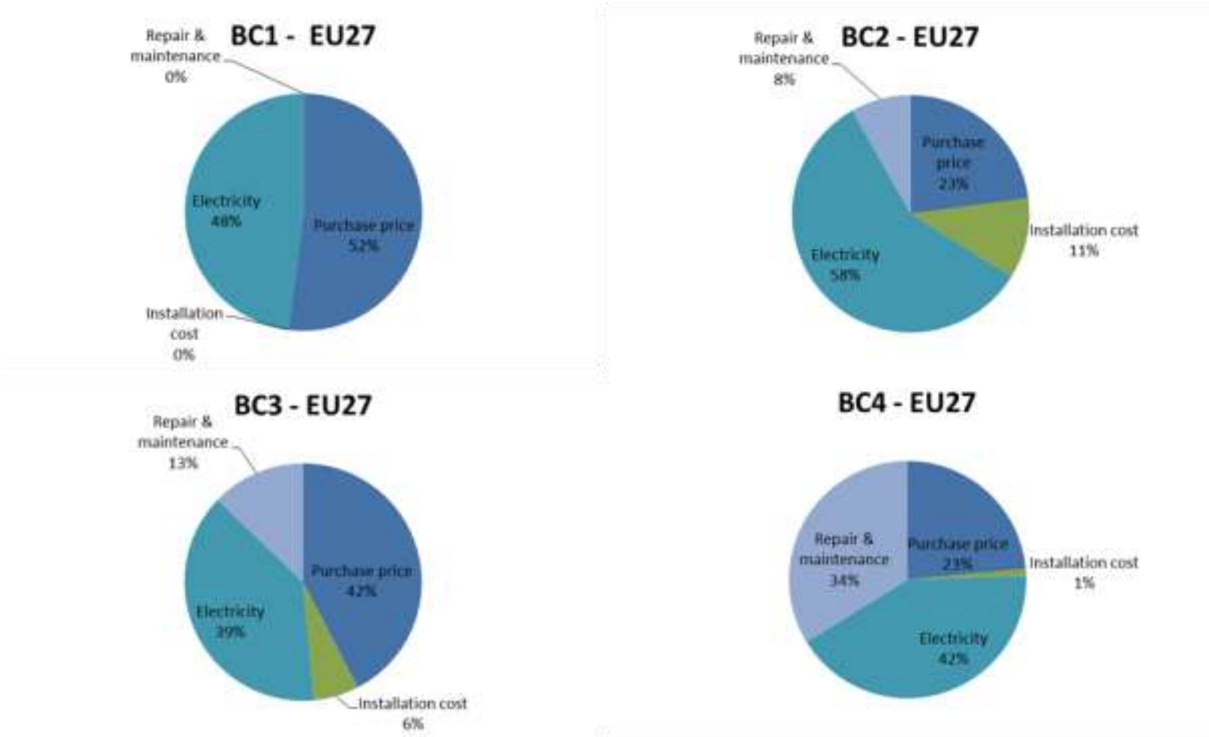


Figure 32: Proportion of different life cycle cost elements (EU-27 Totals) for each base case

5.6 Subtask 5.5 – EU-27 Total System Impact

The aggregated results for Base Cases 1, 2, 3 and 4 are shown in Table 68, together with a comparison against total EU impacts.

The environmental assessment identified the in use phase, driven by energy use (electricity) as the key area of environmental impact. The total electricity consumption by UPS covered by the four base cases is 14.34 TWh, representing 0.51% of total EU-27 electricity consumption[174].

The only information identified for comparison against the EcoReport outputs is in the CEMEP publication 'Environmental Considerations, Focus on UPS'[175]. This includes information on the proportion of UPS energy consumption compared to total EU energy consumption for key sectors:

- Industry and infrastructure sector – UPS energy consumption is 0.465% of total EU consumption.
- Data centre sector – UPS energy consumption is 0.14% of total EU consumption.
- Residential and small business sector - UPS energy consumption is 0.004% of total EU consumption.

This indicates that UPS energy consumption for these three sectors is approximately 0.61% of total EU consumption. This is similar to the results from the EcoReport analysis outlined in this report, which indicates UPS electricity use is approximately 0.51% of total EU electricity consumption.

The slight difference in figures is due to the exclusion of UPS's above 200kVA in the EcoReport analysis. If the stock figure (calculated in Task 2) for UPS above 200kVA is added to Base Case 4 to provide an indication for all UPS then the total electricity consumption

[174] Based on total EU electricity consumption figure of 2800 TWh included in the output worksheet of the EcoReport tool.
[175] http://www.cemep.org/fileadmin/working_groups/ups/feel_free_to_create_new_folders/publication_UPS/Guide_A5_290609.pdf

figure calculated by EcoReport is 18.6 TWh (168 PJ), which represents 0.66% of total EU electricity consumption. This is highly consistent with the figure from the industry literature.

Table 68: Total EU-27 Impacts for UPS

Main Life Cycle Indicators	Units	UPS EU-27 Total Impacts	EU Total Impacts	Share of UPS impacts as proportion of EU total impact
Materials				
Plastics	Mt	0.01	48	0.01%
Ferrous metals	Mt	0.01	206	0.00%
Non-ferrous metals	Mt	0.00	20	0.01%
Other resources & waste				
Total Energy (GER)	PJ	130.95	75 697	0.17%
of which, electricity	TWh	14.34	2 800	0.51%
Water (process)*	mln.m^3	1.01	24 7000	0.00%
Waste, non-haz./ landfill*	Mt	0.30	2 947	0.01%
Waste, hazardous/ incinerated*	ktonne	0.01	89	0.01%
Emissions (Air)				
Greenhouse Gases in GWP100	mt CO_2eq.	5.67	5 054	0.11%
Acidifying agents (AP)	kt SO_2eq.	25.59	22 432	0.11%
Volatile Org. Compounds (VOC)	kt	26.05	8 951	0.29%
Persistent Org. Pollutants (POP)	g i-Teq.	0.48	2 212	0.02%
Heavy Metals (HM)	tonne Ni eq.	1.58	5 903	0.03%
PAHs	tonne Ni eq.	0.48	1 369	0.04%
Particulate Matter (PM, dust)	kt	0.77	3 522	0.02%
Emissions (Water)				
Heavy Metals (HM)	tonne Hg/20	0.79	12 853	0.01%
Eutrophication (EP)	kt PO_4	0.03	900	0.00%

5.7 Conclusions

Task 5 has analysed the life cycle environmental impacts and life cycle costs for the four UPS base cases, which represent typical products within the EU UPS market. The base cases and market data associated with them were informed by consultation with stakeholders, dismantling trials undertaken by the project team and previous studies and reports.

The environmental impact assessment has been undertaken using EcoReport. This analysis has identified in use phase energy consumption as the key driver for the majority of the impact indicators:

- **Resources and Waste**

  - Total Energy
  - Electricity
  - Water (Cooling)
- **Emissions to Air**
  - Greenhouse gases (Global warming potential)
  - Acidification
  - Persistent Organic Pollutants (POPs)
  - Heavy metals
  - PAHs
  - Particulate Matter (PM)
- **Emission to Water**
  - Heavy Metals
  - Eutrophication

The production phase drives the impacts associated with the remaining impact indicators and is primarily due to the materials associated with the lead acid battery, which is a key component of the UPS.

- **Resources and Waste**
  - Water (process)
  - Waste non-haz/landfill
  - Waste, hazardous/incinerated
- **Emissions to Air**
  - Volatile Organic Compounds (VOCs)

The environmental assessment results are broadly similar for Base Cases 2, 3 and 4. There is a slight variation for Base Case 1, with impact parameters associated with water emissions driven by the production and not the use phase due to a shorter lifetime and slightly different material composition.

Sensitivity analysis has also been undertaken as part of the environmental impact assessment, which indicates the replacement of spare parts, excluding the battery has a negligible effect on results. However the sensitivity analysis does show there is scope for improvement as a result of reduced material use as a result of longer battery lifetimes negating the need to replace batteries over the lifetime of the product.

Aggregating the results for the base cases and using installed stock to provide EU-27 totals indicates that Base Cases 2 and 4 account for the majority of the impacts for the different indicators, while having significantly different proportions of the market in terms of number of units installed (41% for Base Case 2 and just 2% for Base Case 4). The EU-27 totals indicate approximate energy consumption of 131PJ, of which electricity is 14 TWh.

At the EU-27 level aggregated consumer expenditure is dominated by electricity, which accounts for approximately half of total consumer expenditure. However it is important to note that this varies between the base cases, for example, product purchase and electricity expenditure are similar for Base Cases 1 and 3.

The results from the environmental and life cycle cost analysis undertaken in Task 5 will provide a reference point against which potential improvements can be compared. The potential improvement options will focus primarily on those that will improve energy use, but will also consider further those that will reduce material associated with minimising battery replacement, in line with the results of the EcoReport analysis.

6 Task 6 – Technical analysis of BAT

6.1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design working plan 2009-2011. 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 Commission's 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 are be posted on the website for stakeholders who cannot attend workshops.

6.1.1 Task 6 – Objectives

Task 6 is focus on identifying and technically reviewing the best available technologies (BAT) for UPS. BAT is defined as the currently available technology, which is expected to be introduced at product level and reached the main stream market within two to three years. The outcome of this BAT analysis will enable evaluation of technology in terms of its feasibility and cost. Best not yet available technology (BNAT) is defined as the technology that is in the research and development stage and not yet ready for large-scale implementation. The assessment of BAT will form an input to Task 7, which will involve analysis of the improvement potential that could be achieved via a range of design options.

The objective of Task 6 is to assess the state-of-the-art technologies at the stages of development as shown in Figure 33. Such assessment considers products and components in all levels of analysis, based on a literature search and stakeholder contributions.

For pre-market stages, products and components are likely to be at prototype (as noted earlier), test and field test stages. The task 6's objective is to illustrate various technically available (or potentially available) options, not taking into account intellectual property, technical feasibility and market availability at this stage.

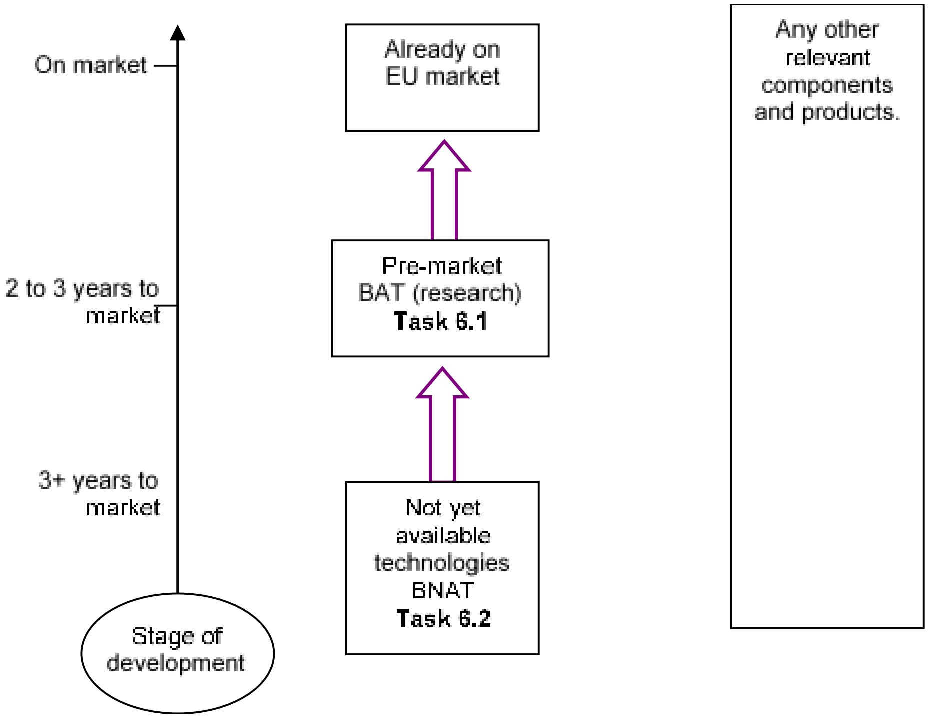


Figure 33: Stages of development for BAT consideration

The section looks first at improvement potential at the products level followed by improvement realisable at components levels. It goes on to define the topology of semi-conductors, and review best technology available outside the European Union.

6.2 Subtask 6.1 - State-of-the-art in applied research at the product level

This section focuses on BAT and BNAT at the product level, it presents the detailed analysis of:

- Weighted efficiency and flat efficiency curve;
- Intelligent control;
- DC distribution.

6.2.1 Weighted Efficiency and Flat Efficiency Curve

The first BAT reviewed is aimed at improving weighted efficiency and flat efficiency curve.

Weighted efficiency is the average efficiency of the product, weighted by the proportion of time spent at each load level.

An efficiency curve can be considered as presenting a flat efficiency if the efficiency achieved with different load levels presents a small variation. Flat efficiency curve will be achievable as new control methods and improved components and topologies will make it possible to increase the efficiency to the lower load levels to smooth the efficiency curve.

In order to assess the improvements achieved on energy efficiency, the four base cases (BC) defined in Task 5 are considered:

- Base Case 1 - Below 1.5 kVA (Standby);
- Base Case 2 - 1.5 to 5.0 kVA (Line Interactive);
- Base Case 3 - 5.1 to 10 kVA (Double Conversion - Online);
- Base Case 4 - 10.1 to 200 kVA (Double Conversion - Online).

To characterize the existing products the minimum levels of conversion efficiency defined in the UPS Code of Conduct from JRC, using version 1[176] for products above 5 kVA and version 2[177] for products below 5 kVA were used. Figure 34 shows the efficiency curves used for the four base cases. As can be seen the existing products present a lower efficiency for smaller products and much lower efficiency at lower load levels (mainly with 25% load).

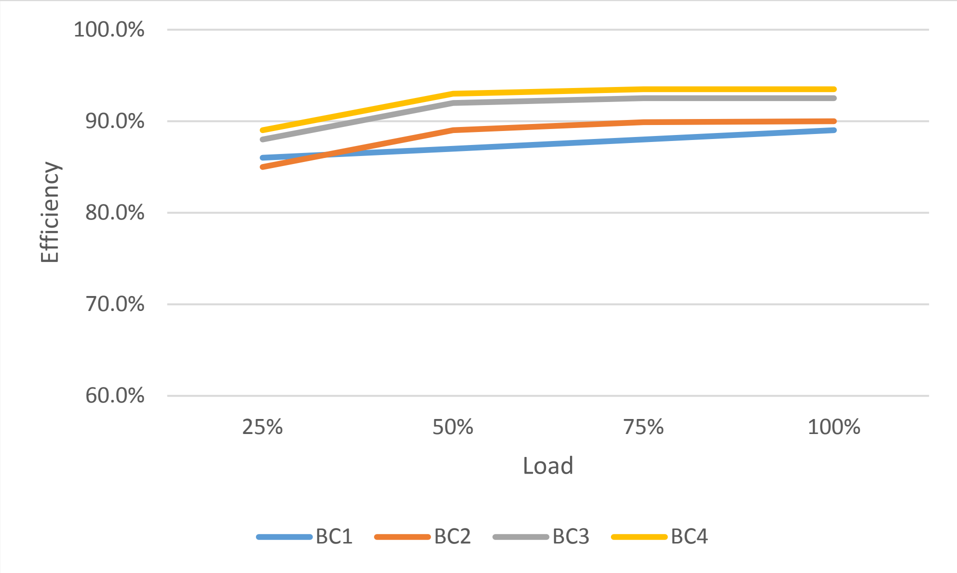


Figure 34: Efficiency curves for the four base cases

There are however, already products on the market with much higher efficiency. To characterize the best products available on the market, the ENERGY STAR database[178] was used. The products with the highest weighted efficiency (weighted by the proportion of time spent at each load level[179]) were selected to compare with each base case (taking into account products with the same size and topology of those considered in each base case). Table 75 presents the achieved improvement between the considered reference and the best product available on the market for each base case.

Table 69: Weighted efficiency for the reference and BAT for each base case

	Weighted Efficiency (%)	
	Reference	BAT
BC1	87.7%	98.7%
BC2	89.7%	98.7%
BC3	92.4%	95.0%
BC4	92.1%	95.8%

176 JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, 2006
177 JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011
178 ENERGY STAR Uninterruptible Power Supplies Product List, August 23, 2013, available at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=UPS
179 ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.

In terms of efficiency, the latest topologies have almost reached an asymptote with very high efficiency at full load (95-98%). Therefore, it will be more and more challenging to gain additional efficiency at full load. UPS efficiency has improved by almost 50% over the last 30 years. If the same results are achieved in the next 30 years, an additional 1.5 to 2% in the global efficiency of a UPS can be reached. Therefore, the achievable improvement within the next 3+ years is limited to a window of few percentage points to reach the limit of 100% efficiency[180].

However, many UPSs are running with a load size representing 50%, or less, of the UPS power rating. New installations of UPS systems are often oversized, since users intend to add additional equipment later and do not want to resize the UPS again. Therefore, in the near future, one of the main challenges for manufacturers will be to improve efficiencies to low load levels. Figure 35, Figure 36, Figure 37 and Figure 38 present the comparison between the efficiency curves for the product with highest efficiency (Eff), the product with a flatter efficiency curve (Flat) and the reference (BC), for each base case. It was considered as the product with a flatter efficiency the product with the smallest difference between the maximum and minimum efficiency with different load levels.

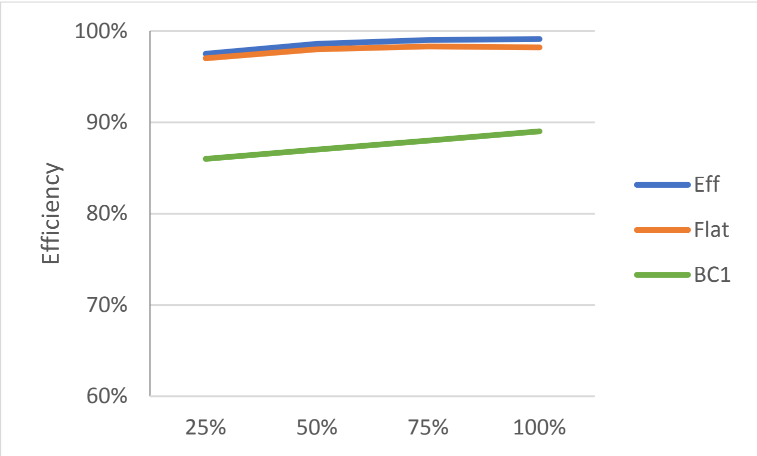


Figure 35: Efficiency curves for the more flat and more efficient product (Base Case 1)

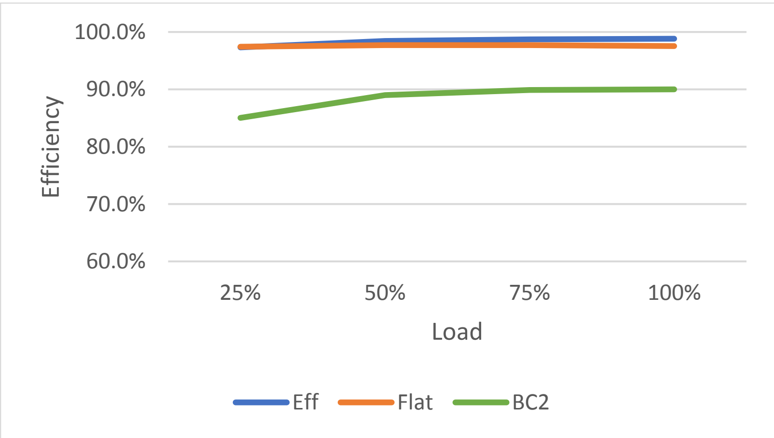


Figure 36: Efficiency curves for the more flat and more efficient product (Base Case 2)

[180] Feedback received from CEMEP, June 2013.

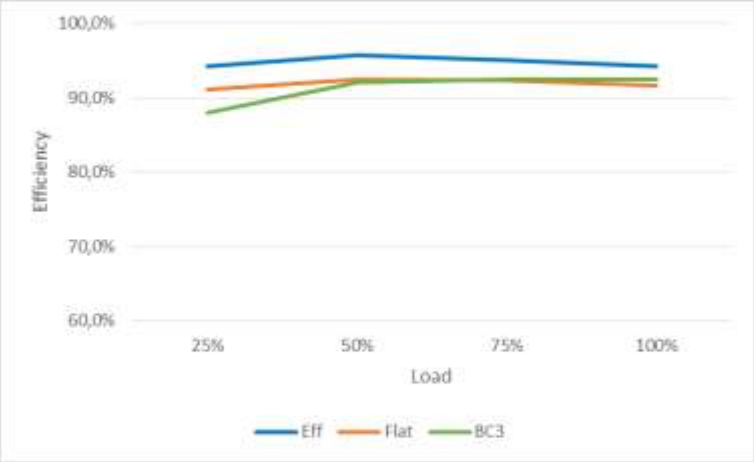


Figure 37: Efficiency curves for the more flat and more efficient product (Base Case 3)

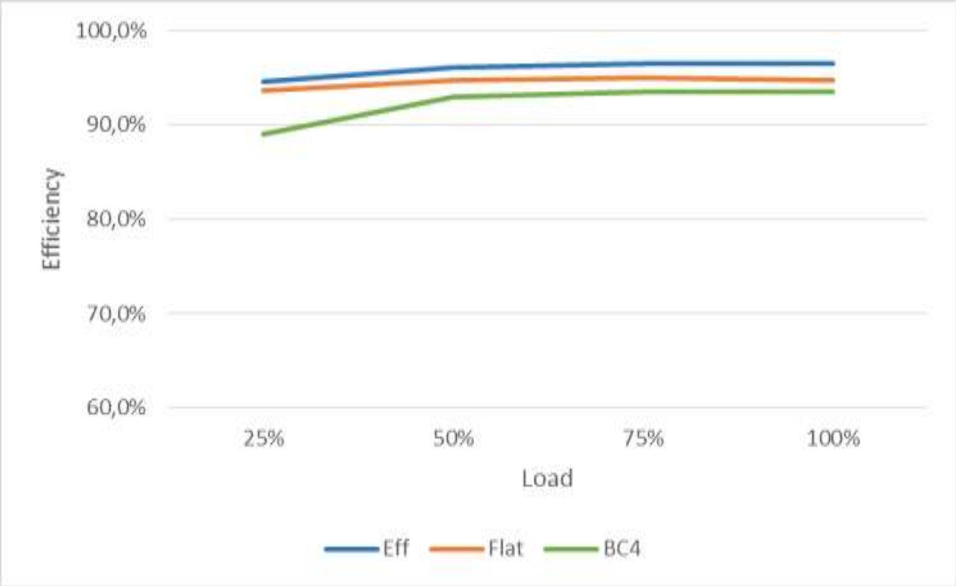


Figure 38: Efficiency curves for the more flat and more efficient product (Base Case 4)

As can be seen, the best products present a much higher efficiency and a more flat curve in all base cases. Nowadays, the best available products from the ENERGY STAR database already have high efficiency in the low load levels and are not far from a flat efficiency curve. Table 70, Table 71, Table 72, and Table 73 present the efficiency data for the products with a more flat efficiency curve and with highest efficiency (currently available on the Energy Star database) for each base case.

Table 70: Efficiency data for the more flat and more efficient product (Base Case 1)

Best Product	Power		Efficiency at X% Load				Weighted Efficiency
	(kW)	(kVA)	25%	50%	75%	100%	
Flat	0.51	0.85	97.0%	98.0%	98.3%	98.2%	97.9%
Efficient	0.39	0.65	97.5%	98.6%	99.0%	99.1%	98.7%

Table 71: Efficiency data for the more flat and more efficient product (Base Case 2)

Best Product	Power		Efficiency at X% Load				Weighted Efficiency
	(kW)	(kVA)	25%	50%	75%	100%	
Flat	0.9	1.5	97.4%	97.7%	97.7%	97.5%	97.8%
Efficient	4.5	5	97.3%	98.4%	98.7%	98.8%	98.7%

Table 72: Efficiency data for the more flat and more efficient product (Base Case 3)

Best Product	Power		Efficiency at X% Load				Weighted Efficiency
	(kW)	(kVA)	25%	50%	75%	100%	
Flat	9	10	91,1%	92,5%	92,4%	91,6%	9,2%
Efficient	9	10	94,3%	95,8%	95,1%	94,2%	95,0%

Table 73: Efficiency data for the more flat and more efficient product (Base Case 4)

Best Product	Power		Efficiency at X% Load				Weighted Efficiency
	(kW)	(kVA)	25%	50%	75%	100%	
Flat	10	11	93.6%	94.8%	95.0%	94.8%	94.9%
Efficient	144	166	94.6%	96.1%	96.5%	96.5%	95.9%

However, manufacturers are focusing their efforts on improving UPS efficiencies at low load up to the same level as they currently present when the UPS unit is loaded between 50% and 100% of its capacity, to achieve a pure flat efficiency curve to the tested load levels. The achievement of a flat efficiency curve is possible using technologies such as: digital signal processing (DSP) for a better digital control of power components, the availability of new power components in the field of semi-conductors and magnetics, as well as multi-level power topology design (such technologies are presented in Section 6.3.3.2). Improving the efficiency at high load draws systematically to an oversizing of parts (more copper and more Semi-conductors) and an increase of the cost for the customer. On the other hand the improvement of the efficiency at lower load levels is achievable with a better design (smarter control) and reduction of energy use by "auxiliary circuits" (internal PSUs[181], fans, coils) which impacts less the product cost.

6.2.2 Intelligent control of UPS

6.2.2.1 Power quality problems and correction solutions

Double conversion UPS technology is accepted by the industry as the optimum and reliable solution for power quality problems. The principal AC source power quality problems that may require treatment before distribution to the load may be summarised as:

- Voltage fluctuations and flicker
- Voltage interruptions and dip (sag)
- Voltage imbalance
- Induced low frequency voltage transients
- Harmonics and inter-harmonics
- DC components, notching and electric noise
- Frequency variations in AC power source

[181] PSU: Power Supply Units

There are several individual solutions that can be applied to individually or collectively improve some or all of the above power quality problems:

- Double conversion UPS
- Static transfer switch (to optimised alternative AC supply)
- Transient voltage surge suppressor
- Series active filters
- Parallel active filters
- Hybrid active filters

The active filters listed above can be designed to correct, with high efficiency, all of the power quality disturbance categories, within limits, except voltage and frequency disturbances.

Of the solutions listed, the full double conversion UPS is, to date, the leading solution that is capable of compensating for the power quality problems summarised and guarantees high quality voltage supply to the load in large extremes of AC source voltage fluctuation and even supply failure. The penalty for this solution is loss of power transfer efficiency. A significant amount of energy is lost in the process of continuously converting AC source power to DC power and then DC power to high quality AC load power. Typical conversion losses can introduce up to a 4% efficiency penalty, even with best available component technology.

6.2.2.2 Intelligent Double conversion UPS solution for high efficiency

Industry monitoring of AC source power quality and AC load power quality impairment tolerance shows that the continuous high level of power quality treatment offered by the double conversion UPS is often not needed. For given AC source quality conditions and AC load power quality and power resilience of supply requirements, the application of the double conversion UPS power treatment solution can be improved in efficiency by the intelligent use of the double conversion mode of a UPS only if required by an out of tolerance AC source voltage.

This solution requires a UPS design which can analyse the quality of the AC power source, synchronise with that source to facilitate the seamless switching of direct or power treatment paths to the load and automatically correct, with efficient active filters, both distortion and power factor at the load power distribution point. Internal pre-programmed software control of digital signal processing power circuitry in the UPS facilitates these requirements.

The intelligent UPS deploys three basic power paths for power treatment scenarios as shown in Figure 39 below.

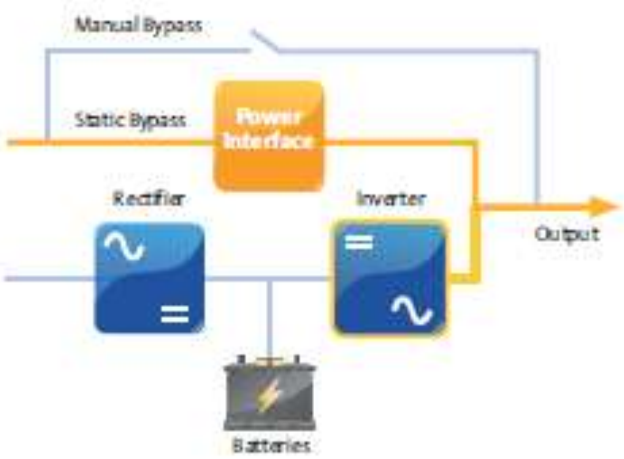


Figure 39 Simplified UPS Power Paths

The UPS uses the power interface circuitry to continuously monitor the quality of the AC source (voltage parameters and frequency parameters) and to monitor the load power quality (distortion and power factor). This circuitry will then control the functions of the UPS to optimise the power transfer efficiency of the UPS to provide pre-programmed power quality limits for the load.

The stages of an intelligent working cycle for the UPS may be as follows:

- AC power source and load power distribution are within all pre-programmed quality limits. The power interface operates in static bypass mode and the power source is effectively transferred directly to load. Operating power transfer efficiency is up to 99%.
- AC power source is within pre-programmed quality limits but load power distribution harmonic distortion or power factor limits are exceeded. The power interface operates in static bypass mode and configures the inverter stage to provide an active filter and to act as a load power factor corrector. In this power conditioning mode the UPS can provide a power transfer efficiency of 97% to 98.5%.
- AC power source exceeds all power quality conditions (Voltage and/or Frequency).The power interface configures the UPS to act in full double conversion mode providing optimum power quality. The power transfer efficiency in this mode is typically 95%.

Industry monitoring of a large installed base of UPS over a one year period[182] shows that the intelligent mode switching of a UPS can provide an average improvement in the power transfer efficiency of up to 2% over that of a UPS of identical design continuously running in full double conversion mode. Manufacturers' data for 2013 UPS products shows that the additional control electronics required for intelligent mode switching have not increased the average cost of UPS of 10 kVA and above rating.

Nearly all double conversion UPSs (VFI) have a static bypass circuit and that circuit can allow to propose an Eco-mode (VFD) with a limited cost impact as it requires only the modification of the control circuits. On the other hand to automatically enter and exit Eco-mode on online UPS with an advanced algorithm is requiring more digital control capability which could be prohibitive in cost for low power rating UPSs. Furthermore the multiplicity and variety of algorithms for such energy efficiency optimisation is so that process to measure and compare the actual efficiency of UPS products would be very difficult and controversial.

[182] Chloride/Emerson Trinergy system monitoring programme Consultation Prof. Ian Bitterlin

Tri-mode UPSs, capable of VFD, VI and VFI mode operation, currently represent a small minority of products available on the market. Adding a VI mode to an online UPS can increase cost and certainly increases complexity, which could reduce reliability. In addition patents may prevent all manufacturers from being able to offer such products. Adding a VFD mode to a VI product typically adds cost by requiring a bypass path around the voltage regulator which is not universally present, especially in smaller UPSs. Patents also exist in this area, which limit implementation options for non-patent holders[183].

6.2.3 DC distribution

Data centre IT equipment such as servers and storage devices are essentially DC-based loads. The backup supply system commonly required for critical facilities consists of batteries, which are also based on DC. Thus, by deploying a DC distribution rather than conventional AC, a number of conversion steps in the power delivery system can be eliminated. As a result, distribution losses can be reduced.

Google data centres have changed to a +12 V single DC power supply to improve energy efficiency and Lawrence Berkeley National Laboratory teamed with about 20 companies to demonstrate that using DC entirely throughout a data centre will save 10% to 20% in power costs and improve reliability[184].

With facility DC-UPS for 380 VDC it is possible to involve renewable energy in a very simple and reliable way. PV modules on the roof can be connected direct to the DC bus via a simple DC regulator device. Since most DC applications in the telecom sector are running at 48 VDC, there are a few data centres using 380 VDC systems. For example the Swedish Energy Agency is running its data centre including server and storage in Eskilstuna using a 380 VDC system combined with a rooftop PV system and a DC UPS. The in-house electricity distribution is a strict DC operation, powered by the PV system at daylight. The UPS is on the DC level with DC input and DC output. The rectifiers are powered by the national grid, if there is no or not sufficient sunlight and not enough PV power. The batteries are part of the UPS system and not so called PV batteries that could store excessive PV power during the day.

The total efficiency of a DC system can be made greater than in present AC systems owing to elimination of the extra conversion step of the inverters. An optimal system might integrate the ICT equipment with the facility in such a way as to minimize power conversions. This can be accomplished with the individual power supplies elimination and the centralization of rectifiers and power factor correction circuits. This can be done if the correct voltages of DC power could be supplied efficiently from a central system, or in the case of fuel cells or other distributed energy resource (DER), directly from the power source. Connection of such DER to a direct current system is highly efficient as no losses for transformation to alternating current will occur[185].

As seen in Table 26, the efficiency of electric power distribution and equipment can become 20% higher as compared to the present AC solutions. DC-DC converters can reach an efficiency of 90-94% as compared to AC-DC power supplies which provide an efficiency of 65-75%. Even comparing best-in-class AC-DC to DC-DC a 2-5% advantage to the DC-DC solution can be reached. The efficiency findings show that 380 V DC provides the highest efficiency DC option, particularly when compared with the 48 V DC system, however, it requires a critical mass of 380 V DC commercial equipment to exist before any user could decide for this option [186].

[183] Feedback received from CEMEP, November 2013.
[184] V. Sithimolada, and P. W. Sauer, "Facility-level DC vs. Typical AC Distribution for Data Centers, A Comparative Reliability Study", TENCON 2010 - 2010 IEEE Region 10 Conference. 2010
[185] A. Moreno-Munoz et al., "Distributed DC-UPS for energy smart buildings", Energy and Buildings 43 (2011) 93–100
[186] A. Moreno-Munoz et al., "Distributed DC-UPS for energy smart buildings", Energy and Buildings 43 (2011) 93–100

Table 74: Power distribution efficiency comparing AC and different DC distribution methods[185]

	UPS	Distribution wiring +PDU[187]	PSU[188]	Load Converter 12 V–1V	Total Efficiency
Facility AC-UPS	92.00%	99.00%	75.00%	88.00%	60.00%
Facility DC-UPS 48V/24V	92.86%	99.00%	91.54%	88.00%	74.00%
Facility DC-UPS 380V	96.00%	99.00%	91.75%	88.00%	76.73%
Distributed DC-UPS	92.00%	99.00%	94.00%	88.00%	75.34%

Recently an innovative per-system DC-UPS has been presented, which provides a backup power source or a shutdown time off process for at least 0.5–30 min (configurable) in the supply of power. This DC block (available for nominal DC voltage 12, 24 or 48 V), essentially is a battery that floats on the DC side of the power supply. As seen in Figure 40, the design effectively shifts the On-board DC-UPS concept. Using this UPS in programmable logic controller (PLC), microcontrollers system, and server will lead to excellent voltage sag ride-through.

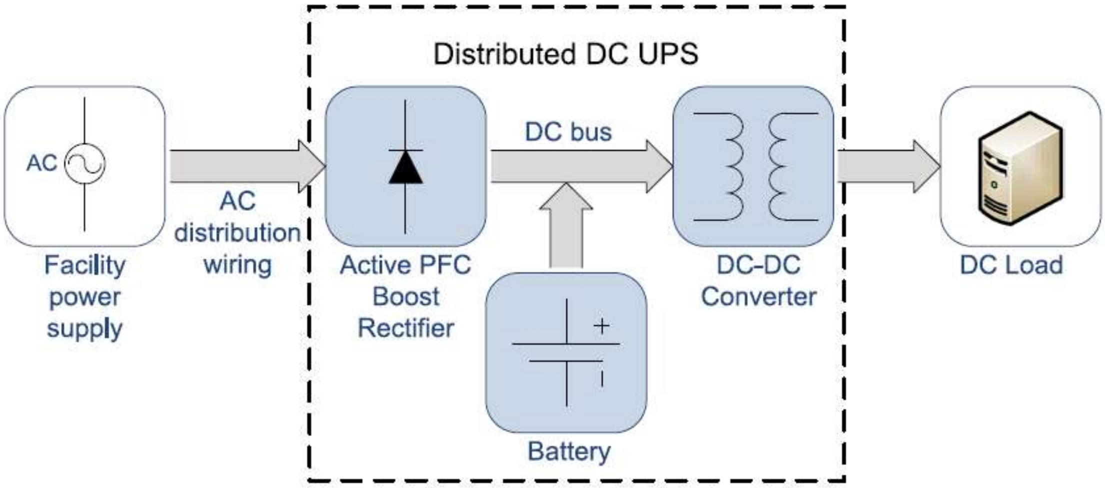


Figure 40: On-board DC-UPS concept[185]

This concept provides direct connection of the battery to the load, which is a great advantage for reliable service. In comparison the DC-UPS, offers the unsurpassed opportunity of simple parallel redundancy and direct contact between the specific load and the backup battery. With a distributed DC-UPS approach, this power supply is replaced by a high efficiency DC–DC converter that provides significant heat reduction within each data processing channel. A well-designed DC–DC card operating at 94% efficiency reduces the heat load per channel by 80%. The reduced losses in the power supplies also mean less cooling requirements for the premises (and the reduced environmental impact attributable to cooling function).

Besides the obvious advantages of energy conservation, this on-board DC-UPS also vastly increases reliability, simply by avoiding unnecessary power conversion steps (the total number is reduced from six to four), thereby reducing the total number of electronic components and circuit complexity. The DC–DC converter employed in individual servers is

[187] PDU - Power Distribution Unit
[188] PSU - Power Supply Unit

built around low-voltage technology, which is fundamentally more reliable than higher voltage components utilized in offline equipment[189].

Nevertheless, DC power distribution makes sense only if a company is building a petabyte-scale data centre from the ground up. There are many problems, such as compatibility with existing computer equipment and cable standardizations. Some server blade systems support DC distribution using dynamic load-sharing methods to improve power efficiency. However, these blade systems are expensive and do not provide compatibility with low-cost commodity volume servers or PC system power. To solve the problems, one possible solution is the use of a rack-level DC power distribution system for the data, which is fully compatible with existing data centre power infrastructures, racks, and servers and can solve power problems in a volume server, such as low-power efficiency, no power redundancy, and no power monitoring. The measurement results show over a 10% power efficiency improvement compared to an AC system providing N+1 redundant power[190].

6.3 Subtask 6.2 - State-of-the-art at component level

At the component level, one key component is the energy storage device, with batteries being the most common used. However, fuel cells and super-capacitors can also be used to replace or complement batteries. Another component with a high impact due to its weight and physical size is the transformer. The efficiency of transformers can also be improved, but the main positive impact on UPS system efficiency is achieved with a transformerless design. With the new topologies and the replacement of active switches, such as IGBTs[191], MOSFETs[192], and Thyristors[193], with diodes it is possible to achieve higher efficiency, as well as size and weight reduction.

6.3.1 Energy Storage

6.3.1.1 Lead acid Batteries

In UPS systems, batteries provide reliable temporary backup power (AC) to applications when their primary power source is suddenly unavailable. This must be maintained until the primary power re-engages or a proper shutdown is performed. In the EU, batteries in UPS systems typically operate under a 10-15 minute discharge cycle, and must provide a high amount of energy over that time period. The length of discharge can differ according to power stability and reserve capacity in different regions[194].

Lead acid batteries are the most used type of rechargeable batteries in all types of UPS. There are primarily two kinds of batteries used in UPSs — valve-regulated lead-acid (VRLA), also known as sealed or maintenance-free, and wet-cell (also called flooded-cell). At present, the vast majority (>95%) of traditional stationary standby applications are fulfilled by Lead-based batteries; either vented/flooded, VRLA AGM[195], or VRLA Gel batteries.

- Vented/Flooded batteries offer the longest service life (up to 20 years[196]), but have a greater self-discharge rate and require regular maintenance.
- Valve-Regulated Lead-acid (VRLA) batteries are preferable in certain circumstances because they require less regular maintenance, but present a shorter lifetime.

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189 A. Moreno-Munoz et al., "Energy efficiency criteria in uninterruptible power supply selection", Applied Energy 88 (2011) 1312–1321
190 Kwon, Wonok, "Design and Modeling of Highly Power efficient Node-level DC UPS", 9th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2012.
191 IGBT - Insulated-Gate Bipolar Transistor, is a three-terminal power semiconductor device primarily forming an electronic switch and in newer devices is noted for combining high efficiency and fast switching.
192 MOSFET - Metal–Oxide–Semiconductor Field-Effect Transistor, is a transistor used for amplifying or switching electronic signals.
193 Thyristor - is a solid-state semiconductor which act as bistable switches, conducting when their gate receives a current trigger, and continue to conduct while the voltage across the device is not reversed.
194 Feedback received from EUROBAT, June 2013.
195 Absorbed Glass Mat
196 EATON Corporation, "The Large UPS Battery Handbook", Eaton.com/UPSbatteries

- VRLA AGM batteries are especially well-fitted for use in UPS systems, because of the requirements for high-powered discharges over a relatively short duration.

High operating temperatures (up to 45ºC) can improve the battery performance in terms of higher capacity, but reduce the life time of the system. In addition to the relatively poor performance of the battery at low and high ambient temperatures (for each extra 10ºC step above the optimum running temperature the product lifetime at the previous step is halved), the main disadvantages of the Lead-Acid battery are the necessity for periodic water maintenance (in the case of a flooded battery) and its low specific energy and power (30 Wh/kg and 180 W/kg respectively). The output of the given energy depends on the discharge current and the batteries life also depends on discharge depth and the number of charging cycles. The deeper the discharge, the longer the time the battery is in a discharging state and fewer charge-discharge cycles occur. In addition, Lead-Acid batteries present difficulties in providing frequent power cycling, often at a partial state of charge, which can lead to premature failure due to sulphation[197].

Despite the accepted classification of lead acid technology as very mature, a wide array of research efforts continue today by addressing limitations in order to make it competitive with other battery technologies. Improvements in battery technology have been evolutionary rather than revolutionary. Capabilities such as advanced charging regimes, software management for accurate remaining life information and firmware adding intelligence to batteries have reduced, but not eliminated, the risks inherent in depending on a basic battery.

The main areas of research include the use of, secondary lead through hydrometallurgy production of plates, grid alloys, advanced charging methods, battery health monitoring and carbon electrode materials for enhanced cycle life. Lead-carbon batteries are presently a very active area of research as initial results from lab tests and a limited number of demonstration projects have shown dramatically increased cycle life over conventional lead-acid batteries. Lead-carbon batteries have carbon in the negative electrode in the forms of, a carbon additive, a carbon foam skeleton, or partial carbon electrodes. Initial estimates and tests suggest that the cycle life during high rate partial state of charge operation of lead-carbon batteries is 4-5 times greater than a comparable valve regulated battery (12,000 cycles at 10% depth cycles with lead-carbon vs. 2000 cycles with standard VRLA), potentially making this a promising and low cost technology option for this application[198].

6.3.1.2 Lithium-ion Batteries

An alternative type of battery with potential for use in UPS is the lithium-ion (Li-ion) battery. Li-ion batteries are widely used in small applications, such as mobile phones and portable electronic devices; with an annual worldwide production gross of around 2 billion cells. In addition, this type of battery attracts much interest in the field of material technology and others, in order to obtain high power devices for applications like electric vehicles and stationary energy storage.

Since the performance and the range size of the battery are strongly related to the active materials of the electrodes and the electrolyte, there is a tremendous amount of research in the field of material technology nowadays. As important features of Li-ion batteries, it is appropriate to mention their high energy density and specific energy, 170–300 Wh/l and 75–125 Wh/kg respectively. Another major feature is their fast charge and discharge capability with time constants (understood here as the time to reach 90% of the rated power of the battery) of around 200 ms, with a relatively high round trip efficiency of 78% within 3500 cycles. Maintaining safe terminal voltage and temperature operating ranges are essential aspects for this technology, due to its fragility. In addition, the use of flammable organic electrolytes raises issues about security and greenness[197].

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[197] Francisco Díaz-Gonzáleza, Andreas Sumpera, Oriol Gomis-Bellmunta, Roberto Villafáfila-Roblesb, "A review of energy storage technologies for wind power applications", Renewable and Sustainable Energy Reviews 16 (2012) 2154– 2171.
[198] Jason Leadbetter, Lukas G. Swan, "Selection of battery technology to support grid-integrated renewable electricity", Journal of Power Sources 216 (2012) 376-386.

The performance profile from a Li-ion battery best fits systems where the battery must undergo frequent cycling with deep discharge, which is not the case of UPSs. Li-ion batteries also achieve long calendar life even in high ambient temperature areas, and can be cycled frequently without significant loss of capacity and at very high energy efficiency. Therefore, they can be a good option for applications in areas where elevated temperatures and /or frequent cycling are an issue, such as high-temperatures data centres.

The major barrier to the use of Li-ion batteries in UPS is the high cost of production. However, this cost is decreasing, mainly driven by the research development associated with the application in Electric Vehicles. Li-ion batteries are presently the most actively researched battery technology due to their wide range of potential uses and superior performance to other battery technologies. Present research objectives include reducing production costs, enhancing performance, increasing lifetime, improving the material recycling and enhancing safety. These are being implemented by research in cathode and anode materials, electrolyte materials, and manufacturing processes[198].

Table 75 presents the main characteristics of Lead-acid and Li-ion batteries.

Table 75: Battery technology characteristics

	Lead-Acid	Li-ion
Capital cost (€/kWh)	200 - 600	600 - 1200
Specific energy (Wh/kg)	30 - 50	75 - 200
Specific power (W/kg)	75	75 - 300
Cycle life (cycles @ % SOC)	200 - 1800 @80%	3000 @ 80%
Cycle efficiency (%)	63 - 90	80 - 98
Daily self-discharge (%)	<0.5%	0.1 - 0.3

6.3.1.3 Batteries in UPS

Conventional energy storage systems for UPS basically rely on the choice of good lead-acid batteries. In general, Lead-based batteries remain best fitted for their established applications because of their: low cost; superior floating charge capability; proven technology in the application; robust design; high resource efficiency across the lifecycle, including high levels of recyclability; and high European manufacturing capacity. Lithium-based batteries are principally only used when space and weight are the driving factor, but they are not yet fully adapted to stationary applications not only due to the very high cost, but also due to the complex battery management system and safety issues. Nickel-Cadmium batteries can also be used in applications when environmental conditions impose extra demands that cannot be fulfilled by other technologies, but their higher upfront cost per kWh prevents them from being a mass-market substitute for all situations.

However, extracting pulsed power instead of average power from a battery can decrease its lifespan. First, the current variations cause voltage transients that can be interpreted by the low-voltage detection circuit as a discharged battery creating a premature shutdown. Second, the pulsed currents have a higher Root Mean Square (RMS)[199] value, which might cause increasing battery losses. Third, pulsating currents also reduce greatly the battery runtime[200].

Advanced technologies in battery manufacturing allow very high energy densities, but often insufficient power densities for applications with high pulsating loads. In fact, for systems having typically large power surges, the batteries become the most vulnerable part of the UPS and are continually requiring regular maintenance and replacement. Lead-acid batteries, the conventional energy storage choice for UPS, cannot be designed to bridge interruptions that last for less than many minutes. They are usually used to provide 5 to 15 minutes of backup power before a generator starts and is ready to accept the full load. In

[199] The root mean square (RMS) voltage or current is the time-averaged voltage or current in an AC system.
[200] Amine Lahyani et al., "Battery/Supercapacitors Combination in Uninterruptible Power Supply (UPS)", IEEE Transactions on Power Electronics, VOL. 28, NO. 4, 2013.

contrast to batteries, supercapacitors are ideally suited for UPS applications. They are able to supply only 5 to 20 seconds of backup at full power[201] and are mostly efficient when used to supply low, reasonably steady power levels.

6.3.1.4 Supercapacitors

The EDLC (Electric Double Layer Capacitor), which is commonly termed supercapacitor (SC) and ultra-capacitor (Figure 41) is a complex devices in which the charge is stored in a double layer formed at the interface between a large surface area material such as activated carbon and a liquid electrolyte. A SC stores energy not by a chemical process as in a battery but in an electrostatic field between two parts charged oppositely when they are separated. A SC is actually two capacitors in series. A supercapacitor can store a thousand times more energy than a typical capacitor and shares the characteristics of both batteries and conventional capacitors.

Figure 41: Supercapacitor UPS module (Maxwell Technologies)

This energy storage option has higher reliability and higher power density, but smaller energy density than a lead-acid battery (provides an energy density about 20% of a battery). Other main advantages of supercapacitors are the rapid recharge capability, a large number of charge and discharge cycles (several hundred thousand cycles), the capability to supply much higher currents, a wider temperature range, a low degradation (up to 1,000,000 cycles), high efficiency (above 95%), reduced maintenance needs and an easy to implement charging technology. However, they still present a high price, the energy density is lower and the voltage depends on the degree of charge[202].

With the ability of supercapacitors to withstand high voltage transients superimposed on AC mains, a new approach to develop a surge resistant UPS (SRUPS) topology was realized using supercapacitors. While the early version of the circuit blocks indicated a promising approach, the final circuits achieved during the early work were not adequately cost effective to go into a commercially viable design. However, the concepts proven through the work have opened up a new way to use supercapacitors in the middle of a UPS topology. Here they are used both as an energy storage medium, and surge absorbing elements providing a higher reliability level for the inverter circuits and the critical load. Further developments could lead to achieving a fully versatile SRUPS topology while minimizing the battery pack requirements for short term blackouts on the AC mains[203] [204].

In UPS applications, batteries usually provide 5–15 minutes of backup power before a generator starts and is ready to accept the full load. Supercapacitors can supply only 5–20 seconds of backup at full power. This means that SCs could be a good battery replacement only when long runtime is not required because of their high price, their large size and high

[201] Amine Lahyani, Pascal Venet and Alaa Troudi, “Design of Power Sharing System Between Supercapacitors and Battery in an Uninterruptible Power Supply”, 2011 IEEE 33rd International Telecommunications Energy Conference (INTELEC).
[202] Andrew Stepanov, Ilya Galkin, “Concept of Modular Uninterruptible Power Supply System with Alternative energy storages and sources”, 7th International Conference-Workshop Compatibility and Power Electronics (CPE), 2011.
[203] Nihal Kularatna and Lasantha Tilakaratne, “Design Approaches to Supercapacitor Based Surge Resistant UPS Techniques”, IECON 2011 - 37th Annual Conference on IEEE Industrial Electronics Society, 2011.
[204] An example for SCs powered UPS: (http://www.j-schneider.de/en/ups-power-supplies/ac-ups-with-ultra-capacitors/)

mass[205]. Advantages of SCs are their high efficiency (typically 99%), quick availability in case of grid failure providing on-line speed with off-line topology and fast recovery after discharge due to the short recharge time and their reliability and the availability of the full capacity. As a result they are used for power conditioning and voltage sag compensation or short-term UPS, where battery-based energy storage is not fast enough (Figure 42 presents an example of use of capacitors in UPSs). They work at ambient temperatures from -40°C up to 40°C where batteries provide only reduced or no power. Other advantages are a lifetime of 20 years at temperatures much higher than the 20°C optimum for batteries and no problems with deep discharge. The development of electric vehicles is one of the drivers of the SC development and UPS systems will benefit from this development. Carbon nanotube technology could further improve the capacity of SCs.

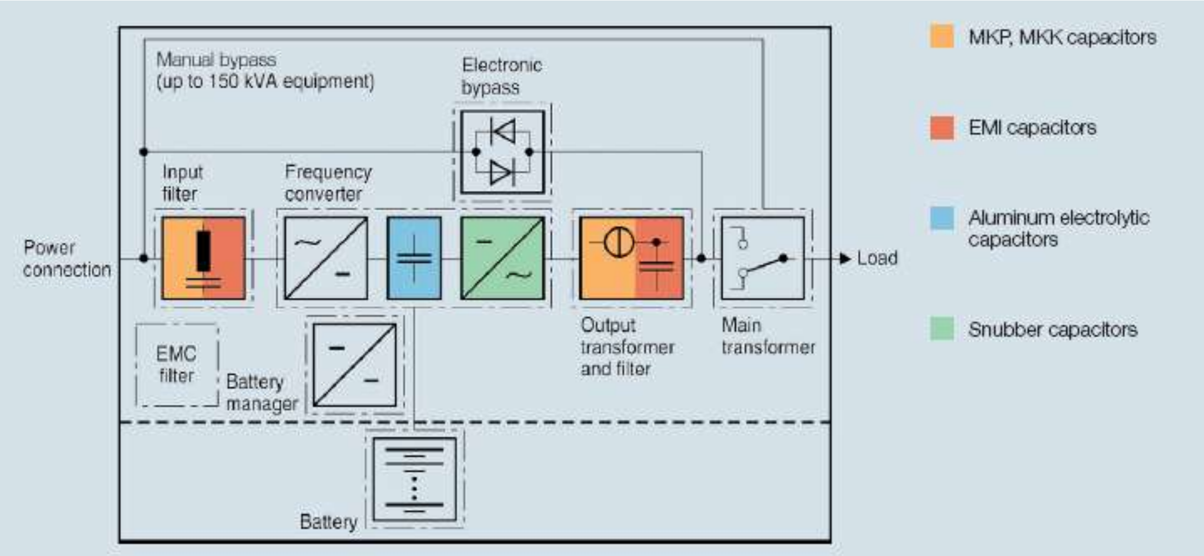

Figure 42: Use of capacitor in UPSs[206]

By using a SC combined with a battery the power performance of the SC and the greater energy storage capacity of the battery is realised. A hybrid[207] solution combining SCs and batteries could cover short interruptions, voltage and frequency variations without discharging the battery. This significantly extends the battery lifetime (reducing the battery stress[208]) by reducing the number of discharge-charge-cycles and it reduces the cost of maintenance. The load power is filtered by a low-pass filter, the SCs support the peak power, reducing high power demands on the battery[201].

6.3.1.5 Fuel Cells

Fuel cells (FCs) are electrochemical devices, generating electric power without process of burning, using a chemical process, almost the same as battery. The difference is that in a FC other chemical substances are used, such as hydrogen and oxygen; and a product of the chemical reaction is water, making them a generation source, environmentally safe and very efficient. These kinds of electrical sources can be used in stand-alone single-phase high quality power generation[209].

[205] Amine Lahyani et al., "Battery/Supercapacitors Combination in Uninterruptible Power Supply (UPS)", IEEE Transactions on Power Electronics, VOL. 28, NO. 4, APRIL 2013
[206] Source: EPCOS AG
[207] An example of an hybrid UPS is the PCS100 from ABB (http://www04.abb.com/global/seitp/seitp202.nsf/0/2f66db4e642fbf8fc125784e0047c044/$file/2ucd301083_h+pcs100+ups-i.pdf)
[208] Amine Lahyani, et al., "Utilization of Supercapacitors to Reduce Lead Acid Battery Stresses in UPS", 2012 First International Conference on Renewable Energies and Vehicular Technology.
[209] M. Tarafdar Hagh, E. Mokhtarpour Habashi, A. Khoshkbar Sadigh and G. Gharehpetian, "Flying Capacitor Multicell Converter Based Uninterruptible Power Supply Fed by Fuel Cell", SPEEDAM 2010, International Symposium on Power Electronics, Electrical Drives, Automation and Motion.

Backup is one of the most extended applications for FCs due to its relatively low number of requirements when compared to other applications (e.g. in the automotive industry). In comparison to batteries, FCs provide longer continuous runtime and better durability under hard environmental conditions. They require less maintenance than both generators and batteries because they have few moving parts. Compared to generators, FCs are quieter and can involve no emissions[210].

The integration of fuel cells with UPS would become a potential market application for extended run-time UPS. Among fuel cell technologies, the proton exchange membrane fuel cell (PEMFC) and the liquid-fed direct methanol fuel cell (DMFC) are the most promising[211]. Fuel cells will potentially be a future contender in the long term as demand and power capacities requirements for UPS increases, especially in grid-connected applications where good quality reliable power supply is required, or interruptions could last long time, e.g. over 8 hour. Nowadays fuel cells are already used in telecommunication systems. Such systems are one of the most interesting commercial applications for PEMFC based backup systems, which may require 1–10 kW power capability and 12–24 h autonomy[210].

Nevertheless, FCs also involve drawbacks that primarily include high capital cost, slow dynamics in starts and transients, and low power density. Limited by their inherent characteristics, the fuel cells have a long start-up time (usually several seconds to minutes) and poor response to instantaneous power demands[212], needing an auxiliary power source to perform secondary functions such as supplying starts-up, fast dynamics, and power peaks.

The combination of fuel cells with a small capacity of batteries (Figure 43) or supercapacitors yields hybrid power sources that make the best use of the advantages of each individual device and may meet the requirements for the above mentioned applications regarding both high power and high energy densities[213]. On the other hand, the UPS system employing a PEMFC as the main power source must involve the battery or supercapacitor to protect the PEMFC, in order to keep the water content balance, avoid excessive use, avoid reactants starvation of the PEMFC and feed power smoothly to the external load[212].

[210] Manuel Jesús Vasallo, José Manuel Bravo, José Manuel Andújar, “Optimal sizing for UPS systems based on batteries and/or fuel cell”, Applied Energy 105 (2013) 170–181.
[211] Yuedong Zhan, Hua Wang, Jianguo Zhu, Youguang Guo “Fault Monitoring and Control of PEM Fuel Cell as Backup Power for UPS Applications”, IEEE Energy Conversion Congress and Exposition, 2009.
[212] Yuedong Zhan, Hua Wanga, Jianguo Zhu, “Modelling and control of hybrid UPS system with backup PEM fuel cell/battery”, Electrical Power and Energy Systems 43 (2012) 1322–1331.
[213] Yuedong Zhan, Hua Wang, Zongkai Shao, Jianguo Zhu, Youguang Guo, “Modeling and Control of Power Converters in UPS Applications with PEM Fuel Cell”, 2009 IEEE International Conference on Applied Superconductivity and Electromagnetic Devices.

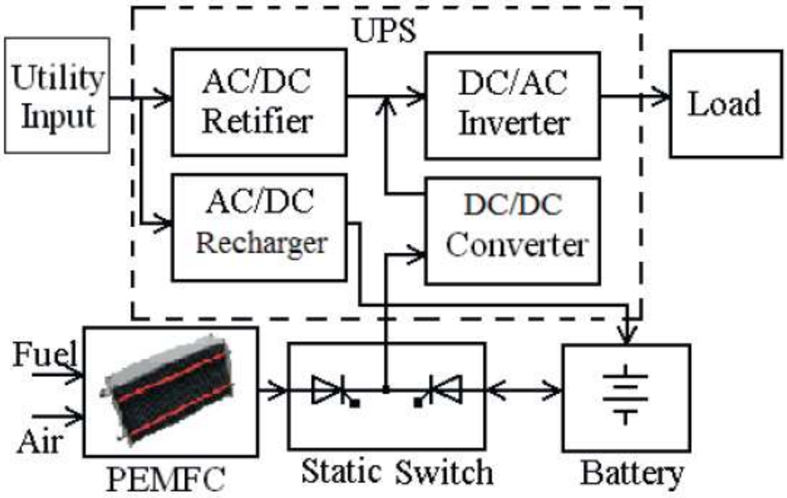

Figure 43: Scheme of UPS with backup PEMFC and battery power sources[213]

6.3.2 Transformers

Most of the double conversion online UPSs operate with a low-frequency transformer using a silicon-steel core. In this configuration, an isolating transformer is required for proper operation of the bypass circuit and also to improve reliability of the system, since the transformer offers a galvanic isolation to the load from undesirable disturbances of the grid. A transformer such as this is placed at the output, employing a delta/wye winding configuration. The addition of such a magnetic component increases both weight and volume and also adds cost and difficulties in the transportation to the installation site[214].

Transformer efficiency is mostly characterised by two factors – standing (magnetic) losses and load dependent (resistive) losses (Figure 44), both of which need to be characterised separately in order to give total losses over a wide range of loads.

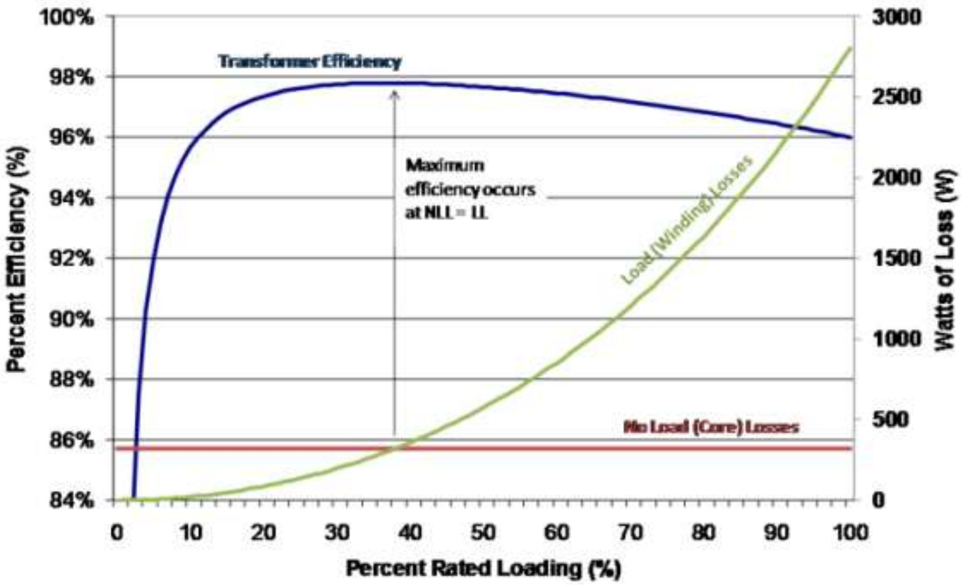

Figure 44: Transformer efficiency and losses for 75 kVA oil immersed transformer[215]

[214] Carlos G. C. Branco, René P. Torrico-Bascopé, Cícero M. T. Cruz, and Francisco K. de A. Lima "Proposal of Three-Phase High-Frequency Transformer Isolation UPS Topologies for Distributed Generation Applications", IEEE Transactions on Industrial Electronics, Vol. 60, N. 4, April 2013

[215] VITO & BIOIS, "LOT2 Distribution and Power Transformers, Preparatory Study", 2011.

Transformers can be improved by using similar technology based on silicon steel transformers with[215]:

- The use of copper compared to aluminium conductors;
- The use of a circular limb core cross-section;
- The use of High permeability Grain Oriented Electrical Steel (HGO) with lower losses (Cold rolled Grain-Oriented steel, High permeability steel, Domain Refined high permeability steel);
- The use of amorphous steel (significant lower core losses) (not possible to larger power transformers);
- The use of transformers with silicon liquid, synthetic esters or biodegradable natural esters instead of dry cast resin transformers or mineral oil;
- Increasing the cross section of the conductor and cross section of the core;
- Core construction techniques (e.g. mitred lapped joints);
- The transformer design variability combining above improvements;
- Improved coatings between the laminations of conventional silicon steel;
- Reducing the transformer noise.

All the above improvement options increase the product price. Several improvement options increase the product volume and mass. The improvements options considered as Best Not yet Available Technologies concern[215]:

- Further improvements of Grain oriented magnetic steels, amorphous microcrystalline material as core materials;
- The use of superconducting technology;
- The use of smart grid technology to switch off a by-pass transformer's off peak load (system level).

For small transformers the scope for improvement, as well as the savings potential in absolute terms, is limited. The improved transformers can be achieved by the manufacturers using existing technology (e.g. high grade commercially available silicon electrical steel) and their existing manufacturing equipment. For separation/isolation transformers a consumption reduction of 2.5% is expected until 2025[216].

A transformerless UPS incorporating a common neutral bus line is a solution to improve power conversion efficiency and volume and weight reduction. Although this type of UPS topology offers a way to obtain these advantages, it does not provide isolation to critical loads, such as medical instruments. The high-frequency transformer (HFT) isolation technology could be used when the desired feature of the UPS is weight and volume reduction of the transformer-isolation-based equipment. In order to implement this technique, there is a requirement for the addition of more power conversion stages, thereby achieving a final energy conversion efficiency which is lower than that of any available conventional UPS solution. Considering the constant development of the semiconductor industry, advanced technology on topology, core of transformer, and soft switching, there is an expectation that this solution could be used in the next generation of UPS or solid-state transformer (SST) applications[190].

6.3.3 Semiconductors and topologies

6.3.3.1 Semiconductors

In this section the latest development in semiconductor relevant to UPS are discussed.

Silicon power products continue to have incremental improvements, yet the evolution of technologies in Power Conversion is not following the Moore law[217] but more reaching the asymptote of semi-conductor and electromechanical theoretical limits of performances.

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[216] ISR-UC & Ricardo-AEA, "LOT2 Power Distribution and Small Transformers, Impact Assessment", 2013.
[217] Moore's law is the observation that, over the history of computing hardware, the number of transistors on integrated circuits doubles approximately every two years.

However, some breakthroughs for active components are foreseeable with the use of silicon carbide (SiC) or gallium nitride (GaN).

Silicon carbide is a compound semiconductor with superior power characteristics to silicon, which makes it ideal for power electronics applications. The properties of SiC which make it superior to Si in the area of high power electronics include wider band gap, higher critical electric field and high thermal conductivity[218]. Figure 45 shows that with a SiC Schottky barrier diode (SBD), switching losses are reduced by 2/3 compared to a silicon fast recovery diode (FRD)[219].Therefore, SiC devices can operate at higher temperatures and higher radiation levels than silicon and gallium arsenide based devices. Nevertheless, one of the main hurdles for a fast market penetration was the SiC crystal size, quality and cost[220].

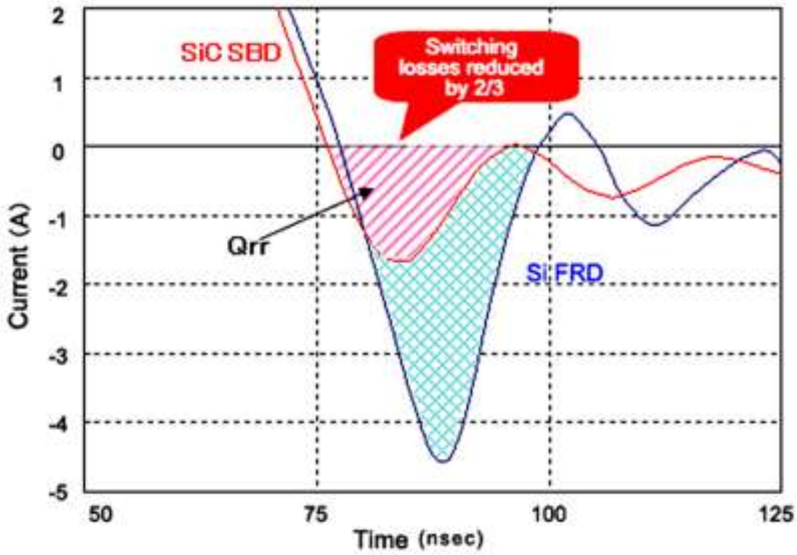

Figure 45: Comparison of switching losses between SiC and silicon diodes[219]

Silicon carbide (SiC) semiconductor devices for high power applications are now commercially available as discrete devices. Recently Schottky diodes and active switching devices such as bipolar junction transistors (BJTs), field effect transistors (JFETs and MOSFETs) are now available on the commercial market[221].

GaN has similar bandgap and dielectric constant (hence comparable breakdown voltage) to SiC. It has higher electron mobility but only ¼ the thermal conductivity. This technology is early in its development/commercialization phase relative to SiC and is available only as heterostructures with a thin layer of GaN on top of other materials (sapphire, silicon or SiC). Therefore, it is difficult to build vertical devices, thus making this material less appealing for power applications. For GaN materials the main application area is geared towards the lower power rating level up to 1 kV on mostly lateral field effect transistors designs.

Other option is the diamond technology which is currently at a very early stage, with no good quality wafers available, and a lot of process steps to be developed.

Some of the physical properties of several semiconductor materials are listed in Table 76[222].

[218] Bayne SB, Pushpakaran BN (2012) Silicon Carbide Technology Overview. J Electr Eng Electron Technol 1:1.
[219] ROHM Semiconductor, Silicon Carbide Schottky Barrier Diodes, 2011
[220] Friedrichs, P., "SiC power devices for industrial applications," Power Electronics Conference (IPEC), 2010 International , vol., no., pp.3241,3248, 21-24 June 2010
[221] Ostling, M.; Ghandi, R.; Zetterling, C. -M, "SiC power devices — Present status, applications and future perspective," Power Semiconductor Devices and ICs (ISPSD), 2011 IEEE 23rd International Symposium on , vol., no., pp.10,15, 23-26 May 2011
[222] Cyril Buttay, Dominique Planson, Bruno Allard, Dominique Bergogne, Pascal Bevilacqua, Charles Joubert, Mihai Lazar, Christian Martin, Hervé Morel, Dominique Tournier, Christophe Raynaud, State of the art of high temperature power electronics, Materials Science and Engineering: B, Volume 176, Issue 4, 15 March 2011, Pages 283-288

Table 76: Physical properties of the different semiconductor materials[222]

	"Classical"		Wide-bandgap				
	Si	GaAs	3C–SiC	6H–SiC	4H–SiC	GaN	Diamond
Bandgap energy E_g (eV)	1.12	1.4	2.3	2.9	3.2	3.39	5.6
Elec. mobility μ_p ($cm^2\ V^{-1}\ s^{-1}$)	1450	8500	1000	415	950	2000	4000
Hole mobility μ_p ($cm^2\ V^{-1}\ s^{-1}$)	450	400	45	90	115	350	3800
Critical elec. field E_c ($V\ cm^{-1}$)	3×10^5	4×10^5	2×10^6	2.5×10^6	3×10^6	5×10^6	107
Saturation velocity v_{sat} ($cm\ s^{-1}$)	10^7	2×10^7	2.5×10^7	2×10^7	2×10^7	2×10^7	3×10^7
Thermal cond. λ ($W\ cm^{-1}\ K^{-1}$)	1.3	0.54	5	5	5	1.3	20
Dielectric constant ε_r	11.7	12.9	9.6	9.7	10	8.9	5.7

However, SiC and GaN technologies are not at all yet available at the right size, cost and quality level. SiC proof of concept should be ready to be implemented in UPS design within 5 years, but it should be introduced progressively according to availability and size of this new SiC components that will be used in various UPS power ratings. On a business stand point this might not be effective in the market before 10 years due to the high cost of these new components when they are usually available and the actual integration ramp up related to new UPS design cycles in the years to follow the year of availability[223].

6.3.3.2 Topologies

In accordance with the topology or configuration, the UPS can be classified as on-line, off-line and line-interactive types. The on-line UPS is generally preferred due to the wide tolerance of the input voltage variation, the precise regulation of output voltage and high reliability of the system. A conventional three-phase on-line UPS consists of a rectifier/charger, a battery set, an inverter, a transformer and bypass switches. In this configuration an isolating transformer is normally required for proper operation of the bypass circuit and also to improve the reliability of the system, since the transformer offers a galvanic isolation to the load from undesirable disturbances of the main supply. Such a transformer is placed at the input or output depending on the topology arrangement[224].

However, the conventional UPS has several drawbacks and BAT solutions are discussed below.

High voltage batteries

First, the high-voltage battery set has the problem associated with space, cost, reliability and safety. To solve it, a separate charger/discharger can be used to reduce the voltage of the battery set and the number of batteries[225].

Transformer-based and transformerless UPSs

Secondly, since the transformer is operated at line frequency, the transformer which often weighs tens of kilograms increases the size, weight and cost of the UPS and makes it difficult to move and install[225]. Other topologies were proposed in the research literature studied to overcome this problem, using the isolation transformer in a high frequency DC link. Although this UPS topology incorporating a high frequency transformer reduces the weight of the system, it increases the number of active switches and power stages, compromising the system's overall efficiency and reliability.

[223] Feedback received from CEMEP, November 2013.
[224] René P. T. Bascopé, Carlos G. C. Branco, Cícero M. T. Cruz, Eduardo F. de Oliveira and Gean J. M. Sousa, "Proposal of a 5kVA single-phase on-line UPS with high frequency isolation and power factor correction", Brazilian Power Electronics Conference, 2009, COBEP '09.
[225] E.-H. Kim J.-M. Kwon B.-H. Kwon, "Transformerless three-phase on-line UPS with high performance", IET Power Electronics, Volume:2, Issue: 2, 2009.

Transformerless UPS (Figure 46) incorporating a common neutral bus line using a half-bridge converter and inverter has attracted special interest for applications in computer and telecommunication systems[226]. This type of system is highly cost-effective and acceptable due to its total power conversion efficiency improvement, volume and weight reduction. However, some disadvantages exist such as: the unbalance between the upper and lower side DC link capacitors and the exposure of the AC-DC and DC-AC converters switches to the total DC link voltage[226]. This type of configuration is more susceptible to interference from spikes and transients caused by assorted devices connected to the utility grid.

Several UPS topologies with high frequency isolation characteristic are possible. These configurations belong to topologies based on converters such as the isolated boost full-bridge[227], flyback[228] and chopper boost[229]. Common drawbacks found in most of these approaches are the hard commutation of the controlled switches resulting in compromised efficiency, the requirement for, several batteries in series connection to achieve high DC-link voltage and pulsed current drawn by the battery bank that affects the reliability of the battery set[224]. Table 77 provides a comparison between transformer-based and transformerless UPSs.

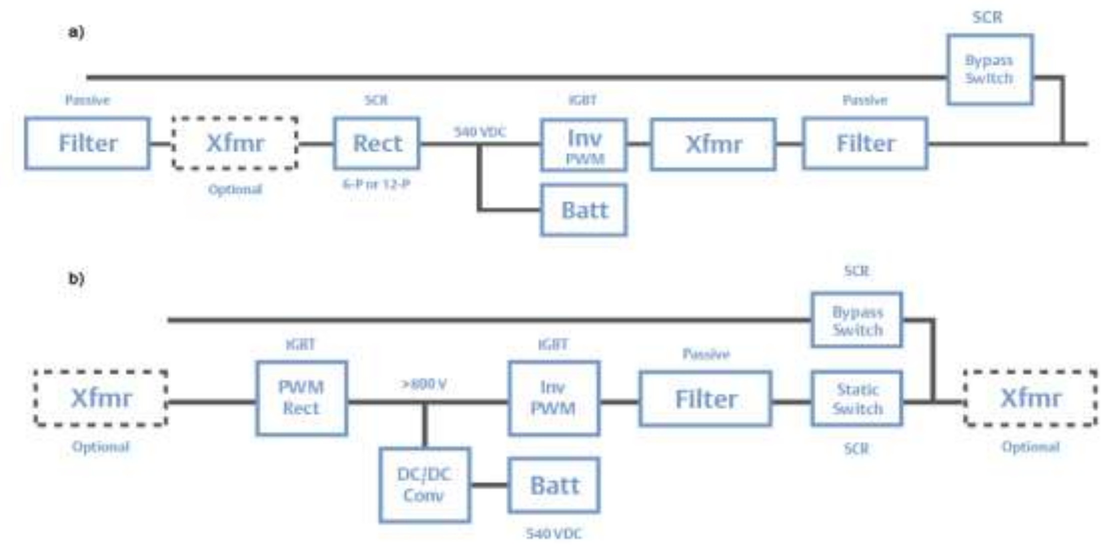

Figure 46: Transformer-based (a) and transformer-free (b) UPS block diagram[230]

Table 77: Comparison of transformer-based and transformerless UPSs[230]

Feature	Transformer-based UPS	Transformerless UPS
Weight and size		Typically 25% less weight and 40% smaller footprint
Efficiency	90 to 93%	92 to 97%
Energy saver mode	Less efficient, slow to transition	99% efficient, 2 minutes transition time
4-wire output availability	Yes	Yes

[226] Raphael A. da Câmara, Paulo P. Praça, Cícero M. T. Cruz, René P. Torrico-Bascopé, "Voltage Doubler Boost Rectifier Based on Three-State Switching Cell for UPS Applications", 35th Annual Conference of IEEE Industrial Electronics, 2009. IECON '09.
[227] Full-bridge isolated boost converters have a transformer in their topology and are very attractive in applications where an output DC voltage that is considerably larger than the input voltage is needed.
[228] The flyback converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and any outputs. More precisely, the flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation.
[229] A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage.
[230] Emerson, "Comparing Transformer-free to Transformer-based UPS Designs", 2012

Separately-divided source	Not when on bypass	Not when on battery
Support for high-resistance ground (HRG) sources	Yes, with reduced HRG benefit	Yes, with HRG fault tolerance preserved
Reliability (MTBF)	Lower	Higher, due to lower component count
Ability to limit fault current and mitigate arc flash	Good	Better, due to faster detection and isolation (not slowed by output impedance)
Generator compatibility	Requires larger filter, contactor and generator	Allows closely-sized generator and both reduces part count and raises efficiency by not requiring a 12-pulse rectifier or input filter

Multilevel circuit topology

To further improve the efficiency of double conversion UPS systems and promote size/weight reduction, multilevel circuit topology presents a wide range of benefits for UPS systems in comparison with the traditional two-level converter. The term multilevel refers to a circuit configuration that divides the DC-link voltage to generate three or more voltage levels at the output terminals. There are many topologies including neutral-point clamped (NPC), capacitor clamped; and cascaded H-bridge. Technically, the NPC circuit is the most attractive and has become the most popular configuration featuring many industrial applications[231].

Diode-clamped NPC circuit has been used in UPS for achieving higher efficiency due to the fact that multilevel topology enables lower switching losses. By using the bidirectional-switch NPC multilevel topology, UPS systems can realize higher efficiency in comparison with other conventional circuit topologies. Test results using an UPS rated at 750 kVA confirm superior efficiency (97%) and performance[232].

Despite the fact that three-level converter requires a higher number of components, the overall efficiency actually increases in comparison with a traditional two-level topology. A three-level converter uses twice the numbers of IGBT modules. Therefore, the average conduction losses become higher. However multilevel converters promote lower voltage stresses on power semiconductors that reduce the losses of conversion. Figure 47 shows the comparison of losses in a two- and a three-level circuit with same specification of IGBT modules by simulation with 7.2 kHz switching frequency. Switching losses accounted for over two-thirds of total power dissipation in a two-level circuit. In a three-level circuit using bidirectional-switch neutral point clamp topology, switching losses accounted for nearly 34% of semiconductor losses, a reduction of about 40% in comparison with a two-level topology[232].

[231] Eduardo Kazuhide Sate, Masahiro Kinoshita, Yushin Yamamoto, and Tatsuaki Amboh "Design and Realization of a Novel Green-Oriented Double Conversion Uninterruptible Power Supply", 31st International Telecommunications Energy Conference, 2009. INTELEC 2009
[232] TingAn Lee, Masahiro Kin oshita, Kazunori Sanada, "High-Efficiency Large-Capacity Uninterruptible Power Supply Using Bidirectional-Switch-Based NPC Multilevel Converter", 8th International Conference on Power Electronics – ECCE 2011.

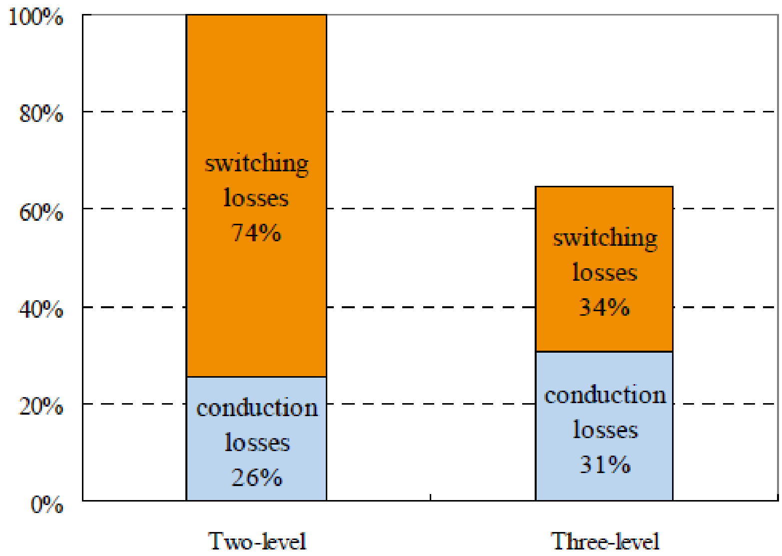

Figure 47: Comparison of semiconductor losses in a two-level and a three-level Circuit[5]

Single-conversion and Delta-conversion

Line-interactive UPS is regarded as the most recent innovation among available UPS systems. Offering many advantages of the other two types of the on-line and off-line UPS systems, and overcoming many of their drawbacks, line-interactive UPS has proved suitable to be employed in many applications such as small business, web and departmental servers. Based on their structures, two groups of line-interactive UPS exist; single-conversion and delta-conversion line-interactive (SL and DL) UPSs (Figure 48)[233].

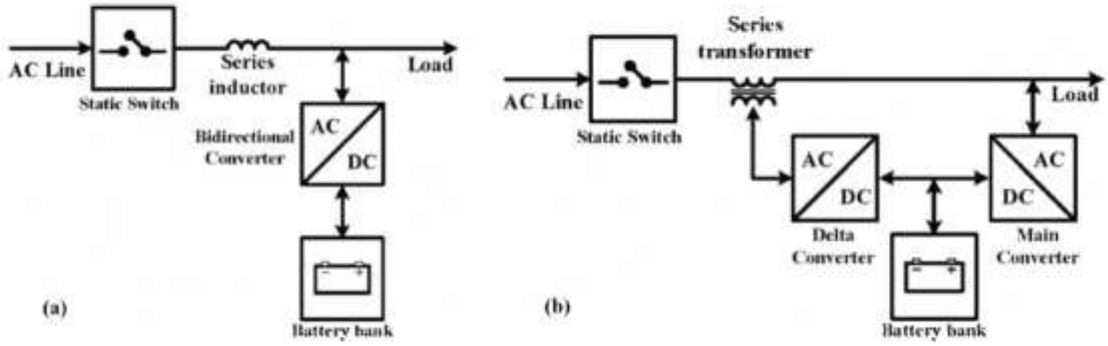

Figure 48: Line interactive UPS, (a) Single-conversion (b) Delta-conversion[233]

Compared to the off-line UPS, the performance of the SL UPS is far superior considering several factors such as voltage conditioning, power factor correction and transfer time. However, the topology suffers from two primary disadvantages. First, the simultaneous regulation of the output voltage and input power factor is restricted especially when the voltage drop across the input inductor and hence its consumed reactive power is considerable and secondly, the bypass operation is not transient-free. These drawbacks have limited the use of SL UPS[233].

Delta-conversion UPSs use a special transformer configuration to interface between the load utility power, with a “delta” inverter in the transformer secondary to regulate input current and power. With this configuration, the UPS can regulate the magnitude, wave shape, and power factor of the current supplied at the UPS input, while still controlling the voltage at the load.

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[233] A. Fatemi, M. Azid, M. Mohamadian, A. Yazdian, “Single-phase Delta-conversion UPS With Reduced Components”, 2012 3rd Power Electronics and Drive Systems Technology (PEDSTC)

This results in an optimised power factor at the UPS input. However UPS output is not independent of input supply frequency variations[234]. The availability provided to the load by all the "hybrid" solutions, such as Delta-conversion, is difficult to compare to well defined UPS types and the energy efficiency performances are linked to the energy quality provided to the load (harmonic distortion, power factor correction, etc.) which make it difficult to specify and compare.

6.3.4 Size and weight reduction

The conventional on-line UPS topology employs a big number of switches and as a consequence, suffers from high cost, which often does not allow its adoption in some cost sensitive applications. Therefore the idea of developing different topologies to reduce the cost of UPS systems attracts research and development attention. Reducing the number of active switches brings one of the most significant cost reductions. This could be implemented by replacing IGBTs, MOSFETs, and Thyristors, with diodes[235] (this is a possible approach, but no yet implemented in commercial products). Not only are diodes cheaper than active switches, but there is also a cost reduction from eliminating gate drivers for active switches. This contributes to a further cost reduction by eliminating the circuitry for driving power switches and simplifying the control circuit by lowering the voltage stress across power switches and eliminating passive components like transformers, capacitors and inductors. Removing bulky passive elements and lowering the number of power switches would bring some advantages like greater compactness and higher reliability[236].

To further improve the efficiency of double conversion UPS systems and at the same time promote size/weight reduction, multilevel circuit topology presents promising benefits for UPS systems in comparison with the traditional two-level converter[237]. Therefore, three-level power converters potentially have a competitive advantage in terms of size/weight reduction. A multilevel topology requires a smaller filter to obtain a clean sinusoidal waveform. It implies that a three-level UPS has smaller dimensions in comparison with a conventional two-level UPS. The dimensions and footprint for a 160 kVA module are reduced by approximately 30% in comparison with a conventional UPS (Figure 49). Weight is dramatically reduced (over 60% reduction) owing also to a transformerless design[238]. Therefore, a three-level UPS requires less space and infrastructure and ensures plenty of room for maintenance and layout reconfiguration.

[234] A. Baggini, M. Granziero, "Performances Comparison of Delta-Conversion and Double-Conversion UPS", Socomec UPS, 2011
[235] Sharifian, M. Niroomand, M. "Novel reduced switches single-phase to three-phase on-line uninterruptible power supply", 2011 International Aegean Conference on Electrical Machines and Power Electronics and 2011 Electromotion Joint Conference (ACEMP).
[236] Bahram Ashrafi, Mehdi Niroomand, Behzad Ashrafi Nia, "Novel Reduced Parts On-Line Uninterruptible Power Supply", 2012 IEEE International Power Engineering and Optimization Conference (PEOC02012)
[237] Eduardo Kazuhide Sato, Masahiro Kinoshita, Yushin Yamamoto, and Tatsuaki Amboh, "Redundant High-Density High-Efficiency Double-Conversion Uninterruptible Power System", IEEE Transaction on Industry Applications, VOL. 46, NO. 4, July/August 2010
[238] Eduardo Kazuhide Sate, Masahiro Kinoshita, Yushin Yamamoto, and Tatsuaki Amboh "Design and Realization of a Novel Green-Oriented Double Conversion Uninterruptible Power Supply", 31st International Telecommunications Energy Conference, 2009. INTELEC 2009

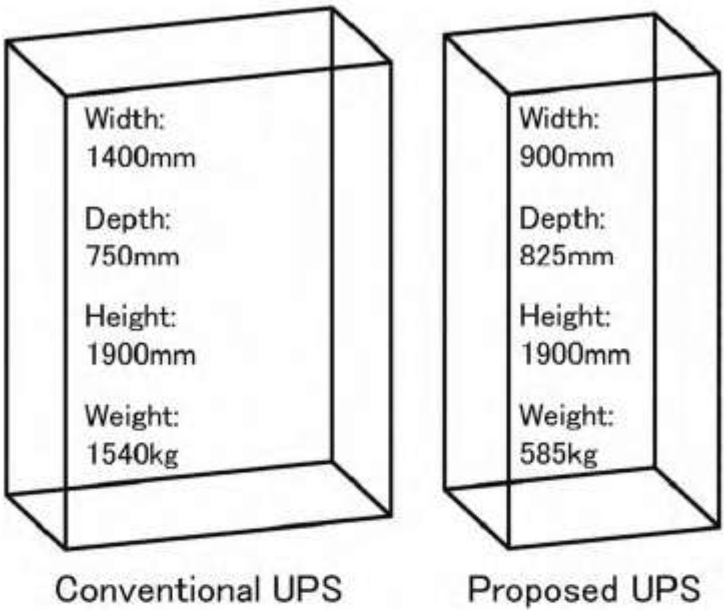

Figure 49: Dimensional comparison for a 160 kVA UPS[238]

The dimensions and footprint for a 225 kVA module (Figure 50) are also reduced by approximately 30% in comparison with a conventional UPS. Weight is dramatically reduced (over 60% reduction) owing also to a transformerless design[239].

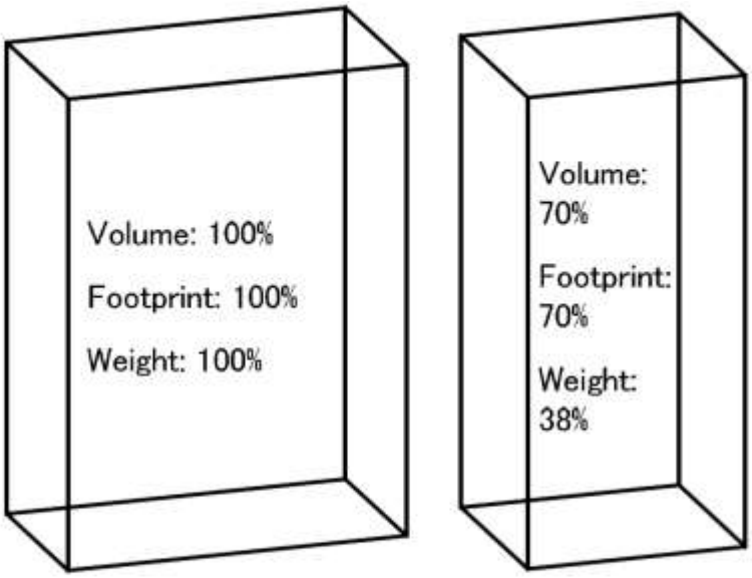

Figure 50: Dimensional comparison for a 225 kVA UPS[239]

Figure 51 presents the main circuit configuration of an online UPS with transformerless design, which comprises a PWM-based rectifier, a PWM inverter, a bidirectional chopper circuit, a DC-link circuit and an input and output LC filter[240].

[239] Eduardo Kazuhide Sato, Masahiro Kinoshita, Yushin Yamamoto, and Tatsuaki Amboh, "High Efficiency Multilevel Uninterruptible Power Supply", IEEE Energy Conversion Congress and Exposition ECCE 2009.
[240] TingAn Lee, Masahiro Kinoshita, Kazunori Sanada, "High-Efficiency Large-Capacity Uninterruptible Power Supply for 3-Phase 4-Wire Power System", 2012 IEEE 7th International Power Electronics and Motion Control Conference.

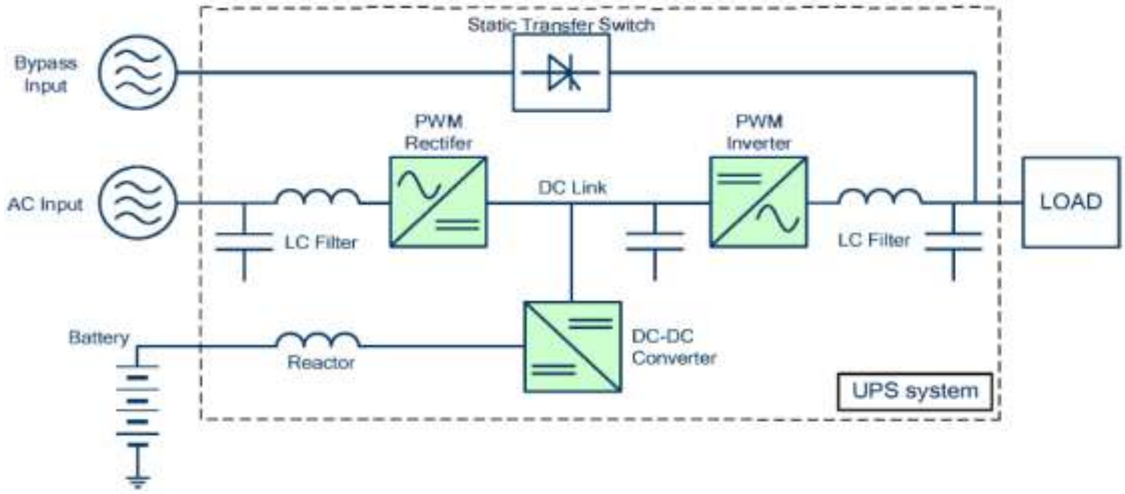

Figure 51: Main circuit configuration of the proposed UPS[240]

Using such approach in a 600 kVA UPS, the dimension, footprint and weight are reduced by approximately 46% in comparison with a conventional UPS. In a 750 kVA UPS, the same level of reductions can be achieved[241].

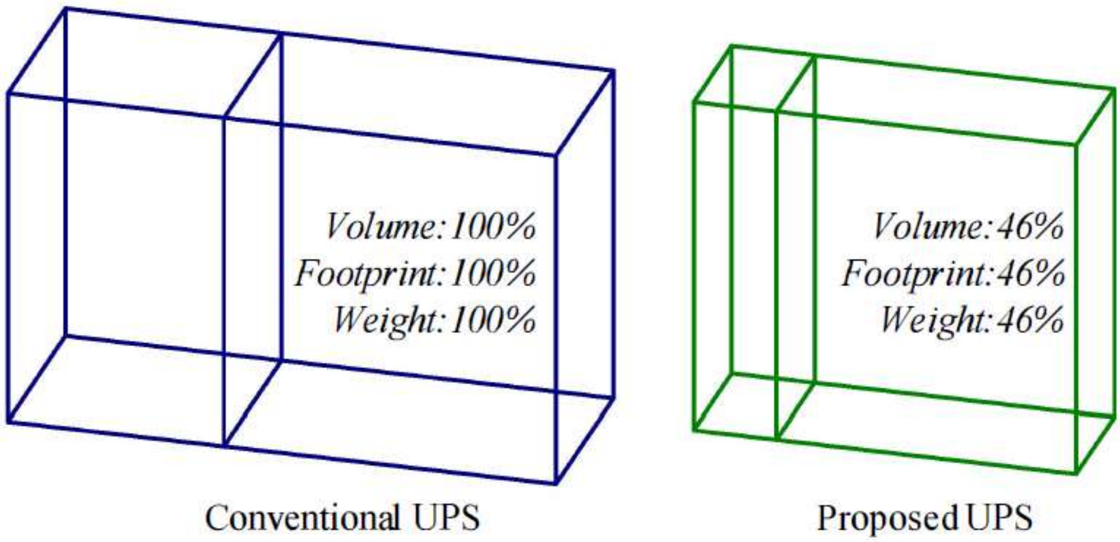

Figure 52: Dimensional comparison for a 600 kVA UPS[240]

[241] E. K. Sato, M. Kinoshita, and K. Sanada, "Double DC-DC Converter for Uninterruptible Power Supply Applications", 2010 International Power Electronics Conference.

6.4 Subtask 6.3 - Best existing product technology outside the EU

Most of the market of UPS is concentrated in a small group of companies, which are global companies. Therefore, all the major companies have their products available in EU and all the best existing products available outside the EU are also available in EU.

6.5 Conclusions

At product level improvements are achievable not only in terms of global efficiency, but also by ensuring a flat efficiency curve. In terms of efficiency, the latest topologies have almost reached an asymptote with very high efficiency at full load (95-98%). Therefore, it will be more and more challenging to gain additional efficiency at full load. However, many UPSs are running with a load size representing less than 50%, or less, of the UPS power rating. Therefore, in the near future, one of the main challenges for manufacturers will be to improve efficiencies to low load levels. In order to assess the improvements achieved on energy efficiency, the four base cases (BC) defined in task 5, were considered and to characterize the best products available on the market, the ENERGY STAR database was used. The BAT products already present much higher efficiency and almost flat efficiency curve.

Regarding the intelligent control of UPS, the application of the double conversion UPS power treatment solution can be improved in efficiency by the intelligent use of the double conversion mode of a UPS. This circuitry will then control the functions of the UPS to optimise the power transfer efficiency of the UPS to provide pre-programmed power quality limits for the load. Another option to achieve higher efficiency at product level is through DC distribution. The data centre IT equipment provides essentially, a DC-based load. Thus, by deploying a DC rather than a conventional AC, power distribution, a number of conversion steps in the power delivery system can be eliminated, thus reducing the distribution losses.

At the component level, one key component is the energy storage device, with lead-acid batteries being the most common used. Improvements in battery technology have been evolutionary rather than revolutionary. The increased application of advanced charging regimens, software management for accurate remaining life information and firmware adding intelligence to batteries have reduced, but not eliminated, the risks inherent in depending on a basic battery. The main areas of research include the use of secondary lead through hydrometallurgy production of plates, grid alloys, advanced charging methods, battery health monitoring and carbon electrode materials for enhanced cycle life. An alternative type of battery with potential to be used in UPS is the lithium-ion (Li-ion) batteries, which present higher efficiency and energy density. However, they present a high cost, which currently prohibits general commercial UPS application. Hybrid solutions combining supercapacitors and batteries could cover short power source interruptions, or voltage and frequency variations to significantly extend the battery lifetime. The integration of fuel cells is also an option for extended run-time UPS, especially in grid-connected applications where a good quality reliable power supply is required, or where protection is required from long term power

Another component with a high adverse impact on the UPS due to its weight and physical size is the transformer. The efficiency of transformers can also be improved, but a preferable solution is achieved with a transformerless design, which ensures higher efficiency and less weight. To further improve the efficiency of double conversion UPS systems and promote size/weight reduction, multilevel circuit topology presents a wide range of benefits for UPS systems in comparison with the traditional two-level converter. Diode-clamped NPC circuit has been used in UPS for achieving higher efficiency due to the fact that multilevel topology enables lower switching losses. Other possible topology is the Delta-conversion which uses a special transformer configuration to interface between the load utility power, with a “delta” inverter in the transformer secondary to regulate input current and power, resulting in an optimum power factor at the UPS input.

Another possible approach is the reduction of the number of active switches and such as IGBTs, MOSFETs, and Thyristors, by replacing them with diodes. This has the potential to further reduce costs by eliminating the circuitry for driving power switches, simplifying the control circuit by lowering the voltage stress across power switches and eliminating passive components like transformers, capacitors and inductors. Removing bulky passive elements and lowering the number of power switches would bring other advantages such as greater compactness and higher reliability.

Table 78 presents the main improvements at the component level, identifying the improvements to be considered as BAT or BNAT.

Table 78: BAT and BNAT Technologies

Components	Improvement	BAT/BNAT
Intelligent multi-mode operation	Up to +2% increase in efficiency	BAT
Improved Lead-acid batteries	Better performance and lifetime	BAT
Lead-carbon batteries	Increased cycle life	BNAT
Lithium-ion batteries	+20% of efficiency	BNAT
Supercapacitors	Better performance and lifetime	BNAT
Fuel cells	Better performance	BNAT
Transformerless UPS	+3% of efficiency and 25% less weight	BAT
High-frequency transformer	alternative to the transformerless topology	BAT
Three-level converter	reduction of 35% on the semiconductor losses	BAT
Transformerless + Three-level converter + elimination of active components	+3% of efficiency and 46-60% less weight	BNAT
Delta-conversion line-interactive UPSs	Better performance	BAT

7 Task 7 – Improvement potential

7.1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the Eco-Design working plan 2009-2011. This preparatory study is the starting point of this process. It aims to identify the current market size and composition, technical solutions, potential future technology improvements and possible policy options.

The Preparatory Study will follow the Commission's 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 have been posted on the website for stakeholders who cannot attend workshops.

7.1.1 Task 7 - Objectives

Task 7 of a Preparatory Study involves the identification and assessment of design options based on the information collated in Task 6 – Best Available Technology. The aim of task 7 is to identify the improvement potential of the product and consider these in relation to life cycle costs, by identifying the least life cycle costs and environmental improvement of the different options.

The Ecodesign Directive requires the following key points to be considered:

- Functionality
- Excessive costs
- Environmental improvement

This analysis is undertaken using the EcoReport tool and compares the design options against the base cases defined in task 5. The purpose of this assessment is to identify realistic and cost effective options that could be taken forward in policy options for task 8.

The analysis is structured as follows:

- Identification and description of design options for environmental improvement;
- Quantitative assessment of environmental improvement;
- Estimations of the change in costs due to the implementation of the design options; and
- Assessment of least life cycle costs and best available technology

This section presents the results from Task 7, outlining the design options, environmental improvement potential, cost implications of the design options and an assessment of least life cycle costs and best available technology.

As a reminder the base case scenarios that have been developed for this work are as follow:

- Base case scenario 1 covers UPS below 1.5 kVA
- Base case scenario 2 covers UPS between 1.5 – 5 kVA
- Base case scenario 3 covers UPS between 5.1 – 10 kVA
- Base case scenario 4 covers UPS between 10.1 – 200 kVA

7.2 Subtask 7.1 – Design Options

A number of potential design options for environmental improvement have been identified following the work undertaken in the previous tasks, including stakeholder engagement. The five main areas identified for consideration are:

- High Flat Efficiency
- Improved Components
- Multi-mode UPS
- Batteries, including longer battery lifetime and design for replacement
- Reduced levels of redundancy

Each of these options are outlined and considered in further detail below. Where it is not considered appropriate to take forward a design option for detailed analysis the reasons for this are provided in the relevant section.

A number of other design options were discussed with stakeholders at the third stakeholder meeting. A brief summary of these are provided in Section 7.2.6.

7.2.1 High weighted and Flat Efficiency

UPS can operate at different load levels e.g. 25, 50, 75 and 100%, depending on particular installation circumstances. Many UPS products have an efficiency curve, which drops off at lower load levels, for example below 50%. Flat efficiency aims to address this by having a high level of efficiency across different load levels, including those below 50%.

The achievement of a flat efficiency curve is possible using technologies such as: digital signal processing (DSP) for a better digital control of power components, the availability of new power components in the field of semi-conductors and magnetics, as well as multi-level power topology design (further information is provided in the Task 6 report).

Stakeholder feedback indicates that it is not the norm for a UPS to operate below 20-25% and a UPS operating below this load level would be considered poor system design. UPS systems may operate below this level for limited periods, for example soon after system installation, where an over allowance has been included to allow for IT equipment load expansion. This is reflected in the information presented in Task 3, which indicates many datacentres operate at 15-30% load. Further stakeholder feedback indicates that UPS will generally not reach loads above 50-60%, however this is not always the case and some UPS applications may have higher loads depending on specific circumstances. Therefore this design option focuses on the load levels of 25, 50, 75 and 100%, which are consistent with the load levels at which products are tested under IEC 62040[242].

To understand the level of flat efficiency in existing products, analysis of the Energy Star database[243] was undertaken in Task 6 to identify available products with higher weighted efficiency and a flat efficiency curve. This information has been used to propose two different levels in relation to high flat efficiency to be modelled in this task:

- BAT level as identified from the Energy Star 2013 database, and
- Intermediate level (this is based on the BAT level (as above) and the efficiencies used in the assessment of the base cases in Task 5 which is based using the Code of Conduct).

Table 79 presents the efficiency levels applied for each base case scenario and their variant. Figure 53, Figure 54, Figure 55 and Figure 56 summarise the efficiency levels for each base case scenario compared to the efficiency levels achieved by the two variations of the base case scenario.

Table 79: Design option efficiency levels

Load Levels / Scenario	25%	50%	75%	100%
BC1	86.0	87.0	88.0	89.0
BC1 Intermediate	91.8	92.8	93.5	94.1
BC1 BAT (highest efficiency)	97.5	98.6	99.0	99.1
BC2	85.0	89.0	89.9	90.0
BC2 Intermediate	91.2	93.7	94.3	94.4
BC2 BAT	97.3	98.4	98.7	98.8
BC3	88.0	92.0	92.5	92.5
BC3 Intermediate	91.2	93.9	93.8	93.4
BC3 BAT	94.3	95.8	95.1	94.2
BC4*	85.0	90.1	90.6	90.3
BC4 Intermediate *	87.8	91.7	92.1	91.8
BC4 BAT*	90.6	93.2	93.6	93.3

**Figures for BC 4 take into account transformer losses for this design option.*

[242] International Electrotechnical Commission (IEC) standard IEC 62040-3-2011 Edition 2.0
[243] ENERGY STAR Uninterruptible Power Supplies Product List, August 23, 2013, available at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=UPS

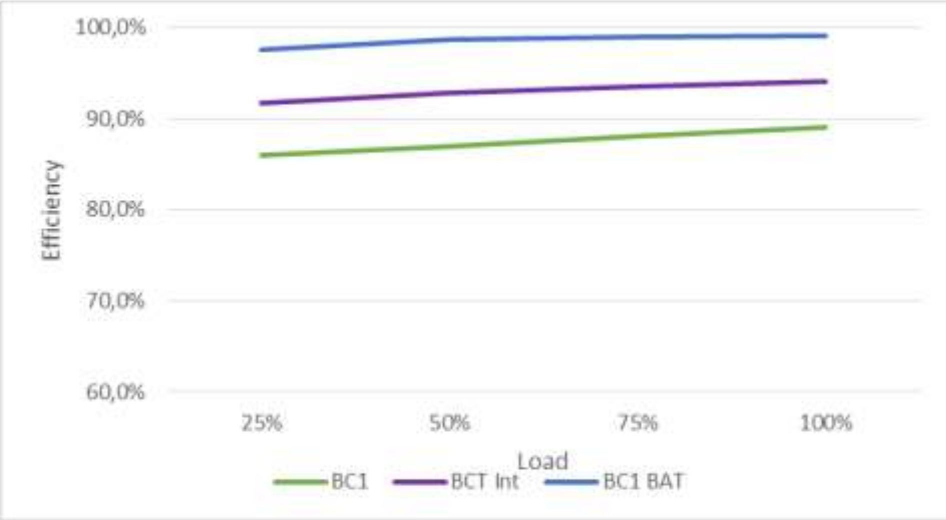

Figure 53: Different efficiency levels for Base Case 1

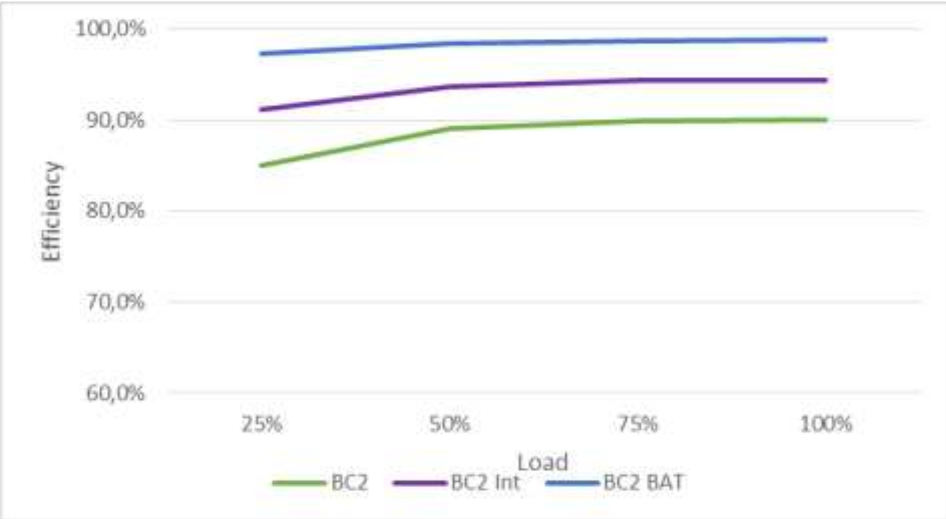

Figure 54: Different efficiency levels for Base Case 2

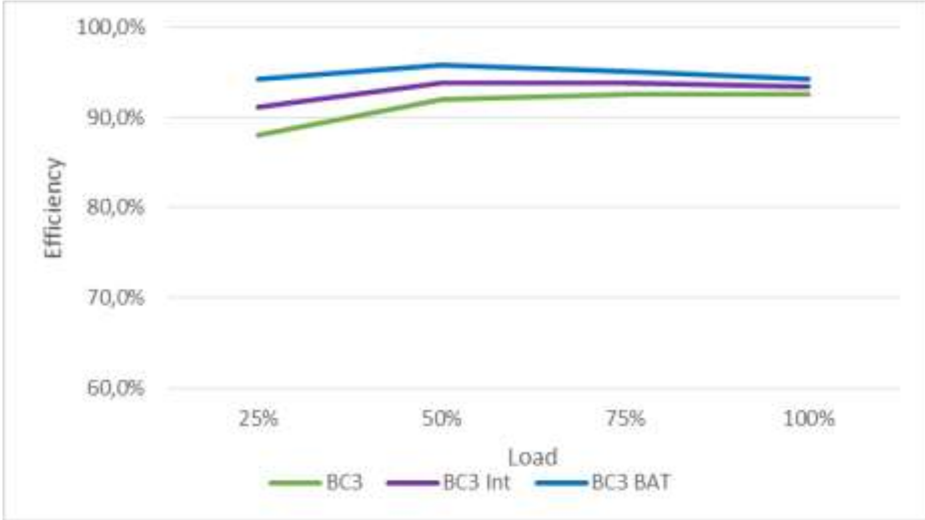

Figure 55: Different efficiency levels for Base Case 3

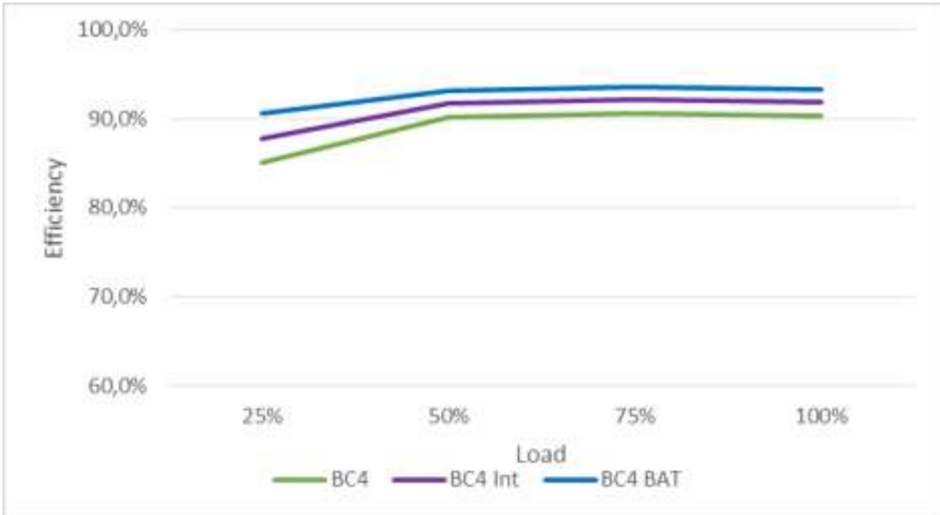

Figure 56: Different efficiency levels for Base Case 4

Using the revised efficiency levels, and the same assumptions from Energy Star as presented in Task 5 for the time spent at different load levels, revised annual energy consumption inputs for the EcoReport tool have been calculated, and are summarised in Table 80.

Table 80: Revised energy consumption (losses) input figures for EcoReport for high flat efficiency design option

Scenario	Annual Energy Consumption (kWh)
BC1	378
BC1 Intermediate	206
BC1 BAT	36
BC2	1 929
BC2 Intermediate	1 089
BC2 BAT	249
BC3	3 121
BC3 Intermediate	2 603
BC3 BAT	2 102
BC4	42 840
BC4 Intermediate	35 751
BC4 BAT	28 870

Within the high flat efficiency design option the only parameter to change is the annual energy consumption (losses) of the UPS as outlined above. It is assumed that the bill of materials and lifetime remain the same.

The change in environmental impact, which compares the EcoReport output for the different scenarios based on the design options presented above, is provided in Section 7.3. The cost implications of the design options are discussed in Section 7.4.

7.2.2 Improved Components

The component improvements identified in Task 6 (i.e. energy storage, transformers, topologies and semiconductors) result in improved reliability and performance, for example stability of supply, but do not necessarily provide a stepped change in the performance of the product that will result in significant environmental improvement, for example energy efficiency improvements. Stakeholder feedback indicates that implementation of improved components is de facto as they become viable.

Transformers are one component that could potentially offer an improvement in efficiency. Eliminating transformer based UPS designs is not appropriate, as there is still a small specialist market requiring full galvanic isolation of UPS, which is driven by health and safety requirements. Stakeholder feedback indicates that this market is relatively small and applicable to less than 10% of 10kVA and above products, with the main trend towards transformer less UPS.

For a UPS configuration with a transformer it is possible to achieve high efficiencies through the UPS itself, but this is then reduced due to the use of the transformer. Therefore improving the efficiency of the transformer is another option. For small transformers, which are typically used with UPS, the scope for improvement and saving potential in absolute terms is limited. The improved transformers can be achieved by the manufacturers using existing technology (e.g. high grade commercially available silicon electrical steel) and their existing manufacturing equipment. For separation/isolation transformers a total consumption reduction of just 2.5% is expected between now and 2025[244].

Due to the small market size and limited improvement potential for isolation transformers, which has been identified by the previous preparatory study and associated impact assessment, this has not been considered further as a design option in Task 7 of this study.

As transformers are still used in limited circumstances, consideration of allowances for the use of transformers where appropriate will be considered as part of the policy recommendations in Task 8. This will take into account any relevant allowances for transformers from existing policy instruments, for example the Code of Conduct or the proposals for an Ecodesign Regulation for transformers.

7.2.3 Multi-mode UPS

Task 6 has identified Multi-mode UPS as a potential design option. These types of UPS can switch seamlessly between different modes, for example standby, line interactive and on-line depending on quality of the incoming mains supply. Multi-mode features have already been identified in products down to 6 kVA and therefore this design option focuses on Base Case 3 (5.1-10kVA) and Base Case 4 (10.1 to 200kVA) products.

The Energy Star voluntary labelling scheme includes the following equation, which can be used to assess the impact of multi-mode UPS:

$$Eff_{AVG} = 0.75 \times Eff_1 + 0.25 \times Eff_2$$

Where:

- Eff_{AVG} is the average loading-adjusted efficiency,
- Eff_1 is the average loading-adjusted efficiency in the lowest input dependency mode (i.e., VFI or VI),
- Eff_2 is the average loading-adjusted efficiency in the highest input dependency mode (i.e., VFD).

Using this formula together with the equation used in Task 5 to calculate energy consumption, revised energy inputs for use in the EcoReport tool have been calculated for two multi-mode scenarios based on switching between VFI (on-line) and VFD (standby) modes. The first scenario (Multi-mode CoC), utilises the current Code of Conduct energy efficiency levels, whereas the second combines the multi-mode feature with BAT levels for the different modes, based on data from the Energy Star database and stakeholder feedback (Multi-mode BAT Efficiency). Table 81 outlines the efficiency levels used for the different modes for Base Cases 3 and 4, with the revised annual energy consumption figures summarised in Table 82.

It is assumed that there is no change in the time spent at different loads, the bill of materials or product lifetime in comparison to the base cases for this design option. The energy input is the only EcoReport input parameter that is updated.

Table 81: Efficiency levels for multi-mode design options

Load Level / Scenario	Mode	25%	50%	75%	100%
BC3 Multi-mode CoC	VFI (online)	85.5%	91.5%	92.5%	92.5%
	VFD (standby)	90.0%	93.0%	94.0%	94.0%
BC3 Multi-mode BAT Efficiency	VFI (online)	94.3%	95.8%	95.1%	94.2%
	VFD (standby)	99.0%	99.0%	99%	99.0%
BC4 Multi-mode	VFI (online)	87.5%	91.1%	91.6%	91.3%

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CoC*	VFD (standby)	91.0%	94.1%	94.6%	94.3%
BC4 Multi-mode BAT Efficiency*	VFI (online)	90.6%	93.2%	93.6%	93.3%
	VFD (standby)	95.0%	96.1%	96.1%	95.8%

**Note BC4 efficiencies take into account transformer losses as per the base case in Task 5 to allow like for like comparison with the base case outputs from EcoReport.*

Table 82: Revised energy consumption (losses) input figures for EcoReport for multi-mode UPS design option

Scenario	Annual Energy Consumption (kWh)
BC3	3 120
BC3 Multi-mode CoC	3 008
BC3 Multi-mode BAT Efficiency	1 679
BC4	42 840
BC4 Multi-mode CoC*	34 756
BC4 Multi-mode BAT Efficiency*	25 831

7.2.4 Battery Design Options

Design options relating to batteries have been split into two categories. Firstly those relating to long life batteries and secondly alternative options where long life batteries are not necessarily the most appropriate option. These options take into account feedback from stakeholders and Task 3 research, which considers the user behaviour and application of UPS relating to different product sizes.

The sections below outline the rationale for the design options presented.

7.2.4.1 Longer life Batteries for Base Case 1

The lifetime of UPS Base Case 1 products was informed by stakeholders. When applied in Task 5, the UPS lifetime means a single standard battery is sufficient; it does not need to be replaced. Feedback from some stakeholders during the third workshop and subsequent written feedback raised the question of why longer life batteries are not considered appropriate for Base Case 1 UPS products. The discussion is taken up in Section 7.2.4.3 below.

7.2.4.2 Longer Life Batteries for Base Cases 2, 3 and 4

The sensitivity analysis undertaken in Task 5 identified eliminating the need to replace batteries could ***reduce material use and associated environmental impacts*** for Base Cases 2, 3 and 4. Further analysis has been undertaken to understand the change in bill of materials when using longer life batteries for these case cases.

Based on the UPS product lifetime and the assumption of a single battery replacement as part of the Base Case 2, 3 and 4 scenarios, we studied the change to a no battery replacement scenario when using a longer life battery. To do this we formed the assumptions in Table 83 regarding the battery lifetime. An assessment of UPS batteries has been undertaken and indicates a difference in weight for longer life batteries. This is summarised in Table 83.

Table 83: Battery lifetime assumptions and change in weight for longer life batteries

Base Case	Assumed battery life time based for original base case scenario	Assumed battery lifetime for the no battery replacement scenario	Increase in weight between the two battery lifetime scenarios
BC2	5 years	8 years	18%
BC3	5 years	10 years	8%

BC4	8 years	12 years	5%

The increase in weight[245] results in a change to the battery bill of material component of the UPS. Using the same proportion of materials in the battery as in Task 5, the bill of materials has been updated to reflect a longer life battery. The revised long-life battery bill of materials information is summarised in Table 84.

Table 84: Revised long life battery bill of materials

	%	BC2 - Weight (g)	BC3 Weight (g)	BC4 Weight (g)
Lead	0.6	12 658	25 228	37 0850
Primary Lead	0.4	5 063	10 091	148 340
Secondary lead	0.6	7 595	15 137	22 2510
PP	0.1	2 110	4 205	61 808
Sulphuric Acid	0.1	2 110	4 205	61 808
Water	0.16	3 375	6 727	98 893
Glass	0.02	422	841	12 362
Antimony	0.01	211	420	6 181
Total		20 885	41 626	611 902

For the purposes of this design option, all other EcoReport input parameters for the environmental impact assessment have remained the same. There are some implications for the costs, which are summarised in Section 7.4.1 and analysed in Section 7.5.2.

7.2.4.3 Battery Design Options for Base Case 1

Due to the smaller load sizes Base Case 1 UPS products are designed to protect, they are typically used as business to consumer (B2C) as well as business to business (B2B) products, whereas the larger capacity UPS are mainly used as B2B only products. This variation in users of Base Case 1 products, for example by household users, home offices, small businesses/offices and retail means there is a range of different factors that needs to be considered when assessing design options relating to batteries, including the use of long life batteries.

A key aspect to understand as part of this assessment is what drives the lifetime and replacement of Base Case 1 products. Stakeholder feedback indicates that in some instances UPS replacement is driven by the replacement of the IT equipment it is protecting, which can be every 3-4 years. While this may be the case in some circumstances, for example where equipment is leased as may be the case in an office or retail environment for example, other users may keep IT equipment for longer, for example householders, or small businesses that purchase rather than lease equipment.

Where IT equipment is replaced and there is a change in the power requirement of the load, then it would be appropriate to change the UPS to ensure it matches the load of the new equipment. In these circumstances, the use of longer life batteries in smaller UPS products would not be appropriate as the UPS's lifetime is not driven by that of the battery. In this scenario, including a long life battery would increase the product price and material use[245] without any environmental benefit. Where IT equipment is kept for longer than 3-4 years, or the power requirement of the new IT equipment is similar to that of the IT equipment replaced, then extending the lifetime of smaller UPS products is relevant.

[245] Increasing the amount of lead in a lead acid battery is a well-known option to extend the battery life and has been adopted by several manufacturers. Such a solution increases the weight of the battery and has an associated influence on the BoM. The project team is aware that there are other technological options to increase the battery life. Since these different technologies are not standardised and may vary from manufacturer to manufacturer, the focus has been on the common technology. As the impact of the implementation of long life batteries is marginal compared to other design options (1%), independent from the technology applied, it was decided to model the worst case scenario in terms of weight. This is based on data currently available to the public from products available on the market (the percentage of weight increase was assessed using the datasheets of batteries with the same characteristics, from the same manufacturer, but with different lifetime) and not to model other potential technological and design options with smaller or no influence on the battery weight.

A further factor to consider is the operating environment of the UPS and its battery. Task 3 highlighted the effects of operating temperatures on certain battery types, for example lead acid. For these, lifetime reduces by half for every 10 degrees above the design reference temperature of 20/25°C. Therefore in order to maximise battery lifetime it is preferable for UPS to be installed in temperature controlled environments. The range of users for Base Case 1 products means that some are unlikely to be used in such environments, for example those in households, or home office locations, where air conditioning will not necessarily be available. Again, in these circumstances the benefits of a longer life battery would not be realised.

The variations in user types and operating environments for Base Case 1 products mean that the use of longer life batteries will not be beneficial in some circumstances. Limited information is available regarding the relative importance of the different circumstances outlined above; therefore at this stage design options relating to batteries need to offer a degree of flexibility.

To provide the flexibility required for these smaller UPS products in light of their variable use and drivers for lifetime, the most appropriate design options to consider are:

- Designs that facilitate battery replacement;
- Information on optimal operating conditions (temperature/ventilation); and
- Information on battery checking/testing, or some form of automatic battery testing.

With regards battery replacement, some existing Base Case 1 products are designed such that the battery cannot be replaced, or is not easy for the user to replace without using a technician with the relevant skills. In practice this option is unlikely to be undertaken as the price of a replacement battery and labour charges are not dissimilar to the price of a new Base Case 1 product which is typically about 180 euros as noted in the Task 2 and 5 reports. Therefore in order to enable a UPS to be used beyond its current lifetime, it is proposed that designing Base Case 1 products to make battery replacement simple and easy for the end user is considered. There are already examples of existing products for Base Case 1 on the market that include easy battery replacement, and only require a screwdriver[246].

In addition, the operating conditions of a battery will affect its lifetime. Therefore providing information with regards optimum operating conditions e.g. temperature and ventilation and on battery checking/testing is appropriate.

Improvements from these options for Base Case 1 products would results from lower resource use, by keeping the UPS in operation for longer. The extent of this is very much dependent on user behaviour and their specific circumstances and it has therefore not been able to quantify the level of improvement, however implementation of these options is considered further in Task 8.

7.2.5 Redundancy

Different levels of redundancy can be incorporated into the installation of a UPS system in order to meet the level of resilience required. An overview of redundancy and the different configurations is provided below.

The topology of a UPS installation system is usually described using the letter “N”. A single or group of UPS which provide exactly the power capacity required to meet the needs of a load would be a basic “N” system. Apart from bypass to the incoming mains supply there would be no back-up for the failure of a UPS module or for maintenance.

Where UPS are configured in a system installation topology to allow redundancy of one of the UPS for maintenance or failure but still meet the needs of the full load, the system is usually described as an N+1 UPS system topology and generically as a parallel redundant

[246] http://www.criticalpowersupplies.co.uk/filedata/0000/0648/Eaton_3S_datasheet.316.pdf and http://www.emersonnetworkpower.com/documents/en-us/products/acpower/desktopworkstationups/documents/sl-23285.pdf

UPS system (Figure 57). In this system installation topology, the failure of one UPS or its removal for maintenance is covered by the remaining UPS.

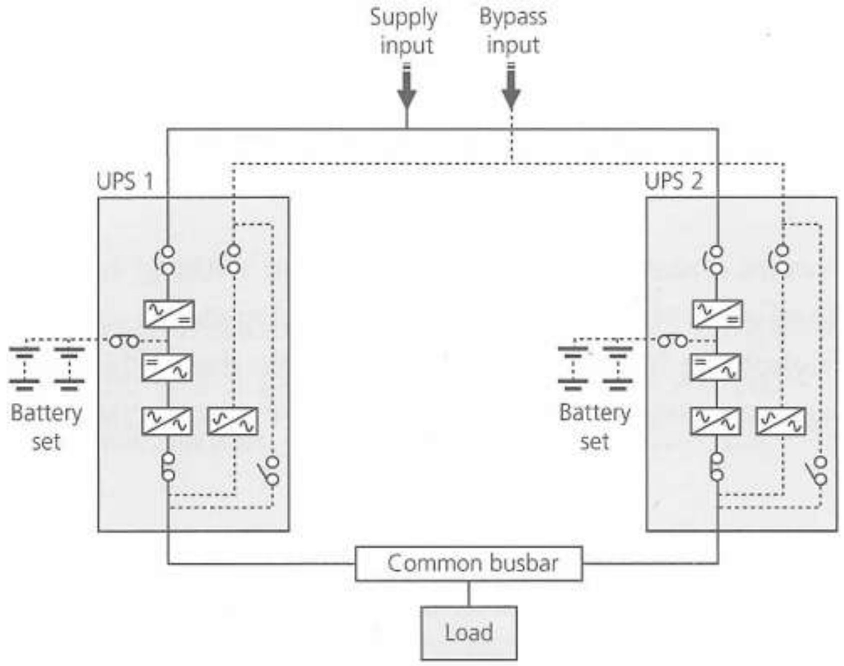

Figure 57: Parallel Redundant UPS (N+1)[247]

Where the N+1 system is duplicated to supply the load e.g. in a parallel - redundant UPS group, the system is termed a 2N or 2 (N+1) system. A 2(N+1) installation system is shown in (Figure 58). In this installation topology a parallel systems joiner (PSJ) is used to connect the outputs from two parallel redundant (N+1) systems to the protected loads. All system functions are redundant, even during maintenance and the system is capable of handling high overload currents.

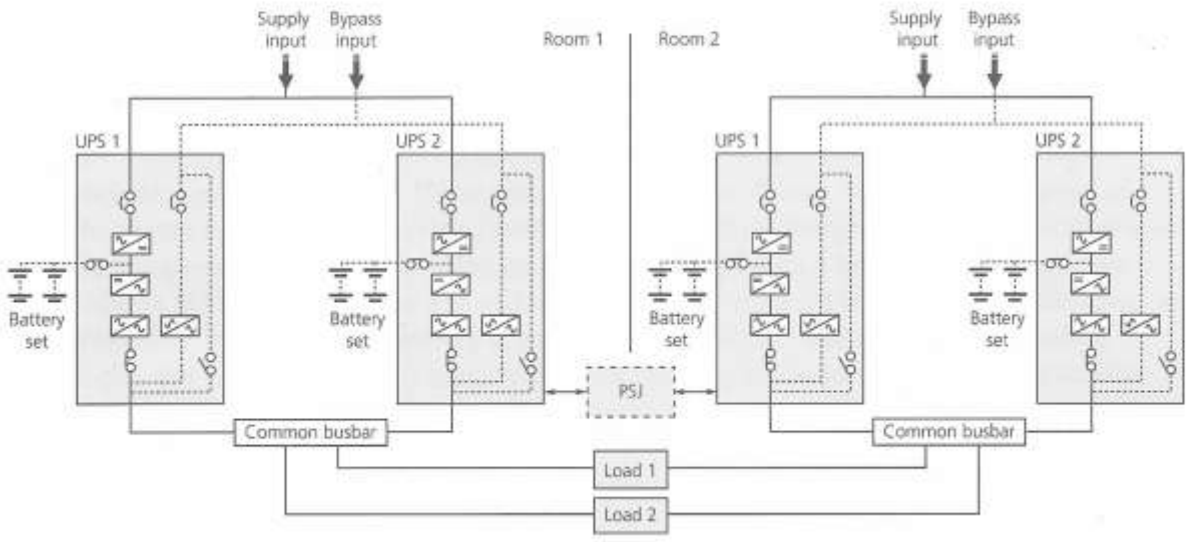

Figure 58: Parallel Redundant UPS (2N+1)[248]

[247] Riello UPS power protection guide Stillwater Publications.
[248] Riello UPS Power Protection Guide, Stillwater publications

Table 85 summarises the key characteristics of availability, reliability and redundancy of the installation systems discussed in this section.

Table 85: Summary of Installation system topology specifications

Installation System Topology	Number of UPS Units for a given load	MTBF of UPS System (hours)	MTBF during maintenance (hours)	Redundancy during Maintenance	Availability
N	1	250 000	50	No	99.998%
N+1	2	950 000	250 000	No	99.9997%
2(N+1)	4	2 500 000	750 000	Yes	99.9999%

Informed industry sources estimate that for the data centre market 10% of the installation typologies would have an "N" UPS system, 70% an N+1 topology and 20% a 2N topology. This provides an indication of where the level of redundancy can be reduced, potential savings in terms of the number of UPS units required and associated energy consumption of the UPS can be made.

A technical solution, identified through stakeholder discussions addressing the level of redundancy, while maintaining the required resilience, is the addition of features allowing the automatic replacement, deactivation and load sharing of a UPS. For example, Multi –mode UPS can be supplied with an additional software/interface feature allowing automatic replacement of a UPS without any interruption of the UPS system supply. This is achieved by maintaining one redundant UPS (running at 99% efficiency in eco-mode) in a rack system of many UPS and having a software interface. The software allows the automatic switching of that spare UPS to replace any other UPS in the rack, in a fault condition or for maintenance without interruption to the protection mode for the load. The software can also allow automatic load sharing to optimise the number of UPS required for optimum energy efficient operation in a given load power requirement.

In the absence of a common industry or Technical Standards' name for the functionalities allowing the automatic replacement, deactivation and load sharing of a UPS, they are referred to here as automatic management systems (AMS). This AMS facility effectively makes the resilience of an N+1 system as good as the resilience of a 2N+1 system (six 9s – 99.9999% availability) because the spare UPS can be automatically shared between several N+1 systems in a rack.

There is a significant saving in UPS units to be achieved by implementing AMS. According to a major European UPS distributor, this AMS installation facility has, in 2013, a price premium of around a 30% increase but this extra cost is easily offset by the saving in UPS units and is falling with the trend to modular system design with AMS.

Reducing redundancy is a system consideration, and not a specific product requirement. It is understood that in some cases the level of resilience installed is beyond that required by some users, and therefore a potential saving in terms of resource use through the use of features such as AMS does present significant resource savings in systems using a modular rather than central UPS approach to installation design. In Task 8 a scenario involving a 100% modular AMS UPS installation system, providing a resilience of "six 9s" shows a 46% saving on required UPS units in comparison with an installation system of the same resilience without this functionality.

It is acknowledged that some UPS installations cannot compromise on their level of resilience, for example mission critical IT in banks, data centres, etc., however in less critical circumstances, features supporting resilience such as AMS may not, at current cost premiums, be a justifiable installation option. While this issue of redundancy does not offer a specific design option for products, it is an important consideration that purchasers and installers need to be aware of in order to minimise their energy consumption and resource use for their own particular circumstances. Task 8 will consider ways of raising the awareness of the importance of redundancy with end users as part of the policy scenarios.

7.2.6 Other design options

This section provides a brief overview of other design options as discussed at the third stakeholder meeting and the alternatives to long life batteries for Base Case 1 products.

At the third stakeholder meeting, aspects relating to battery monitoring and the internal resistance of batteries were discussed as potential design options to help extend the lifetime of batteries. Variation in internal resistance between batter cells, could contribute to battery failure. However stakeholder feedback highlighted this is just one factor that may result in battery failure. At present establishing requirements in relation to internal resistance is not straight forward. This is reflected in the Blue Angel, which was unable to set a stricter requirement than +/- 30%. The lack of an approved internal resistance test is unhelpful too.

Stakeholders also highlighted that battery failure is a serious consideration for manufacturers. Cell assembly as part of a UPS is a key quality issue that manufactures address in order to maintain brand reputation. Stakeholders indicated that it is addressed as part of manufacturers' Quality Management System, with customer feedback regarding battery failures limited.

At this point in time a design option relating to internal resistance is not considered further. The issue should be re-visited in the future at revision stage of any potential Ecodesign Regulation when more information and an accepted test method are available to help set appropriate requirements.

With regards battery monitoring, the discussion at the third stakeholder meeting focused on possible requirements for smaller UPS. These products are generally installed and then left as they are designed for no or very limited maintenance. It was proposed that battery monitoring would help users ensure the UPS was still functioning and providing the protection intended. Stakeholders highlighted that at present there is no standard approach to battery testing. This makes it difficult to include a requirement at the present stage; however it is possibly an area where a future mandate from the Commission to CEN would be useful, so that requirements could be set in the future. Providing information to consumers concerning battery maintenance would be helpful.

7.2.7 Summary of Design Options

Table 86 summarises the design options presented and discussed in this section and clearly identifies which are taken forward for further analysis in this task.

Table 86: Summary of design options that are taken forward in this task

Base Case	Use of Improved Components for High Flat Efficiency	Use of Improved Components for Transformer less design	Extended battery lifetime	Redundancy	Multi-mode operating
BC - 1 (< 1.5 kVA)	Y	N/A	N/A	System level issue – see Task 8	N/A
BC - 2 (1.5 – 5 kVA)	Y	N/A	Y		N/A
BC - 3 (5.1 - 10 kVA)	Y	N/A	Y		Y
BC - 4 (10.1 - 200 kVA)	Y	N/A	Y		Y

7.3 Subtask 7.2 – Environmental Impact

This subtask provides an overview of the environmental impact related to the improvement potential for the different design options presented in Section 7.2 that have been modelled. While the main focus of the study is on energy efficiency other environmental impacts are resource and waste related. Some options[249] provide only limited improvement potential

[249] The option E (Base Case modified by long life batteries) for BC2, BC3 and BC4 provides no improvement concerning energy efficiency.

concerning energy efficiency, but their implementation could reduce the amount of hazardous and non-hazardous waste sent to landfill or the demand of process water.

The results are presented in separate tables for each base case (BC) and include the design options that are appropriate for each of the base cases as follow:

- Option A: Intermediate flat efficiency (average between the reference Base Case and BAT levels)
- Option B: Best Available Technology (BAT) flat efficiency from current Energy Star database
- Option C: Base Case modified by intelligent multi-mode technology (CoC efficiency level)
- Option D: Base Case modified by flat efficiency and intelligent multi-mode technology (both at BAT efficiency levels)
- Option E: Base Case modified by long life batteries

Each of these design options affects not only energy efficiency, but have additional impacts to the environment. These impacts are related to all phases of the products' lifetime. The modelling was done on the basis of standardised impacts according [250] to the ErP-EcoReport-Tool. Specific variations concerning the energy production mix available at the production site or other locations, where energy is used in the use phase or the respective recycling of the products are not taken into consideration, since specific data for such locations are not available. The improvement potential of each design option was compared against the respective base case scenario for each of the four base cases as far as a calculation of the impacts of such a design option is possible[251]. Table 87 summarises the combination of design options for each base case scenarios that have been modelled and for which the results are presented.

Table 87: Summary of the base case scenario and applicable design options

BC	Flat Efficiency Intermediate	Flat Efficient BAT	Multimode (CoC)	Multimode (BAT)	Longlife Battery
1	Option 1A	Option 1B	n/a	n/a	n/a
2	Option 2A	Option 2B	n/a	n/a	Option 2E
3	Option 3A	Option 3B	Option 3C	Option 3D	Option 3E
4	Option 4A	Option 4B	Option 4C	Option 4D	Option 4E

The five design options flat efficiency (Intermediate and BAT), multi-mode UPS (CoC and BAT) and long-life batteries are described in Subtask 7.1.

For Base Case 1 only the options A and B were modelled, since long life batteries for such devices would be inappropriate. Multimode design (option C and option D) are not available for Base Case 1 and Base Case 2 and so these design options have only been modelled for Base Case 3 and Base Case 4 as discussed in Section 7.2 above.

For the options 3C and 4C multimode and flat efficiency are modelled using the CoC-data. For options 3D and 4D multimode and flat efficiency are modelled using the BAT-data.

The following section presents and discusses the results of the environmental impacts from the modelling for each base case.

As the calculation of the Ecodesign EcoReport Tool is based on standard data regarding the processing of resources and waste, as well as for the production of the supplied energy, such differences are a result of the methodology used. Using standard values provides the opportunities to compare the results of several ErP preparatory studies as they use the same methodology and the same data. Several sets of data, such as the energy production mix, electricity prices and others, are calculated on an EU-27 (EU-28) average, acknowledging

[250] The environmental impacts of specific materials are described in the Methodology for the Ecodesign of Energy-related Products (MEErP). The impacts may vary depending on the applied technologies. The MEErP EcoReport Tool uses average values independent from the local situation on the specific site. Such average data are used for all phases of the product's lifetime. This helps to keep the studies comparable.
[251] For other design options discussed with stakeholders, for example the automatic battery self-test or internal resistance of battery cells, there are no detailed data available to calculate the improvement potential properly. Nevertheless stakeholder confirmed the improvement potential in general.

that most of the components or even products covered by the study are manufactured outside the EU under different circumstances and the data used are simulated.

7.3.1 Base case 1 design options environmental analysis

As mentioned earlier for the Base Case 1 flat efficiency is the only design option modelled. The results are presented in Table 88.

The biggest impact of flat efficiency for Base Case 1 is the noticeable reduction in:

- The total energy consumption which falls by 43% for option 1A and by 86% for option 1B compared to the base case, and
- The electricity consumption over the lifetime of the product 45% lower for option 1A and 89% lower for option 1B compared to the base case scenario.

The other impacts that see a noticeable reduction when Base Case 1 products shift from base case products to Flat Efficiency options are:

- Greenhouse gases: the design option 1A provides a reduction of 43% and option 1B a reduction of 85%
- Acidification could be reduced by 42% (option 1A) or 84% (option 1B)
- Persistent organic pollutants would be 42% lower with option 1A and 84% lower with option 1B

The reduction of waste by the two design options is also significant.

- Option 1A reduces the non-hazardous waste by 38% and the hazardous waste by 28%.
- For option 1B the reduction is 76% for non-hazardous waste and 57% for hazardous waste.

Other results are that the shift to Flat Efficiency options has no impact on the demand of process water, but for cooling water the shift from base case products to option 1A products reduces the demand by 29%. Shifting to option 1B provides a reduction of 58%.

Emissions of volatile organic compounds could be reduced by 39% implementing option 1A and by 77% with option 1B. The reduction of PAH can reach 30% (option 1A) or respective 61% (option 1B). The emission of dust would be reduced by 25% (option 1A) and 50% (option 1B). The emission of heavy metals to air would be lowered by 38% (option 1A) and 76% (option 1B). The emission of heavy metals in to the water could be minimised by 34% (option 1A) and 68% (option 1B). For eutrophication the reduction potential is 30% (option 1A) and 41% (option 1B).

In general the reduction of environmental impacts by implementing the design option 1B is by a factor 2 higher than with implementing option 1A. Implementing option 1B would also provide the higher reduction in overall environmental impacts of the two scenarios modelled.

Table 88: Environmental impacts of the Base Case 1 and its design options

	Life-Cycle indicators	Unit	BC 1	Option 1A Flat Efficiency INT	Option 1B Flat Efficient BAT
Other Resources	Total Energy (GER)	MJ	14 242	8 059	1 936
		% change with BC	0%	-43%	-86%
	of which, electricity (in primary MJ)	MJ	13 755	7 572	1 449
		% change with BC	0%	-45%	-90%
	Water (process)	ltr	63	63	63
		% change with BC	0%	0%	0%
	Water (cooling)	ltr	938	664	391
		% change with BC	0%	-29%	-58%
	Waste, non-	g	8 380	5 194	2 038

	haz./ landfill	% change with BC	0%	-38%	-76%
	Waste, hazardous/ incinerated	g	341	243	147
		% change with BC	0%	-29%	-57%
Emissions to Air	**Greenhouse Gases in GWP100**	kg CO2 eq.	616	352	91
		% change with BC	0%	-43%	-85%
	Acidification, emissions	g SO2 eq.	2 768	1 600	444
		% change with BC	0%	-42%	-84%
	Volatile Organic Compounds (VOC)	g	355	217	81
		% change with BC	0%	-39%	-77%
	Persistent Organic Pollutants (POP)	ng i-Teq	34	20	5
		% change with BC	0%	-42%	-82%
	Heavy Metals	mg Ni eq.	164	101	39
		% change with BC	0%	-38%	-76%
	PAHs	mg Ni eq.	47	33	19
		% change with BC	0%	-30%	-61%
	Particulate Matter (PM, dust)	g	99	74	50
		% change with BC	0%	-25%	-50%
Emissions to Water	**Heavy Metals**	mg Hg/20	77	51	24
		% change with BC	0%	-34%	-68%
	Eutrophication	g PO4	6	5	3
		% change with BC	0%	-20%	-41%

7.3.2 Base case 2 design options environmental analysis

For Base Case 2, three design options have been modelled, flat efficiency (intermediate (2A) and BAT (2B)) and long life batteries. The results from the modelling are presented in Table 89, and discussed below for each design option.

7.3.2.1 Impacts of flat efficiency Base Case 2

For Base Case 2 products the shift from base case products to Flat Efficiency option achieves the biggest savings in:

- Total energy consumption which is reduced by 43% for option 2A and 86% for option 2B compared to the base case scenario. This is the same improvement potential as for Base Case 1.
- Electricity consumption over the lifetime of the product related to the base case scenario is 43% for option 2A and 86% for option 2B.

Other impacts for which noticeable reduction can be achieved through implementing flat efficiency are:

- Greenhouse gases - the design option 2A provides a reduction of 43% and option 2B a reduction of 86%,
- Acidification could be reduced by 42% (option 2A) or 85% (option 2B)
- Heavy metals to air would be lowered by 40% (option 2A) and 80% (option 2B)

Other reduction in impacts can be achieved in cooling water; the shift from base case products to option 2A products reduces the demand by 39%. Shifting to option 2B provides a reduction of 80%, but has no impact on the demand of process water. The reduction of waste by the three design options is significant. Option 2A reduces the non-hazardous waste by

24% and the hazardous waste by 24% as well. For option 2B the reduction is 80% for non-hazardous waste and 47% for hazardous waste.

Persistent organic pollutants (POP) would be 38% lower (option 2A) and 75% lower (option 2B). The reduction of PAH can reach 36% (option 2A) or 72% (option 2B). The emission of dust would be reduced by 35% (option 2A) and 69% (option 2B). The emission of heavy metals into water could be minimised by 38% (option 2A) and 68% (option 2B). For eutrophication the reduction potential is 36% (option 2A) and 72% (option 2B).

In general the reduction of environmental impacts by implementing the design option 2B is by a factor of 2 higher than with implementing option 2A. Implementing option 2B would provide the higher reduction of the two scenarios modelled.

7.3.2.2 Impact of long-life batteries Base Case 2

As presented in Table 89, option 2E shows a limited reduction potential[252] regarding the environmental impact. It provides no improvement concerning the total energy consumption or the electricity demand compared to the base case scenario.

The most significant reduction is given with 27% for volatile organic compounds. Option 2E provides a reduction potential of 17% concerning process water, but only of 2% for cooling water. It reduces the non-hazardous waste by 17% and the hazardous waste by 11%. Implementing option 2E does not reduce any of the other emissions.

Table 89: Environmental impacts of the Base Case 2 and its design options

	Life-Cycle indicators	Unit	BC 2	Option 2A Flat Efficiency INT	Option 2B Flat Efficient BAT	Option 2E Long life Battery
Other Resources	Total Energy (GER)	MJ	140 780	80 275	19 770	140 590
		% change with BC	0%	-43%	-86%	0%
	of which, electricity (in primary MJ)	MJ	139 721	79 216	18 711	139 667
		% change with BC	0%	-43%	-87%	0%
	Water (process)	ltr	442	442	442	367
		% change with BC	0%	0%	0%	-17%
	Water (cooling)	ltr	6 836	4 147	1 456	6 694
		% change with BC	0%	-39%	-80%	-2%
	Waste, non-haz./ landfill	g	131 745	100 565	69 384	109 249
		% change with BC	0%	-24%	-47%	-17%
	Waste, hazardous/ incinerated	g	4 022	3 068	2 113	3 561
		% change with BC	0%	-24%	-47%	-11%
Emissions to Air	Greenhouse Gases in GWP100	kg CO2 eq.	6 035	3 452	869	6 023
		% change with BC	0%	-43%	-86%	0%
	Acidification, emissions	g SO2 eq.	26 909	15 480	4051	26 885
		% change with BC	0%	-42%	-85%	0%
	Volatile Organic Compounds (VOC)	g	8 824	7 473	6 121	6 480
		% change with BC	0%	-15%	-31%	-27%
	Persistent Organic Pollutants (POP)	ng i-Teq	376	235	93	375
		% change with BC	0%	-38%	-75%	0%
	Heavy Metals	mg Ni eq.	1 530	918	306	1 530
		% change with BC	0%	-40%	-80%	0%
	PAHs	mg Ni eq.	393	252	111	393
		% change with BC	0%	-36%	-72%	0%

[252] The technology assumed for increasing the battery life is the traditional solution by increasing the amount of lead used in a lead acid battery. The relevant data related to this technique are well documented from products available to the market. As the impact of longer life batteries on the energy efficiency is below 1% i.e. marginal compared to the other design options described for the base cases 2 to 4 the project team decided to model only the worst case scenario and no other technologies as they are proprietary to the specific manufacturers and not visible to the end customer.

	Particulate Matter (PM, dust)	g	700	458	216	696
		% change with BC	0%	-35%	-69%%	0%
Emissions to Water	Heavy Metals	mg Hg/20	677	416	156	677
		% change with BC	0%	-38%	-76%	0%
	Eutrophication	g PO4	31	20	9	31
		% change with BC	0%	-36%	-72%	0%

7.3.3 Base Case 3 design options environmental analysis

For Base Case 3 in addition to flat efficiency and long life battery, two different versions of a multimode design were modelled. For the option 3C the modelling is based on the CoC data for multimode. The results indicate that "flat efficiency only" achieves the greater reduction in impacts than the added multimode (CoC).

The option 3D using the BAT data for flat efficiency and for multimode shows a further reduction of the environmental impact not only related to the energy demand, but also to all other environmental impacts.

The results are presented in Table 90 and discussed in the following section.

7.3.3.1 Impacts of flat efficiency Base Case 3

For Base Case 3 products the shift from base case products to Flat Efficiency options has the biggest impact on total energy consumption; which is reduced by 16% for option 3A and 23% for option 3B compared to the base case. This is a significantly lower improvement potential than for the Base Case 1 and 2. The electricity consumption over the lifetime of the product related to a Base Case 3 scenario is reduced by 16% for option 3A and 32% for option 3B, Other impacts that also benefits from noticeable reductions including greenhouse gases, the design option 3A provides a reduction of 16% and option 3B a reduction of 32%, acidification could be reduced by 16% (option 3A), 32% (option 3B) and heavy metals to air would be lowered by 15% (option 3A) and 30% (option 3B)

For Base Case 3 products the shift from base case products to Flat Efficiency options has no impact on the demand of process water, but for cooling water the shift from base case products to option 3A products reduces the demand by 15%. Shifting to option 3B provides a reduction of 29%.

The reduction of waste by each of the design options is lower than the Base Cases 1 and 2. Option 3A reduces the non-hazardous waste and the hazardous waste each by 8%. For option 3B the reduction is 15% for non-hazardous waste and 16% for hazardous waste.

Persistent organic pollutants (POP) would be 13% lower (option 3A), 26% lower (option 3B). The reduction of PAH can reach 13% (option 3A) and 25% (option 3B). The emission of dust would be reduced by 13% (option 3A) and 26% (option 3B).

The emission of heavy metals in to water could be minimised by 14% (option 3A) and 28% (option 3B). For eutrophication the reduction potential is 13% (option 3A) and 25% (option 3B).

In general the reduction of environmental impacts by implementing the design option 3A or 3B is lower than the respective environmental impacts by the respective design option for Base Case 1 and 2.

7.3.3.2 Impact of multimode Base Case 3

The largest impact reduction of implementing the multimode design option is on:

- Total energy consumption, option 3C provides a reduction potential of only 4% and option 3D of 35%.
- Electricity consumption over the lifetime of the product 4% for option 3C and 46% for option 3D, and
- the demand for cooling water by 3% for option 3C and option 3D by 41%.

It can be noted in Table 90 that the design option 3C only deliver marginal improvement with regards to environmental impact (3 to 4% at best). However the impact of the design option 3D does deliver noticeable environmental benefits such as:

- Greenhouse gases reduction potential for option 3D 45% (compared to 4% for option 3C)
- Acidification could be reduced by 45% (option 3D) against just 4% for option 3C.
- Heavy metals to air would be lowered by 42% with option 3D and 3% with option 3C.

Option 3C reduces the non-hazardous waste and the hazardous waste each by 2%. For option 3D the reduction is 22% for non-hazardous waste and 23% for hazardous waste.

The emission of persistent organic pollutants (POP) would be 3% lower (option 3C) and 37% lower (option 3D). The reduction of PAH can reach 3% (option 3C) and 35% (option 3D). The emission of dust would be reduced by 3% (option 3C) and 35% (option 3D).

The emission of heavy metals to water could be minimised by 3% (option 3C) and 39% (option 3D). For eutrophication the reduction potential is 3% (option 3C) and 38% (option 3D).

7.3.3.3 Impact of long life batteries Base Case 3

Comparing the design option 3E with the Base Case 3 shows a limited potential to significantly reduce environmental impact. Option 3E provides a reduction potential of 21% concerning process water, but only of 3% for cooling water. It reduces the non-hazardous waste by 22% and the hazardous waste by 16%. The most significant reduction is given with 33% for volatile organic compounds. Implementing option 3E does not result in lower total energy consumption or in electricity consumption over the lifetime of the product and it does not reduce any of the other emissions.

Table 90: Environmental impacts of the Base Case 3 and its improvement options

	Life-Cycle indicators	Unit	BC 3	Option 3A Flat Efficiency INT	Option 3B Flat Efficient BAT	Option 3C Multimode (CoC)	Option 3D Multimode (BAT)	Option 3E Long-life Battery
Other resources	Total Energy (GER)	MJ	285 280	238 715	193 628	275 117	155 564	28 4813
		% change with BC	0%	16%	-32%	-4%	-45%	0%
	of which, electricity (in primary MJ)	MJ	282 808	236 243	191 156	272 645	153 092	28 2673
		% change with BC	0%	-16%	-32%	-4%	-46%	0%
	Water (process)	ltr	1 062	1 063	1 063	1 063	1 063	841
		% change with BC	0%	0%	0%	0%	0%	-21%
	Water (cooling)	ltr	13 966	11 897	9 893	13 514	8 201	13 582
		% change with BC	0%	-15%	-29%	-3%	-41%	-3%
	Waste, non-haz./ landfill	g	307 963	283 967	260 732	302 726	241 116	239 972
		% change with BC	0%	-8%	-15%	-2%	-22%	-22%
	Waste, hazardous/ incinerated	g	8 998	8 263	7 552	8 837	6 951	7 603
		% change with BC	0%	-8%	-16%	-2%	-23%	-16%
Emissions to Air	Greenhouse Gases in GWP100	kg CO2 eq.	12 243	10 255	8 331	11 809	6 706	12 212
		% change with BC	0%	-16%	-32%	-4%	-45%	0%
	Acidification, emissions	g SO2 eq.	54 615	45 820	37 303	52 696	30 113	54 557
		% change with BC	0%	-16%	-32%	-4%	-45%	0%
	Volatile Organic Compounds (VOC)	g	21 716	20 676	19 669	21 489	18 819	14 619
		% change with BC	0%	-5%	-9%	-1%	-13%	-33%
	Persistent Organic Pollutants (POP)	ng i-Teq	824	715	610	800	521	824
		% change with BC	0%	-13%	-26%	-3%	-37%	0%
	Heavy Metals	mg Ni eq.	3 148	2 677	2 222	3 045	1 837	3 148
		% change with BC	0%	-15%	-30%	-3 %	-42%	0%
	PAHs	mg Ni eq.	855	746	641	831	552	853
		% change with BC	0	-13%	-25%	-3%	-35%	0%
	Particulate Matter (PM, dust)	g	1 428	1 241	1 061	1 387	909	1 419
		% change with BC	0%	-13%	-26%	-3%	-36%	-1%
Emissins to Water	Heavy Metals	mg Hg/20	1 431	1 231	1 037	1 387	873	1 431
		% change with BC	0%	-14%	-28%	-3%	-39%	0%
	Eutrophication	g PO4	65	56	48	63	41	64
		% change with BC	0%	-13%	-27%	-3%	-38%	-1%

7.3.4 Base Case 4 design options environmental analysis

For the Base Case 4 scenarios, in addition to the flat efficiency design options, two multimode options were modelled. The option 4C multimode and flat efficiency were modelled using CoC-data for multimode. The option 4D multimode and flat efficiency were modelled using the BAT data for both.

The results of the modelling are presented in Table 91 and discussed in the following sections.

7.3.4.1 Impacts of flat efficiency Base Case 4

For Base Case 4 products the shift from base case products to Flat Efficiency options results in the reduction of total energy consumption by 16% (option 4A) and 32% (option 4B). The reduction of the electricity consumption over the lifetime of the product related to a Base Case 4 scenario is 17% (option 4A) and 33% (option 4B). Again Base Case 1 and 2 achieve better savings in term of total energy and electricity consumption than Base Case 4.

Other impact reductions include lower emission of greenhouse gases. The design option 4A provides a reduction of 16% and option 4B a reduction of 32%. Acidification could be reduced by 16% (option 4A), 32% (option 4B). Both reductions are at the same level as for the respective Base Case 3 design options.

Flat Efficiency options have no impact on the demand of process water, but for cooling water the shift from base case products to option 4A products reduces the demand by 15%. Shifting to option 4B provides a reduction of 30% which is similar to Base Case 3.The reduction of waste by the design options is similar to the Base Case 3 options. Option A reduces the non-hazardous waste by 9% and hazardous waste by 11%. For Option 4B the reduction is 18% for non-hazardous waste and 21% for hazardous waste.

Persistent organic pollutants (POP) would be 14% lower (option 4A) and 28% lower (option 4B). The reduction of PAH can reach 12% (option 4A) and 25% (option 4B). The emission of dust would be reduced by 12% (option 4A) and 23% (option 4B).

The emission of heavy metals to air would be lowered by 16% (option 4A) and 31% (option 4B). The emission of heavy metals in to water could be minimised by 15% (option 4A) and 29% (option 4B). For eutrophication the reduction potential is 15% (option 4A) and 30% (option 4B).

In general the reduction of environmental impacts by implementing the design option 4A or 4B is lower than the respective environmental impacts by the respective design option for Base Case 1 and 2 but similar to the Base Case 3 options.

7.3.4.2 Impact of multimode Base Case 4

For Base Case 4 products the shift to the multimode design results in a significant reduction potential in total energy consumption of 19% (option 4C) and 39% (option 4D) compared to the base case scenario. The reduction of the electricity consumption over the lifetime of the product related to a Base Case 4 scenario is 19% (option 4C) and 40% (option 3D).

Multimode design option 4C reduces the emission of greenhouse gases by 19% and for option 4D it is 39%. Acidification could be reduced by 19% (option 4C) and 39% (option 4D). The demand for cooling water is also minimised by 17% (option 4C) and by 37% (option 4D).

Option 4C reduces the non-hazardous waste by 10% and the hazardous waste by 12%. For Option 4D the reduction is 22% for non-hazardous waste and 25% for hazardous waste

Persistent organic pollutants (POP) would be 16% lower (option 4C) and 34% lower (option 4D). The reduction of PAH can reach 15% (option 4C) and 31% (option 4D). The emission of dust would be reduced by 14% (option 4C) and 29% (option 4D).

The emission of heavy metals to air would be lowered by 18% (option 4C) and 38% (option 4D). The emission of heavy metals in to water could be minimised by 17% (option 4C) and

36% (option 4D). For eutrophication the reduction potential is 17% (option 4C) and 36% (option 4D).

7.3.4.3 Impact of long life batteries Base Case 4

Comparing the option 4E scenario with the Base Case 4 scenario shows a limited reduction potential regarding the environmental impact. Option 4E provides a reduction potential of 38% concerning process water, but only of 2% for cooling water. It reduces the non-hazardous waste by 20% and the hazardous waste by 16%. The most significant reduction is given with 33% for volatile organic compounds. Implementing option 4E does not reduce any of other emissions mentioned for more than 1%. The long life batteries design option provides no improvement concerning the total energy consumption or the electricity demand over the product lifetime.

Table 91: Environmental impacts of the Base Case 4 and its design options

	Life-Cycle indicators	Unit	BC 4	Option 4A Flat Efficiency INT	Option 4B Flat Efficient BAT	Option 4C Multimode (CoC)	Option 4D Multimode (BAT)	Option 4E Long life Battery
Other Resources	Total Energy (GER)	MJ	4 662 190	3 896 664	3 153 487	3 789 099	2 825 205	4 654 959
		% change with BC	0%	-16%	-32%	-19%	-39%	0%
	of which, electricity (in primary MJ)	MJ	4 634 913	3 869 386	3 126 210	3 761 821	2 797 927	4 632 848
		% change with BC	0%	-17%	-33	-19%	-40%	0%
	Water (process)	ltr	7 937	7 937	7 937	7 937	7 937	4 950
		% change with BC	0%	0%	0%	0%	0%	-38%
	Water (cooling)	ltr	222 578	188 555	155 525	183 774	140 935	217 032
		% change with BC	0%	-15%	-30%	-17%	-37%	-2%
	Waste, non-haz./ landfill	g	4 403 754	4 009 253	3 626 270	3 953 821	3 457 095	3 503 875
		% change with BC	0%	-9%	-18%	-10%	-22%	-20%
	Waste, hazardous/ incinerated	g	114 469	102 391	90 665	100 694	85 486	96 003
		% change with BC	0%	-11%	-21%	-12%	-25%	-16%
Emissions to air	Greenhouse Gases in GWP100	kg CO2 eq.	199 617	166 939	135 215	162 347	121 202	199 171
		% change with BC	0%	-16%	-32%	-19%	-39%	0%
	Acidification, emissions	g SO2 eq.	885 574	740 974	600 596	720 656	538 588	884 669
		% change with BC	0%	-16%	-32%	-19%	-39%	0%
	Volatile Organic Compounds (VOC)	g	300 853	283 756	267 158	281 354	259 827	207 071
		% change with BC	0%	-6%	-11%	-6%	-14%	-31%
	Persistent Organic Pollutants (POP)	ng i-Teq	12 539	10 753	9 019	10 502	8 253	12 539
		% change with BC	0%	-14%	-28%	-16%	-34%	0%
	Heavy Metals	mg Ni eq.	48 897	41 157	33 642	40 069	30 323	48 896
		% change with BC	0%	-16%	-31%	-18%	-38	0%
	PAHs	mg Ni eq.	13 826	12 040	10 306	11 789	9 540	13 802
		% change with BC	0%	-12%	-25%	-15%	-31%	0%
	Particulate Matter (PM, dust)	g	25 209	22 147	19 174	21 716	17 861	25 077
		% change with BC	0%	-12%	-24%	-14%	29%	-1%
Emissions to water	Heavy Metals	mg Hg/20	22 272	18 977	15 778	18 514	14 365	22 272
		% change with BC	0%	-15%	-29%	-17%	-36%	0%
	Eutrophication	g PO4	956	811	671	791	609	944
		% change with BC	0%	-15%	-30%	-17%	-36%	-1%

7.3.5 Comparison between Base Cases

Looking at the total energy consumption (GER) for each base case and the applicable design options, it is noteworthy that Base Case and Base Case design option 1A and 2A deliver the largest GER savings in percentage terms (-43%) compared to their base case, as well as for design option 1B and 2B (-86%). These are much higher percentage savings than for any design options for Base Cases 3 and 4 as shown in Table 92. However it should be noted that the absolute savings for Base Case 1 are significantly lower than for Bases Cases 2, 3 and 4.

The majority of the energy consumption for each of the base cases and all related design options derive from the use phase of the products. As a consequence the demand for cooling water and all emissions related to the assumed energy production mix depend on the specific energy consumption. The majority of waste (hazardous and non-hazardous) is a result of the production phase[253].

For the emissions of heavy metals to the air the production phase is responsible for about 50% of the total emissions. Approximately 75% of the emissions of heavy metals and eutrophication are related to the manufacturing of the products and partly depend on the local manufacturing processes.

The multimode BAT design option (D) delivered the most energy savings in Base Case 3 at -45% compared to - 39% for Base Case 4.

It is noted that option E (longer life batteries) delivers negligible (<1%) savings [254] in term of GER for any of the base case scenarios considered.

As discussed in the sections above, flat efficiency and multimode design options deliver the most savings for greenhouse gases, acidification and heavy metals for Base Cases 2, 3 and 4. Significant savings are also realised for hazardous and non-hazardous waste as well as cooling water.

The reduction of the environmental impact of multimode systems for Base Case 3 and Base Case 4 products at CoC-level is significantly higher than those achieved with flat efficiency for these systems.

The long life battery option design as discussed earlier does not generate any savings in term of energy and only results on reduced environmental impacts for process water, hazardous and non-hazardous waste, and volatile organic compounds[255]. This is as expected, as these are the parameters affected by the materials used in batteries, as seen in the Task 5 LCA results. All other environmental impacts considered in the modelling are unchanged.

Most technologies entering as high level products could be scaled down to smaller products as soon as integrated components are available at a lower price level; as a result of increasing demand by larger series.

Table 92: Comparison of base cases total energy consumption (MJ)

	BASE CASE (GER - MJ)	Option A	Option B	Option C	Option D	Option E
BC1	14 242	8 059	1 936	N/A	N/A	N/A
Saving % change to BC		6183 -43%	12 306 -86%			
BC2	140 779	80 275	19 769	N/A	N/A	140 590
Saving		60 504	121 010			189

[253] Reducing redundancy would reduce the amount of material and as a result the amount of waste could be reduced. This design option was not modelled.
[254] Since the majority of the batteries used in UPS systems are manufactured outside the EU data for the energy consumption in the production phase of the batteries are based on the assumptions made for the EcoReport tool. The real energy consumption may vary.
[255] The improvements concerning the reduced environmental impact are based on the assumptions made for and by the EcoReport tool.

% change to BC		-43%	-86%			0%
BC3	285 279	238 714	193 628	275 117	155 563	284 813
Saving % change to BC		46 565 -16%	91 651 -32%	10 162 -4%	129 716 -45%	466 0%
BC4	4 662 190	3 896 663	3 153 487	3 789 098	2 825 205	4 654 958
Saving % change to BC		765 527 -16%	1 508 703 -32%	873 092 -19%	1 836 985 -39%	7232 0%

7.4 Subtask 7.3 – Costs

Information from literature and stakeholder consultation has been sought in order to understand the cost implications of the different design options summarised in Table 86. From the collected information the following assumptions in relation to each design option for different base cases were developed and are presented in the following section.

7.4.1 Extended battery lifetime

The prices of long life batteries were assessed using publicly available datasheets from the main manufacturers. Several different products with the same characteristics (voltages and electric charge), but with different lifetimes were compared to characterise the price variations (Table 93). Such assessment indicates an increase in price associated with moving to long life batteries.

Table 93: Price increase assumptions for longer life batteries

Lifetime variation	Price variation
3 – 5 years	+12%
5 – 8 years	+15%
5 – 10 years	+21%
8 – 10 years	+10%
8 – 12 years	+34%
10 – 12 years	+34%

The use of batteries with an extended lifetime is not effective in Base Case 1, as discussed in section 7.2.4. For Base Case 2, Base Case 3 and Base Case 4, the following extensions of lifetime were considered:

- Base Case 2 - move from 5 to 8 year battery
- Base Case 3 - move from 5 to 10 year battery
- Base Case 4 - move from 8 to 12 year battery

Table 94 shows the price increase assumption in each base case.

Table 94: Price increase assumptions for longer life batteries in each base case

	Assumed battery life time based for original base case scenario	Assumed battery lifetime for the no battery replacement scenario	Increase in price between the two battery lifetime scenarios
BC2	5 years	8 years	+15%
BC3	5 years	10 years	+21%
BC4	8 years	12 years	+34%

However, this increase in price will avoid the replacement of batteries during the product lifetime. Thus, the life time costs of the batteries were assessed (Table 95), showing a decrease in costs associated with moving to long life batteries[256].

Table 95: Costs assumptions during the lifetime for longer life batteries for each base case.

	Cost of each battery		Battery costs during the life time		Costs variation
	Base Case	**Long Life**	**Base Case**	**Long Life**	
BC2	€241	277 €	482 €	277 €	-43%
BC3	1 138 €	1 377 €	2 276 €	1 377 €	-40%
BC4	7 920 €	10 613 €	15 840 €	10 613 €	-33%

7.4.2 Improved components

The evolution of technologies in Power Conversion is reaching the asymptote of semi-conductor and electromechanical theoretical limits of performances. Some breakthroughs for active components are foreseeable like Silicon-carbide or GaN, but these technologies are not all yet available at the right size, cost and quality levels.

Other topologies than the classic VFI, VI and VFD are available as “hybrid” solutions, like the delta conversion. However, the availability provided to the load by “hybrid” solutions is difficult to compare to well defined UPS types and the energy efficiency performances are linked to the energy quality provided to the load (harmonic distortion, power factor correction…) which make it difficult to specify and compare.

However, the implementation of improved components in new products is the normal trend in design, which manufacturers always take into account because of the absolute need to improve products efficiency. Stakeholder feedback indicates that these new components are de facto pro-actively used without any major cost increase.

7.4.3 Flat efficiency

Usually, a UPS has higher efficiency with higher load levels. The increase of efficiency at higher load levels is achievable and comparing the costs of UPS available in the market with the CoC and BAT levels, such improvement is possible without a cost increase. However, the increase of efficiency in higher load levels for products that already have a very high efficiency is only possible with an oversizing of parts (more copper and more Semi-conductors etc.). This would be the case for existing BAT products.

The improvement of the efficiency at light load to achieve almost the same efficiency as in higher load levels (flat efficiency) is achievable with a better design (smarter control) and reduction of energy use by "auxiliary circuits" (internal PSUs, fans, coils etc.) which has a limited impact on product cost. Thus, the implementation of a flat efficiency curve should have no impact on the product price of the products.

7.4.4 Multi-mode design

Nearly all double conversion UPSs (VFI) have a static bypass circuit which can enable the implementation of an Eco-mode (VFD) with a limited cost impact, as it requires only the modification of the control circuits. Therefore, provisions in the design to switch from VFI to VFD topologies can be done at no additional cost. However, stakeholder feedback indicates to automatically enter and exit Eco-mode on an online UPS with an advanced algorithm requires more digital control capability which could be prohibitive in cost for low power rating UPSs.

[256] Using batteries with a longer design-life, described as option E, will increase the initial purchase cost, but lead to a reduced total cost of ownership over the lifetime of the UPS since only one longer life battery is needed instead of two standard life batteries. This assumption is only valid, if the use time of the UPS is according to the average life time expectation of a UPS as mentioned in Task 5. If the life of the respective UPS is shortened due to decisions by the user to shift to new equipment before the end of the scheduled life time, the assumptions made above are not valid. There are no data available about the number of UPS systems taken out of operation before their technical end of life.

Adding a VFD mode to a VI product typically adds cost by requiring a bypass path around the voltage regulator which is not universally present, especially in smaller UPSs. This could represent an increase of 5%[257] in the product cost and increases complexity, which could reduce reliability. In addition, patents may prevent all manufacturers from being able to offer such products.

7.5 Subtask 7.4 – Least Life Cycle Costs and BAT

The previous analysis has identified relevant design options for the different sizes of UPS used in the base cases, their environmental impact and the associated costs of these options at the product level. This section considers the design options for each base case to identify the design option with the least life cycle environmental impacts and the least life cycle costs (LLCC). The life cycle costs were calculated as part of Task 5, taking into account product price, installation and maintenance costs as well as energy costs during the use phase. The life cycle costs are amended as appropriate to reflect the different design options.

For those design options that mainly have an effect on energy consumption, the parameters compared are total energy and life cycle cost. For those design options that affect other environmental parameters, the most appropriate examples have been used.

7.5.1 Design Options Affecting Energy Consumption

7.5.1.1 Base Case 1 – Below 1.5 kVA

For Base Case 1 only flat efficiency has been identified as an appropriate design option that affects energy consumption. Two scenarios have been considered and compared against the original base case (BC1):

- Option 1A – Flat Efficiency (Intermediate level between base case and BAT values)
- Option 1B – Flat Efficiency (BAT levels identified from Energy Star database)

Feedback from industry indicates the introduction of flat efficiency can be achieved with minimal or no additional cost. It has therefore been assumed that there is no increase in product price for introducing flat efficiency. The main impact of flat efficiency for Base Case 1 is a reduction in use phase energy consumption, which is reflected in the costs shown in Table 96.

Table 96: Life Cycle Costs for Base Case 1: Below 1.5 kVA (New product €)

Base Case	BaU (BC1)	FE Intermediate (BC 1A)	FE BAT (BC 1B)
Purchase price	180	180	180
Installation cost	0	0	0
Electricity	166	91	16
Repair & maintenance	0	0	0
Total (% reduction compared to base case)	346	271 (22%)	196 (43%)

Using energy consumption data presented in Section 7.2 for the design scenarios, Figure 59 shows the impact of this option on the total energy consumption of the product over its life time and the life cycle costs. As one would expect, increasing efficiency leads to a reduction in the total energy consumption and also life cycle costs. Given that there is no increase in product price or installation or maintenance costs between the scenarios, the introduction of flat efficiency at the BAT levels represents the least life cycle cost option.

[257] Stakeholder feedback

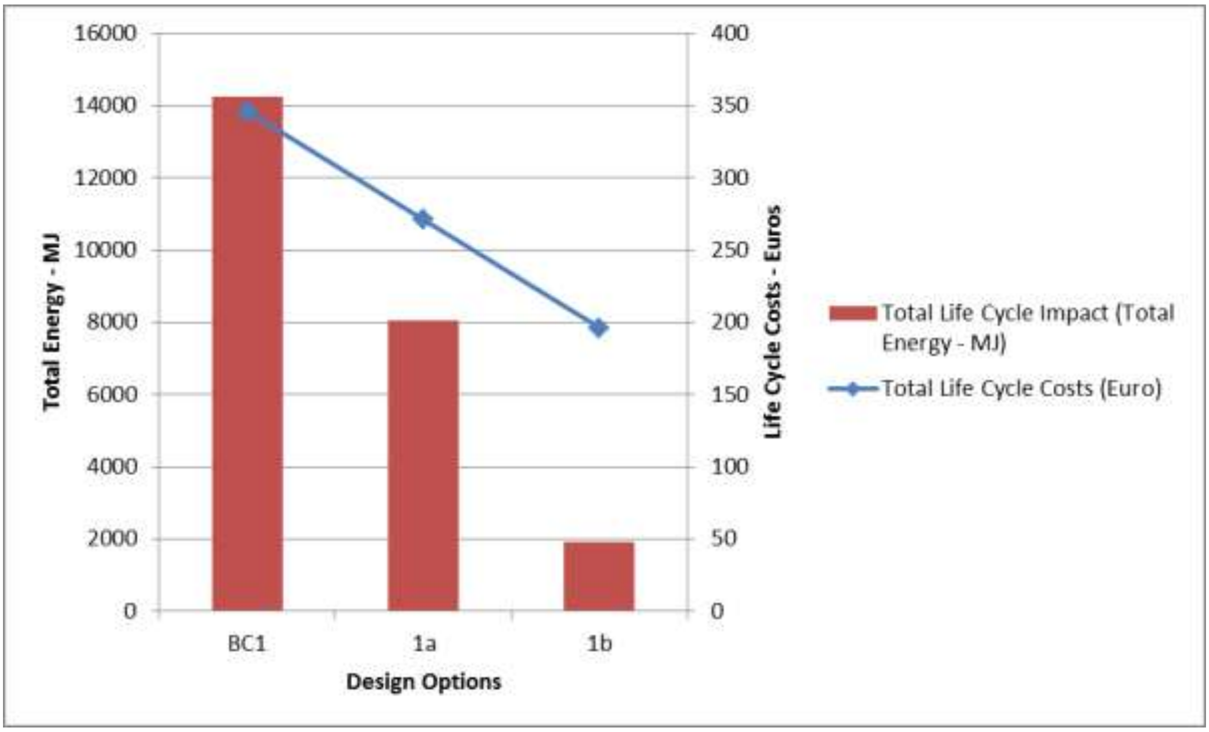

Figure 59: Impact of design options for Base Case 1 on energy consumption and life cycle costs

7.5.1.2 Base Case 2 – 1.5 to 5 kVA

As with Base Case 1, flat efficiency is the only design option identified as applicable for Base Case 2. Two scenarios have been considered and compared against the original base case (BC2):

- Option 2A – Flat Efficiency (Intermediate level between base case and BAT values)
- Option 2B– Flat Efficiency (BAT levels identified from Energy Star database)

As shown in Table 97, the impact on life cycle costs is a reduction in expenditure on use phase energy consumption.

Table 97: Life Cycle Costs for Base Case 2: 1.5-5 kVA (New product €)

Base Case	BaU (BC2)	FE Intermediate (BC 2A)	FE BAT (BC 2B)
Purchase price	643	643	643
Installation cost	308	308	308
Electricity	1 698	958	219
Repair & maintenance	241	241	241
Total (% reduction compared to base case)	2 890	2 150 (26%)	1 411 (51%)

Figure 60 shows the impact of this option on the total energy consumption of the product over its life time and the life cycle costs. As with Base Case 1, increasing efficiency leads to a reduction in the total energy consumption and also life cycle costs. Given that there is no increase in product price or installation or maintenance costs between the scenarios, the introduction of flat efficiency at the BAT levels represents the least life cycle cost option.

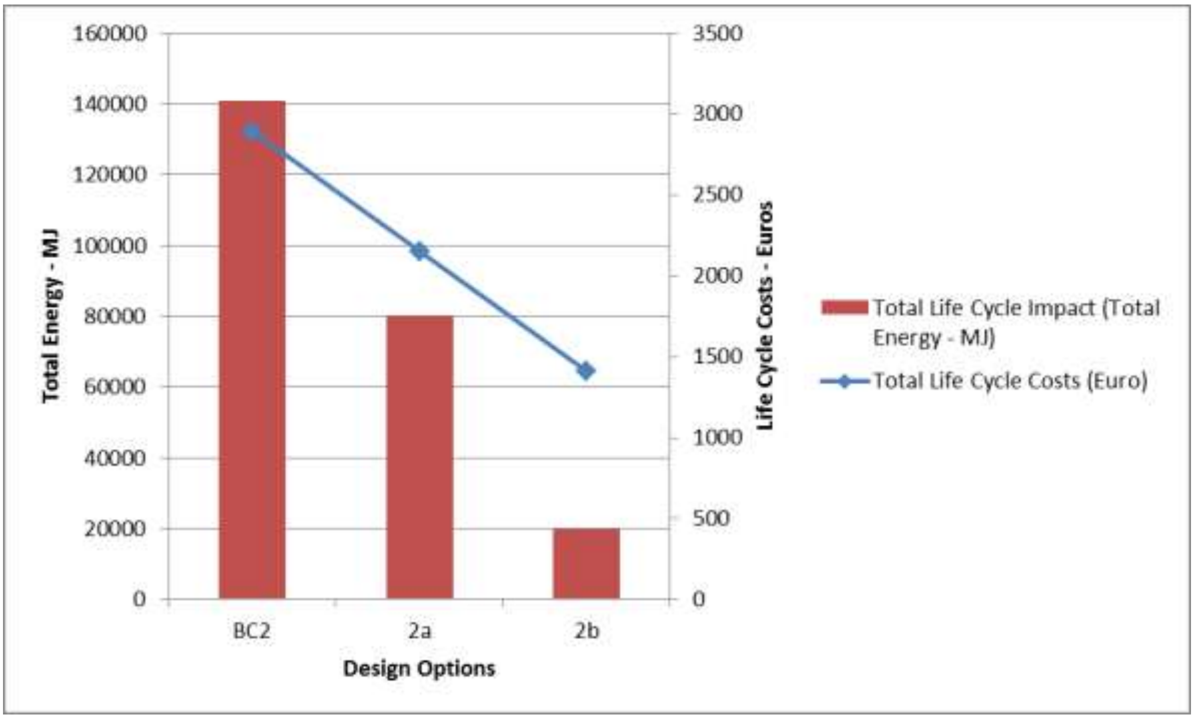

Figure 60: Impact of design options for Base Case 2 on energy consumption and life cycle costs

7.5.1.3 Base Case 3 – 5.1 to 10 kVA

For Base Case 3, both flat efficiency and multi-mode design options are applicable. Four scenarios have been considered and compared against the original Base Case (BC3):

- Option 3A – Flat Efficiency (Intermediate level between base case and BAT values)
- Option 3B – Flat Efficiency (BAT levels identified from Energy Star database)
- Option 3C – Multi-mode (Using data from latest Code of Conduct)
- Option 3D – Multi-mode + BAT Flat Efficiency

Based on the inputs and assumptions outlined in Section 7.2, the life cycle costs are again only impacted through a reduction in expenditure on use phase energy consumption, see Table 98.

Table 98: Life Cycle Costs for Base Case 3: 5.1-10 kVA (New product €)

Base Case	BaU (BC3)	FE Intermediate (BC 3A)	FE BAT (3B)	Multimode (CoC levels – BC3C)	Multimode + BAT Flat Efficiency (BC 3D)
Purchase price	3 502	3 502	3 502	3 502	3 502
Installation cost	503	503	503	503	503
Electricity	3 433	2 864	2 313	3 309	1 847
Repair & maintenance	1 138	1 138	1 138	1 138	1 138
Total (% reduction compared to base case)	8 576	8 007 (7%)	7 456 (13%)	7 763 (9%)	6 990 (18%)

As with Base Cases 1 and 2, Figure 61 shows the same pattern with respect to the Flat Efficiency options for Base Case 3. The multi-mode option based on existing Code of Conduct levels (3c) demonstrates limited improvement potential when compared to the base case. This is primarily because the base case assumes the majority of products already meet the code of conduct efficiency values. The small saving is achieved mainly by switching between the different modes (VFI and VFD). However, by combining BAT flat efficiency with multi-mode, using a high level of efficiency for each of the two modes (VFD and VFI), the savings in terms of energy consumption can be maximised (3D). This option also represents the least life cycle costs, due to the assumptions made with regards these design options i.e. there is no increase in product price as a result of introducing these design options. Improving the efficiency and introducing multi-mode only results in lower energy consumption and therefore lower expenditure.

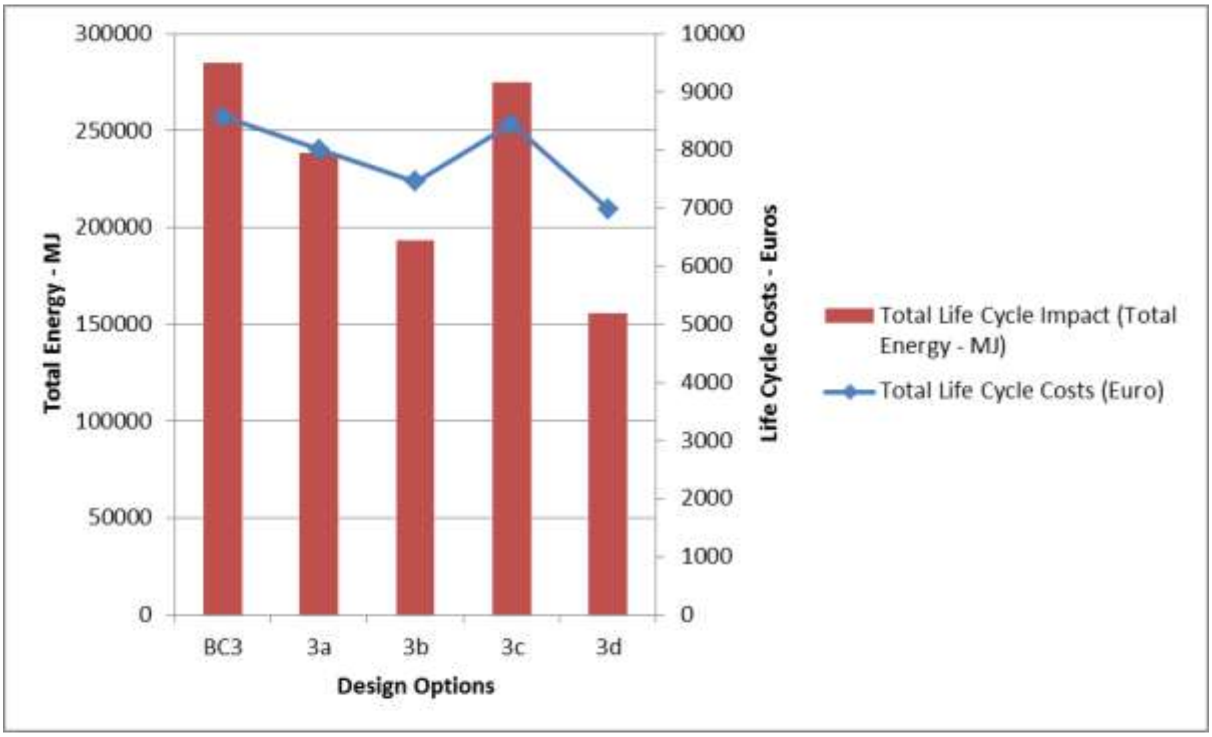

Figure 61: Impact of design options for Base Case 3 on energy consumption and life cycle costs

7.5.1.4 Base Case 4 – 10.1 to 200 kVA

For Base Case 4, both flat efficiency and multi-mode design options are applicable as with Base Case 3. Four scenarios have been considered and compared against the original base case (BC4):

- Option 4A – Flat Efficiency (Intermediate level between base case and BAT values)
- Option 4B – Flat Efficiency (BAT levels identified from Energy Star database)
- Option 4C – Multi-mode (Using data from latest Code of Conduct)
- Option 4D – Multi-mode + BAT Flat Efficiency

The same conclusions as for Base Case 3 can be drawn for Base Case 4. The design option combining BAT Flat Efficiency with Multimode represents the least life cycle cost option and maximises the reduction in energy consumption.

Table 99 and Figure 62 show the extent of the savings in terms of life cycle costs and energy consumption.

Table 99: Life Cycle Costs for Base Case 4: 10.1-200 kVA (New product €)

Base Case 4	BaU (BC4)	FE Intermediate (BC4A)	FE BAT (BC4B)	Multimode (CoC – BC4C)	Multimode + BAT Flat Efficiency (BC 4D)
Purchase price	28 800	28 800	28 800	28 800	28 800
Installation cost	1 220	1 220	1 220	1 220	1 220
Electricity	56 548	47192	38 109	45 877	34 096
Repair & maintenance	45 936	45 936	45 936	45 936	45 936

Total (% reduction compared to base case)	132 504	123 148 (7%)	114 065 (14%)	122 670 (7%)	110 052 (17%)

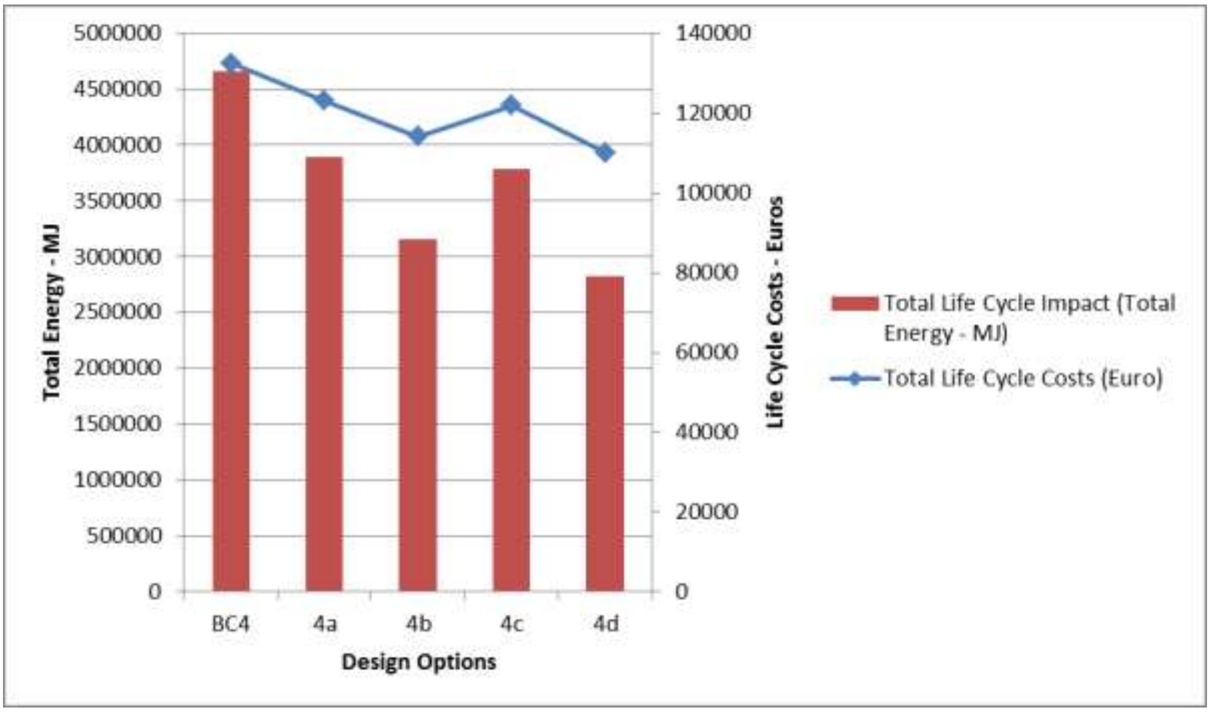

Figure 62: Impact of design options for Base Case 4 on energy consumption and life cycle costs

7.5.1.5 Key observations regarding energy efficiency design options

- Cost assumptions (based on stakeholder feedback) mean options with highest energy consumption savings are also the least life cycle cost options across the four base cases.
- A key issue will be the phasing of these improvements to reflect design cycles – this is addressed in the Task 8 policy scenarios.

7.5.2 Design Options Affecting Resource Consumption

7.5.2.1 Batteries

As outlined in Section 7.2.4, the long life battery design option is only applicable to Base Cases 2, 3 and 4. For this design option there is only one option, therefore identifying the least life cycle option is not applicable. However it is important to highlight the effect that moving to long life batteries will have on life cycle costs.

Using the assumptions for this design option outlined in Section 7.2 and the cost information presented in Section 7.4, Table 100 summarises the impact on total life cycle costs as a result of moving to longer life batteries (design options 2E, 3E and 4E).

Table 100: Life Cycle Costs for long life battery design option (euros)

Parameter	BC2 (BaU)	BC2 (2E)	BC3 (BaU)	BC3 (3E)	BC4 (BaU)	BC4 (4E)
Purchase price	643	679	3 502	3 741	28 800	31 493
Installation cost	308	308	503	503	1 220	1 220
Electricity	1 698	1 698	3 433	3 433	56 548	56 548
Repair & maintenance	241	0	1 138	0	45 936	38 016
Total	2 890	2 685	8 576	7 677	132 504	127 277

The implementation of longer life batteries results in an increase in the purchase price, but this is compensated for by a decrease in the repair and maintenance costs. For Base Cases 2 and 3 it was assumed in Task 5 that repair and maintenance costs covered battery replacement only, whereas for Base Case 4 there is separate battery replacement and service contract costs. In all three base cases there is a reduction in life cycle costs as a result of moving to longer life batteries:

- Base Case 2 – 7% life cycle cost reduction
- Base Case 3 – 10% life cycle cost reduction
- Base Case 4 – 4% life cycle cost reduction

Switching to longer life batteries will reduce the amount of resource use and the impacts of the relevant environmental parameters (waste, VOCs and process water). The impact on the environmental parameters is summarised in Section 7.3. As there is only one design option for long life batteries, the environmental impact and costs of different design options cannot be compared.

A number of key points have been raised by stakeholders in relation to the use of long life batteries which affect their use and have potential implications for the relevant policy measures. These include:

- End users do not necessarily consider they are using long life batteries and take a precautionary approach, replacing them before it is necessary;
- The lifetime of all batteries is affected by a range external factors, for example ambient temperatures and ageing during transportation/storage, therefore depending on these conditions, using a longer life battery may not eliminate the need for a battery replacement over the product lifetime. This would result in increased resource use and life cycle costs.
- Cash flow means that facilities managers will purchase cheaper batteries at the installation stage, rather than the longer life option.

Taking these points into consideration and given that the greater life cycle cost savings and environmental impact reductions can be achieved through design options targeted at energy consumption, it is proposed that MEPS and energy labelling will be the main focus of the policy scenarios in Task 8 rather than longer life batteries.

However, linking with the alternatives to long life batteries for Base Case 1 products, as outlined in Section 7.2.4.3, an information requirement for all UPS could be included covering aspects relating to batteries such as, optimum operating conditions, the benefits of using longer life batteries, and battery monitoring. In addition for Base Case 1 products it is proposed that designs promoting easy battery replacement should be considered, as products with these features are already available on the market at no additional cost, which could depending on the circumstances, as outlined in Section 7.2.4.3, reduce resource consumption. This is considered further in Task 8.

7.6 Conclusions

For the design options identified and modelled, the results clearly show that for energy related design options for Base Cases 1 and 2 the least life cycle cost option is flat efficiency at BAT levels. For Base Cases 3 and 4 it is the use of flat efficiency at BAT levels combined with multi-mode operation that enables switching between VFI and VFD modes. These will be considered as part of the policy scenarios in Task 8.

In addition to energy related design options, the use of longer life batteries has been considered. Due to uncertainties regarding the life time of batteries which is influenced by external factors, and the relatively small life cycle cost savings and reductions in environmental impact when compared to the energy related design options, the use of longer life batteries will not been considered further as part of Task 8 except in the form of an information requirement. For Base Case 1 products, where long life batteries are not necessarily appropriate, an alternative design option to enable the easy replacement of the battery in these products has been proposed to be taken forward for consideration in Task 8.

At the product level the absolute impacts are small, however the relative potential improvement that could be achieved when compared to the business as usual base case is relatively significant, for example over 80% in energy consumption in some cases. However it is important to understand the absolute impacts for the market as a whole when considering the development of policy options to fully understand how important the savings will be. This will be analysed in Task 8 using a simple stock model. In addition other options that affect resource use, but cannot be modelled at a product level, but will affect the system i.e. features that enable a reduction in redundancy, will also be considered as part of the different policy scenarios developed in Task 8.

8 Task 8 – Scenario, policy, impact and sensitivity analysis

8.1 Introduction

Uninterruptible Power Supplies (UPS) were identified as a priority product group under the European Commission's Eco-Design working plan 2009-2011. This preparatory study is the starting point of the 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 Commission's established methodology[258] 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.

8.1.1 Task 8 - Objectives

Task 8 of a Preparatory Study involves developing scenario, policy, impact and sensitivity analysis based on findings from previous tasks, in particular Task 6 and 7. Task 8 looks at presenting what policy scenarios might be viable in terms of future regulations (or other policy options) for implementation.

The section presents policy options developed from the work carried out so far and feedback from stakeholders and the European Commission. Following this the task has to establish what would be the environmental impacts/benefits of the proposed policies as well as the economic impacts. Finally a sensitivity analysis is completed.

[258] Methodology for the Ecodesign of Energy-related Products http://www.meerp.eu/

8.2 Subtask 8.1 – Policy and Scenario Analysis

Subtask 8.1 describes the different policy options available to realise the energy efficiency improvement options developed in Task 7. Policy options typically considered under the Ecodesign Directive include minimum efficiency performance standards (MEPS), Voluntary Agreements (VA) and energy labelling, under the Energy Labelling Directive. Yet other options include Green Public Procurement and the EU Ecolabel. All options are discussed below..

Some of the optional policies are more appropriate to the specific situation of the UPS market than others. The advantages and disadvantages of the proposed policies are explained in this section. The first step at this stage of the project is to first confirm (after refinement) the product group definition to which the policy options will apply.

8.2.1 Scope/Definition

The product group definition is presented in Task 1 report; it was put out for consultation through a questionnaire and stakeholder meeting in 2012. As the project evolved some modifications has been made to arrive at the definition below.

Definition

"A UPS is a combination of electronic power converters, switches and energy storage devices (such as batteries) constituting a power system for maintaining the continuity of power to a load in the case of input power failure."

Qualifying Notes

Input power failure means the failure of the main primary continuous power source (e.g. the AC grid). It can also mean the failure of the primary power source to maintain voltage and frequency within rated steady state and transient bands or to allow distortion or interruptions to the supplied power outside specified limits.

A UPS is a short duration (minutes/hours) power supply system that maintains the functions of the connected load when the main continuous power source has failed. The primary purpose of a UPS is to bridge an unexpected power gap and/or to provide the amount of power needed to safely power down the connected load.

In the case of a primary AC grid failure, the UPS may run in isolated mode and is not grid-connected on the supply side. In standby (when it is not replacing primary grid power) a UPS could operate in on-mode or off-mode, as an AC or DC operated device depending on the specific design.

A system providing electrical power, that supplements or is capable of continuously replacing the main source of grid power, is not a UPS (e.g. an engine or generator system).

Portable devices designed to operate using battery power such as laptop computers are excluded from the product group[259].

As there are specific demands for the installation of UPS systems in certain environments, the following applications should be excluded:

UPS used in the context of a medical installation are excluded from regulation by:

- **a)** the Council Directive 93/42/EEC of 14 June 1993 concerning medical devices[260] or
- **b)** the Council Directive of 20 June 1990 on the approximation of the laws of the Member States relating to active implantable medical devices 90/385/EEC[261], or

[259] Portable devices such as laptop computers or pad-computers are added as being excluded to the original qualifying notes in Task 1.
[260] OJ L 169, 12.7.1993, p. 1.
[261] OJ L 189, 20.7.1990, p. 17.

c) the Directive 98/79/EC of the European Parliament and of the Council of 27 October 1998 on in vitro diagnostic medical devices[262].

UPS which are like for like replacements in the same physical location/installation for existing UPS, where this replacement cannot be achieved without entailing disproportionate costs associated with their transportation and/or installation should be excluded from the regulation.

For non-standard UPS used in mission critical applications with high risks for human life/health, including but not limited to, chemical industries, oil and gas industries, marine or submersed applications, power plants, including nuclear power plants, aviation control and railway systems, the following conditions should apply: For these and similar applications that require additional energy consuming components such as, but not restricted to the following , specific cooling, ingress- prevention- compliant casing, low battery voltages for safety applications, etc. the energy consumption of such components should not be included in the measurements of the UPS system.

Where the requirements of such applications prevent the use of standard components and/or standard designs, the manufacturer must provide documentation explaining the need for using such non-standard components/designs. Such bespoke systems[263] should be excluded from the ecodesign regulation and energy efficiency labelling.

As noted in Task 1, the study has primarily focused on AC input and AC output UPS, which dominate the market. These types of UPS are therefore the focus of the proposals outlined in Task 8. Stakeholder feedback has indicated that DC Power Systems are a niche market and these are discussed in Task 6.

8.2.2 Policy scenarios

Due to the large number of brands available in the market for Base Case 1 (BC1) products, a Voluntary Agreement for this product group cannot be readily negotiated within a suitable timeframe. Since this option is not appropriate for one product group segment and the implementation of two alternative policies for different segments of the same product group are not desired, setting Minimum Efficiency Performance Standards, potentially supported by an energy label is the preferred option. Sub-scenarios such as those associated with suggested allowances in energy labelling which supplement MEPS to encourage resource efficiency, are detailed in section 8.2.3. Where data is available, a sub-scenario resource impact example is given in that section.

8.2.2.1 Minimum Efficiency Performance Standards (Ecodesign Measure)

The first policy scenario considered is the implementation of Minimum Efficiency Performance Standards (MEPS) for UPS. The analysis in Task 5 indicates that the main environmental impact of UPS is from their in use energy consumption; therefore focusing on MEPS is considered appropriate. Task 7 identified improvement options relating to high flat efficiency and multi-mode features that improve the energy efficiency of the product, with a combination of these identified as the least life cycle cost option.

This section outlines a MEPS only scenario, enabling a clear indication of the outcomes of this policy scenario to be modelled using a simple stock model based on the stock data from Task 2. The results of this scenario are discussed in section 8.3. Additional policy scenarios, which consider energy labelling and MEPS are discussed in Section 8.2.3.

[262] OJ L 331, 7.12.1998, p.1.

[263] A bespoke UPS product is defined as “a UPS products made to a customer’s design and/ or specification and not made available to any third party as part of the UPS manufacturer’s product range”

Main MEPS Scenario

When setting MEPS it is important to distinguish between different UPS topologies and sizes. For the purposes of this scenario, this has been undertaken in line with base cases developed in Task 5, and summarised in Table 101[264].

Table 101: Summary of base cases

Base Case	Size	Topology
BC1	< 1.5 kVA	Standby (VFD)
BC2	1.5 – 5.0 kVA	Line Interactive (VI)
BC3	5.1 – 10 kVA	On-line/Double Conversion (VFI)
BC4	10.1 - 200 kVA	On-line/Double Conversion (VFI)

For each base case different efficiencies have been selected relevant to the size and topology of the UPS represented by that base case, this data is summarised in Table 102. For each base case a **business as usual scenario** (BAU), and a **MEPS Scenario**, which consists of Tier 1 and Tier 2 efficiency levels are provided[265].

- Business as Usual

  In the analysis below, the BAU scenario is based on the current (version 2, 2011) Code of Conduct[266] (CoC) levels for Base Cases 1, 2 and 3. For Base Case 4 it is assumed products before 2014 meet version 1 code of conduct[267] requirements as per the Task 5 analysis, but after 2014, the current (version 2) Code of Conduct efficiency levels are met.

- Tier 1

  As part of the analysis in Tasks 6 and 7 a review of products in the Energy Star 2013 database[268] was undertaken. This identified best performing products for each of the base cases, taking into account the relevant size and topology. The tier 1 efficiency levels used in this policy scenario are set at an intermediate level between the base cases and the BAT identified from the Energy Star database.

- Tier 2

  The Tier 2 levels used in this policy scenario are based on the best performing products (BAT) for each of the base cases, taking into account the relevant size and topology, identified from the Energy Star 2013 database. Stakeholder feedback indicates that improving efficiencies beyond exiting BAT levels would require the use of more expensive components for relatively small gains, as efficiencies are already high in BAT products; it is therefore not considered appropriate to set Tier 2 requirements at BNAT.

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[264] The base cases were established up to 200kVA following discussion with stakeholders as part of Tasks 4 and 5. Above 200kVA systems tend to be bespoke and therefore representative bill of materials were not available for these products. The market data in Task 2 was also structured in accordance with these base cases, which have therefore been used to structure our MEPs scenario. One stakeholder questioned whether MEPs could be set for products above 200kVA. There would not necessarily be a reason why this could not include products above 200kVA, which are not bespoke. This should be discussed with the wider industry, whose feedback helped inform the study's base cases, as part of the Consultation Forum. Indeed our labelling proposal aligns with Energy Star boundaries, and would therefore include products above 200kVA.

[265] Feedback from different stakeholders on the appropriate level of ambition for the MEPS varied. Tier 2 is based on 2013 best performing products; these standards would not need to be met until 2019. It is assumed that between now and 2019 the market generally will move towards higher efficiency, however MEPS ensure inefficient products will not be brought onto the market indefinitely. Requiring products to meet the standards in 2013 best performing products prior to 2019 is not considered appropriate once considerations such as the time to develop and implement a Regulation, and product design cycles are taken into account.

[266] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011

[267] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, 2006

[268] ENERGY STAR Uninterruptible Power Supplies Product List, August 23, 2013, available at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=UPS

Table 102: Efficiency levels (based on CoC and Energy Star 2013 data)

BAU / Tier	Scenario	Load Levels			
		25%	50%	75%	100%
BAU	BC1	86.0	87.0	88.0	89.0
Tier 1	BC1 Intermediate	91.8	92.8	93.5	94.1
Tier 2	BC1 BAT	97.5	98.6	99.0	99.1
BAU	BC2	85.0	89.0	89.9	90.0
Tier 1	BC2 Intermediate	91.2	93.7	94.3	94.4
Tier 2	BC2 BAT	97.3	98.4	98.7	98.8
BAU	BC3	85.5	91.5	92.5	92.5
Tier 1	BC3 Intermediate	89.9	93.7	93.8	93.4
Tier 2	BC3 BAT	94.3	95.8	95.1	94.2
BAU	BC4	89.0 (85.0)	93.0 (90.1)	93.5 (90.6)	93.5 (90.3)
	BC4 from 2014	91.5 (87.5)	94 (91.1)	94.5 (91.6)	94.5 (91.3)
Tier 1	BC4 Intermediate	91.8 (87.8)	94.6 (91.7)	95.0 (92.1)	95.0 (91.8)
Tier 2	BC4 BAT	94.6 (90.6)	96.1 (93.2)	96.5 (93.6)	96.5 (93.3)

*Note BC4 efficiencies take into account transformer losses as per the base case in Task 5 and Table 104 below – numbers in brackets.

Based on the efficiency levels presented in Table 2, the inputs for EcoReport have been amended to generate the necessary outputs for use in the stock model. These inputs are calculated using the same assumptions as in Task 5, with only the efficiency levels changing. These inputs and outputs are summarised in Table 3. This is referred to as the **MEPS scenario** throughout this report.

It is important to note that the data for Base Case 4 shown in Table 103 includes allowances for transformer losses (summarised in Table 104). An alternative scenario, without transformer losses is outlined below and summarised in Section 8.2.2.2.

Table 103: Summary of revised EcoReport inputs/outputs

	Scenario	Annual kWh Input	EcoReport Output*
BAU	BC1 Original	378	14 242
	BC1 2014	378	14 242
Tier 1	BC1 Intermediate	206	8 059
Tier 2	BC1 BAT	36	1 936
BAU	BC2 Original	1 929	140 780
	BC2 2014	1 929	140 780
Tier 1	BC2 Intermediate	1 089	80 275
Tier 2	BC2 BAT	249	19770
BAU	BC3 Original	3162	288 975
	BC3 2014	3162	288 975
Tier 1	BC3 Intermediate	2 620	240 194
Tier 2	BC3 BAT	2 102	193 628
BAU	BC4 Original	42 840	4 662 190
	BC4 2014	37 925	4 131 350
Tier 1	BC4 Intermediate	35 751	3 896 664
Tier 2	BC4 BAT	28 870	3 153 487

* Total energy MJ (over lifetime of product)

Table 104: Summary of allowances for Base Case 4 transformers losses

UPS Load (%)	Efficiency allowance for input or output transformer (%)
25	4.0
50	2.9
75	2.9
100	3.2

For the MEPS scenario requirements are implemented in a tiered approach. For the purposes of this scenario the implementation dates were set at:

- Tier 1: 2017
- Tier 2: 2019

The dates were selected to reflect when legislation setting MEPS could be implemented should the European Commission decide to do so (assumed 2016 at the earliest). It also takes into account stakeholder feedback, indicating that the current best performing products identified from the Energy Star 2013 database, which will have been designed two to three years ago could become the norm within four to seven years for the product sizes and topologies represented by the base cases[269]. This is unlikely to be achieved through market drivers alone, for example there are still products on the market that do not meet the industry voluntary code of conduct requirements, despite it being available since 2006.

Alternative Scenarios

In addition to the main MEPS scenario outlined above, a number of additional scenarios were created pushing the level of ambition further by:

- Incorporating multi-mode features into Tier 2 for Base Cases 3 and 4 (Subsequently referred to as the **Multimode Scenario** in this report)
- Considering Base Case 4 without the transformer losses (Subsequently referred to as the **BAU+Tranformerless Scenario, MEPS+Transformerless Scenario** and the **Multimode+Transformerless Scenario** in this report)

Multimode Scenario

Multimode features, which enable the UPS to switch between different modes, can improve the overall efficiency of the UPS. Based on the results of the analysis undertaken in Task 7, the Tier 2 of the MEPS scenario has been revised in the Multimode scenario to include multimode in addition to the BAT efficiency levels. Table 105 summarises the BAT efficiency levels for multi-mode for Base Cases 3 and 4 used for this scenario. The revised EcoReport inputs and outputs are presented in Table 106.

Table 105: Efficiency levels for multi-mode design options

Load Level / Scenario	Mode	25%	50%	75%	100%
BC3 Multi-mode BAT Efficiency	VFI (online)	94.3%	95.8%	95.1%	94.2%
	VFD (standby)	99.0%	99.0%	99.0%	99.0%
BC4 Multi-mode BAT Efficiency*	VFI (online)	90.6%	93.2%	93.6%	93.3%
	VFD (standby)	95.0%	96.1%	96.1%	95.8%

**Note BC4 efficiencies take into account transformer losses as per the base case in Task 5 and Table 104 above*

[269] While the study team believe the timing of the tiers strikes a realistic balance in terms of design cycles and excluding the worst performing products from the market, some stakeholder feedback indicates the proposed tiers may be too soon for larger products. One option would be to exclude certain products from tier 1 requirements to allow design cycles to focus on meeting the tier 2 requirements. This should be discussed at the Consultation Forum to understand the opinions of the wider stakeholder group.

Table 106: Summary of revised EcoReport inputs/outputs

Scenario	Annual kWh figure input for EcoReport	EcoReport output – total energy MJ (over lifetime of product)
BC3 Multi-mode BAT Efficiency	1 679	155 563
BC4 Multi-mode BAT Efficiency*	25 830	2 825 205

Base Case 4 – Transformless Scenarios

For Base Case 4 it was assumed in Task 5 that allowances for transformers applied to all products. Subsequent stakeholder feedback indicates that the use of transformers in UPS design is increasingly limited and only applies to a relatively small proportion of products (less than 10%). In light of this additional scenarios has been developed, which considers Base Case 4 without the transformer losses. This results in revised scenarios, which are referred to as the BAU+Transformless, the MEPS+Transformerless Scenario and the Multi-Mode+Transformeless Scenario

Table 107 summarises the efficiencies for Base Case 4, without transformer losses, and Table 108 presents the EcoReport inputs and outputs.

Table 107: Base Case 4 efficiencies without transformer losses

Scenario / Tiers	Load Levels	25%	50%	75%	100%
BAU+Transformerless	BC4	89.0	93.0	93.5	93.5
	BC4 from 2014	91.5	94.0	94.5	94.5
MEPS+ Transformerless (Tier 1)	BC4 Intermediate	91.8	94.6	95.0	95.0
MEPS+Transformerless (Tier 2)	BC4 BAT	94.6	96.1	96.5	96.5
Multimode+Transformerless (Tier 2)	VFI	94.6	96.1	96.5	96.5
	VFD	99.0	99.0	99.0	99.0

Table 108: Summary of revised EcoReport inputs/outputs

	Scenario	Annual kWh input	EcoReport output*
BAU+Transformerless	BC4 Original	30 267	3 304 358
	BC4 2014	25 352	2 773 519
MEPS+ Transformerless (Tier 1)	BC4 Intermediate	23 179	2 538 831
MEPS+Transformerless (Tier 2)	BC4 BAT	16 298	1 795 656
Multimode+Transformerless (Tier 2)	BC4 Multimode	13 258	1 467 373

**total energy MJ (over lifetime of product)*

8.2.2.2 Summary of the different scenarios

A summary of the different scenarios is presented in Table 109 below. Note that efficiencies relate to the different types of UPS topology as described above.

Table 109: Summary of minimum efficiency performance standard scenarios

Scenario Name	Base Case	Tier 1 (2017)	Tier 2 (2019)
BAU	BC1, 2, and 3	Product efficiencies based in Code of Conduct v2.	As per Tier 1.

	BC4	Product efficiencies based on Code of Conduct v1 for products purchased before 2014, and Code of Conduct v2 for products purchased from. This scenario takes into account transformer losses.	As per Tier 1.
MEPS	BC1, 2, 3 and 4	Efficiency levels set at an intermediate level between the BAU scenario and BAT identified from the Energy Star Database.	Efficiency levels set at BAT efficiencies identified from the Energy Star Database.
Multi-mode	BC1 and 2	As per MEPS scenario.	As per MEPS scenario.
	BC3 and 3	As per MEPS scenario.	Incorporates multi-mode functionality when calculating efficiencies.
BAU+Transformerless	BC1, 2 and 3	As per BAU scenario.	As per BAU scenario.
	BC4	As per BAU scenario but excluding transformer losses for BC4 that were included in the BAU scenario i.e. assume transformerless.	As per Tier 1
MEPS+Transformerless	BC1, 2 and 3	As per MEPS scenario	As per MEPS scenario
	BC4	As per MEPS scenario but excluding transformer losses for BC4 that were included in the BAU scenario i.e. assume transformerless.	As per Tier 1
Multi-mode+Transformerless	BC1, 2 and 3	As per Multi-mode scenario	As per Multi-mode scenario
	BC4	As per Multi-mode scenario but excluding transformer losses for BC4 that were included in the BAU scenario i.e. assume transformerless.	As per Tier 1

8.2.3 Energy Labelling

8.2.3.1 Objectives and target stakeholder group for a UPS energy label

The principle objectives of product energy labelling are:

- To allow the potential purchaser to identify quickly, best performing products using a standard label scale that provides an assessment of the efficiency of the product in terms of energy used to perform its main functions.
- To foster an element of competition between UPS product manufacturers to bring their products to the top of the labelling scale through improved design and the application of better technology.
- Where practicable, to reflect in the label scaling, other environmental impacts of the products' life cycle besides energy in use.

The potential users of a UPS Energy Label are heavily biased towards those who specify multiple product (Base Case 1 and Base Case 2) or large output capability (Base Case 3 and Base Case 4) UPS installations. Single product users are a small and decreasing part of the UPS market. The study team therefore advises that the UPS market can be adequately informed by a single label covering the full range of base cases defined by the project team.

8.2.3.2 Label design and information requirements

In the EU, a standard label presentation for a range of energy using products is well established and governed by a Regulation[270] (see Figure 63).

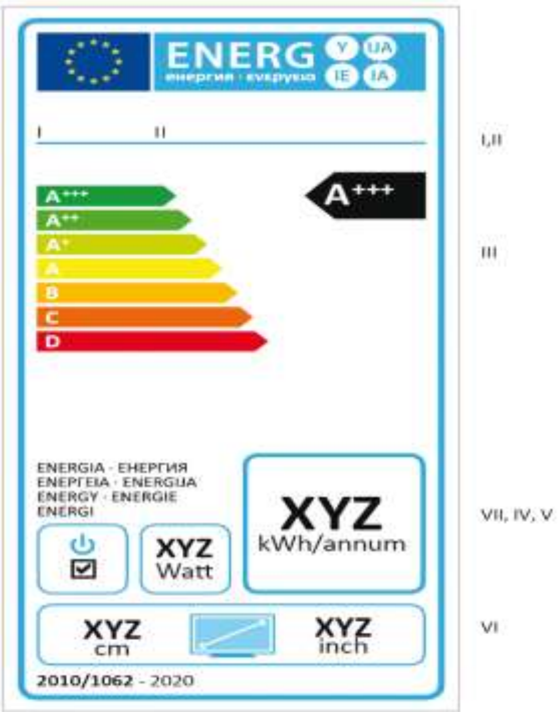

Figure 63 EU Energy Label (TVs/Displays 2020)

The EU Energy Label must include specific details of the manufacturer and model of the UPS. This information is contained in Figure 63 sections I and II.

Annual energy consumption for a UPS product is a meaningless statistic because of the unpredictability of UPS loading in actual use. This is particularly the case for the standby UPS which may never be loaded if there is no mains failure. If it is deemed necessary to

[270] Directive 2010/30/EU on the indication by labelling and standard product information of the consumption of energy and other resources by energy related products. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32010L0030:EN:NOT

declare annual energy consumption (losses) on the label it is suggested that the weighted efficiency of the UPS is used to make a kWh annual energy consumption (energy losses) calculation for section V in Figure 63, this is further explained in Section 8.2.3.3 below.

8.2.3.3 Calculation of the weighted efficiency of the UPS for Energy Label scaling

The power loading of a UPS, in use, is not predictable in terms of the loading level and period of time at that level. Even with flat efficiency technology the loading of the UPS will affect the average efficiency. To enable the consistent calculation of efficiency for Energy Star compliance, the major part of the UPS Industry has agreed a loading level versus time scenario with an associated metric allowing a consistent weighted efficiency calculation. The scenario is modified to reflect better the different efficiency characteristics of low, medium and high power UPS.

For Energy Star purposes, three basic UPS power groupings with separate loading scenarios are identified from current manufacturers', data[271]. The data shown in Table 110 and the weighted (average) efficiency metrics (Equation 1) are from "Energy Star programme requirements for uninterruptible power supplies Eligibility Criteria Version 1.0":

Table 110: AC-output UPS loading assumptions for calculating efficiency (reproduced from Energy Star)

Rated Output Power, P, in watts (W)	Input Dependency Characteristic	Proportion of Times Spent at Specified Proportion of reference Test Load, $t_{0\%}$			
		25%	50%	75%	100%
P ≤ 1500 W	VFD	0.2	0.2	0.3	0.3
	VI or VFI	0.0	0.3	0.4	0.3
1500 W < P ≤ 10,000 W	VDF, VI, or VFI	0.0	0.3	0.4	0.3
P > 10,000 W	VDF, VI, or VFI	0.25	0.5	0.25	0.0

Equation 1: Calculation of average efficiency for Ac-output UPSs

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

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;

For UPS with intelligent multimode operation technology, the calculated weighted efficiency may be modified (improved) by an Energy Star metric introducing the highest efficiency mode of the multimodes (usually the line interactive mode) as presented in Equation 2[272].

[271] ENERGY STAR Program Requirements for Uninterruptible Power Supplies (UPSs), 2012

[272] This equation from Energy Star covers 2-modes to calculate multimode efficiency. The use of this equation was agreed with stakeholders during discussions at the third stakeholder meeting. Stakeholders advised that in their view, it was not necessary to make special provision for 3-mode functionality, as the majority of manufacturers only use 2-mode functionality, which also aligns with the approach and equations already established in Energy Star, reducing the testing burden on manufacturers. It was also indicated that they had no data available to inform the study and a revision of the equation to cover 3-mode functionality. Subsequent feedback from another manufacturer proposes a revised equation to take into account three mode functionality – details are included in Appendix 11. The manufacturer has used their own monitoring data to establish the proposed time spent at each of the 3-modes within their equation, which cannot be verified. It is recommended that this issue is discussed with the wider manufacturing stakeholder group during the Consultation Forum process to establish whether verifiable data is available in order to develop a proposal, the extent of 3-mode functionality and reach a consensus on whether it is appropriate to include a 3-mode efficiency equation.

Equation 2: Calculation of average efficiency for multimode-normal-mode Ac-output UPSs

$$Eff_{AVG} = 0.75 \times Eff_1 + 0.25 \times Eff_2$$

Where:

- Eff_{AVG} is the average loading-adjusted efficiency,
- Eff_1 is the average loading-adjusted efficiency in the lowest input dependency mode (i.e., VFI or VI),
- Eff_2 is the average loading-adjusted efficiency in the highest input dependency mode (i.e., VFD).

For the comparability of international product databases and to contain the burden of declaration and UPS compliance testing for major world markets, it is recommended that the Energy Star approach to providing a weighted efficiency calculation is adopted. This can be used for the primary calculation in an EU Energy Label efficiency declaration for products in the relevant Energy Star power groupings (≤ 1500 W, 1500 W to 10 kW, ≥ 10 kW).

8.2.3.4 Suggested methodology for building in efficiency allowances in the calculation of the UPS label scale position

Efficiency allowances should be allowed regarding four key aspects of UPS design:

- Compensation for transformer losses in UPS where galvanic isolation for safety purposes compromises the efficiency of the UPS for label scaling purposes
- Resource impact bonus for UPS which facilitate automatic, UPS replacement, deactivation and load sharing (for this report termed “AMS”) in an installation system thus allowing a significant reduction in UPS units for a given load without compromising supply security (resilience and availability)
- Compensation for VFI (full double conversion) topology (where a common energy labelling regime is required for all UPS types)
- Resource impact bonus for UPS which provide battery internal resistance monitoring and correction (to be considered)

There is a precedent for allowances in EU energy labels. The TV energy label provides a 5% on-mode power reduction allowance for TVs with automatic brightness control, in the energy efficiency calculation for labelling. Each of these aspects is discussed in more detail below.

Transformer losses

In practice, transformer losses vary significantly according to the UPS load and the UPS maximum power rating. Two approaches to establishing a transformer allowance are suggested.

- The UPS manufacturer provides a practicable testing interface to the product to allow the UPS weighted efficiency to be measured with the transformer bypassed, in independent test laboratories. This measurement will be used for label scaling.
- The BAT transformer losses figure identified in Task 5 as that which is likely to be practicable through to 2025, i.e. 2.5%, is used as an efficiency compensation for label scaling where a galvanic isolation transformer cannot be bypassed in the UPS for efficiency testing purposes[273]. Only one transformer allowance should be given for label scaling purposes.

[273] Direct discussions with a manufacturer indicate that UPS's with integrated transformers are used less frequently, and this is an increasing trend. If UPS's with integrated transformers are likely to be phased out before an Ecodesign Regulation can be implemented, then a transformer allowance would not necessarily be required, however there is insufficient evidence at the present to confirm whether this would be appropriate.

A concern was identified in discussion with UPS manufacturers' representatives regarding transformer allowances. Their issue was that the allowance might be used as a loophole in a regulation to enhance the energy label scaling of low cost UPS electronic designs with a poor efficiency performance. This argument is countered by considerations of the high cost of the transformer required which is likely to significantly exceed the potential cost saving of using inefficient electronic circuit design. It is further countered by the fact that a (low) BAT transformer efficiency allowance of 2.5% is suggested which provides a relatively low efficiency compensation for typical transformer losses. Efficient electronic design in a UPS with a transformer would be essential to meet the MEPS set for UPS in a regulation.

AMS (Automatic UPS replacement deactivation and load sharing without compromise to system availability)

AMS functionality is provided by a number of manufacturers. In the context of UPS this refers to a combination of installation and modular UPS functionality which allows the automatic detection of load requirements to optimise the energy efficiency of the UPS installation and the automatic replacement and disconnection of a faulty UPS for safe maintenance or replacement concurrent with full continuity of installation system usage. Typically this AMS functionality will be provided through a number of key features, which include:

- Fast switching between modes i.e. VI/VFD/VFI to optimise energy efficiency in meeting load requirements
- The ability for a UPS in a modular set up, to be taken in and out of the loading configuration without compromise to the continuity and resilience of the power supply to the load.
- The ability to automatically replace a UPS in an installation system without compromise to the resilience and continuity of the power supply to the load, for example when a fault is detected or the UPS is scheduled for maintenance.

A range of terms are used by different manufacturers to cover AMS functionality, which in some cases describe the individual features, for example "hot swap", "circular redundancy", "fast transfer". "load sharing" and "load balancing"

UPS technology supporting AMS allows high resilience UPS installations to almost halve their UPS product installation number for a given load without compromising the resilience number (e.g. financial /banking server centres demanding six nines resilience of power supply). In an extreme resilience situation of 2N[274] 50% of the UPS units are redundant for a given maximum load compared with an equivalent AMS installation system.

As an example of this AMS up to 30 modular UPS units can be used to automatically support a given load supply. Just one of these units is redundant. Each unit can currently be rated from 6 kVA up to 20 kVA. The equivalent installation without this AMS, using identically rated UPS in a 1+1 redundancy resilience would require 60 modular units. Thus AMS allows a saving of the life cycle resource impact of 29 units (48%).

***Example Scenario**; In Western Europe, in 2013 the annual data centre load requirement is an estimated 79 TWh,[275] of electrical energy. (A load power requirement of approximately 9 GW). In a six nines resilience scenario where this power was maintained by 20 kW modular UPS with AMS, the resource saving would be 432,000 20kW UPS products.*

To encourage the uptake of AMS functionality it is suggested that a (notional) 1.5% energy efficiency bonus is added to the energy label scaling efficiency of UPS products using this technology. A very important aspect of this labelling efficiency credit is that it provides a mechanism to resolve the difficult problem of influencing the UPS installation designer to reduce the UPS product redundancy which is dictated by a user demand for extreme power supply resilience.

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[274] See Task 4. Subtask 4.3 " UPS availability, reliability and redundancy" for background and further explanation relating to resilience and redundancy.
[275] Final Report EU project "Prime Energy" (IEE/09/816/SI2.558 288) 2012.

AMS technology is not currently defined in existing IEC standards. Further input from industry to clearly define and name AMS functionality will be required to ensure it represents adequately the required performance of a UPS installation claiming compliance with AMS functionality.

Compensation for VFI (full double conversion) topology

The basic topology of the UPS product has a direct influence on the potential maximum efficiency of the product. A VFD (standby) or VI (line interactive) UPS should be more efficient than an electronically more complex VFI (full double conversion) UPS product. Comparing the efficiency of these products through a single label scale graphic could be misleading. Based on current UPS data (2013) it is suggested that a 2.3% efficiency debit should be subtracted from the calculated weighted efficiency of VI (line interactive) UPS for the label scaling position (Figure 63, Section lll).

Discussions with industry stakeholders indicated they would prefer label scales to be based on individual UPS topologies rather than attempting a universal label scale with a fixed compensation for a UPS topology providing more demanding power protection (VFI). This would be a feasible alternative to the universal label scale outlined above. Label scaling preferred by UPS manufacturing industry stakeholders are shown in Appendix 10. It should be noted that the Industry scaling for each UPS topology has a wider label scale with a relatively low starting MEPS at “G”. The Industry scaling is estimated to bring 55% of UPS in the market to, or above the current Energy star qualifying level.

A more ambitious scaling for each topology is also suggested in Appendix 10.

Resource Impact bonus

Recent developments in UPS battery monitoring allow the internal resistance of a battery in a bank of batteries to be externally monitored and within specific limits automatically altered to ensure that the battery is not stressed in the charging mode. When these monitoring limits are exceeded a battery failure warning is transmitted from the UPS to the external monitoring. This technology has the potential to extend significantly, the life of UPS batteries with no risk to the resilience of the UPS installation and with a potentially large reduction in the life – cycle resource impact of these batteries. It is suggested that a notional 0.75% efficiency credit is given for battery monitoring. For small standby VFD UPS where battery access for replacement would normally require maintenance skills, a caveat for providing a battery monitoring credit would be that the battery should be accessible to the user without dismantling the product. If this is not the case the user is likely to replace the whole UPS since the cost of a maintenance engineer’s time and the replacement battery is likely to be close to the cost of a new UPS. Automatic battery monitoring, internal resistance correction and condition reporting by data transmission, is still in its infancy as an applied technology. At this stage it would be difficult to model the impact of the technology on life cycle resource savings and life cycle costs.

Conclusion

If the suggested efficiency allowance approach is accepted for label scaling it is suggested that the basic topology of the UPS and its maximum power rating is recorded in the lower information panels of the label along with the calculated weighted efficiency and a list of allowances. Symbols may be preferred for the Transformer, AMS and Battery Monitor graphics to keep the label looking simple and clear. Consideration should be given to the fact that these allowances are for label A to E rating and are not relevant to the efficiency performance of the UPS product in practice. It may be that allowances should not be included in the labelling information.

Figure 64 provides an example of how it could work.

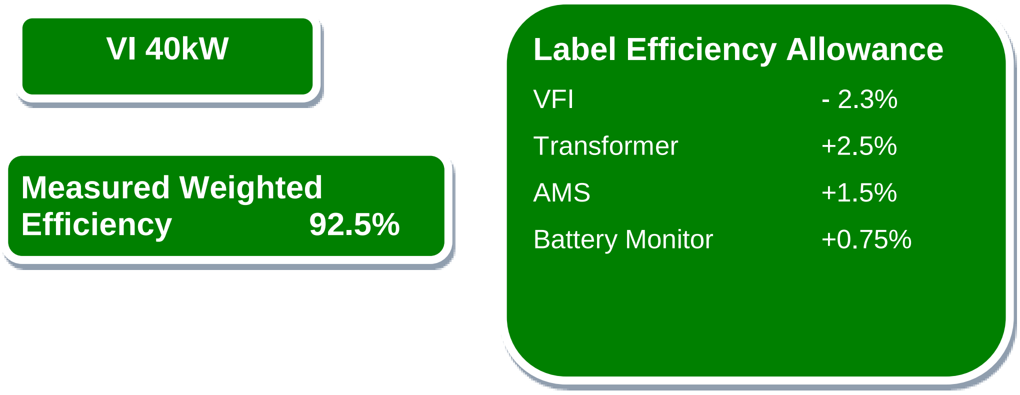

Figure 64: Suggested example of UPS classification, efficiency and allowance label graphics

8.2.3.5 Suggested Scaling Classes for Energy Label

The suggested MEPS scenario and background data on revised UPS efficiencies discussed in 2.2.1 provides the efficiency ranges presented in Table 111 for considering the limits of the scaling classes for an energy label that could complement regulatory policy. It is assumed that the label could be introduced from 2016 using 2014 MEPS. From 2017 the label would be mandatory with MEPS at Tier1 values. From 2019 Tier 2 MEPS values would apply (see Table 102 .). To synchronise labelling data with the Energy Star UPS power grouping, only Base Case 1, Base Case 3, and Base Case 4 data has been considered for the label classification summary. This is dictated by the suggested requirement to synchronise with Energy Star UPS power groupings where Base Case 2 and Base Case 3 would form one grouping. The addition of Base Case 2 MEPS data makes negligible difference to the weighted efficiency MEPS range for the group that encompasses Base Case 2 and Base Case 3 UPS (1500W to 10kW).

Table 111: Weighted Efficiency Summary.

Output Power Group (P)	Weighted Efficiency % (MEPS)		
	2014	2017 (Tier 1)	2019 (Tier2)
P ≤ 1500 W	87.7	93.2	98.7
1500 W < P ≤ 10,000 W	92.2	93.7	95.3
P > 10,000 W	93.5	94.0	95.8

For each UPS power category it is suggested that a different scaling range is used to allow the different spread of weighted MEPS efficiencies to be properly distributed in a full label scale.

An A+++ to E scale is suggested for the 2016 label introduction with band E products removed from the market once Tier 1 becomes mandatory MEPS. Each step in the scale graphic and the indicative efficiency arrow (see Figure 63 Section III) should not show an efficiency value since this will include efficiency allowances where they are applicable (Table 112).

Table 112: Distribution of A to E efficiency label scaling for each output power group

Label Level	UPS Power Group Label Floor Threshold Figures For Label

	Graphic (%)		
	P ≤ 1500 W	1500 W < P ≤ 10 kW	P >10kW
E	87.7	92.2	93.5
D	93.2	93.7	94.0
C	96.0	94.5	94.8
B	98.7	95.3	95.8
A	100	98.0	100
A+	102	100	102
A++	103	102	103
A+++	104	104	104

Note: Scaling values only (e.g. Full allowances when added to a measured 100% weighted efficiency UPS scales at 104.75%).

In the above suggested distribution (Table 112), the 2017 mandatory MEPS level will eliminate all products below D with 2019 MEPS level eliminating all products below B.

8.2.4 Recommendations on information and other Ecodesign requirements

Information for end users should cover all details relevant for the safe and sustainable operation of the UPS including optimal ambient temperature/cooling. The operating temperature range for the suggested or guaranteed battery life is of particular importance. Details should also be provided to confirm that the UPS battery has been tested and meets the relevant IEC standards with regards safety and performance, for example:

First package for VRLA Stationary Lead acid batteries:

-The IEC/EN 60896-21: Methods of test

-The IEC/EN 60896-22: Level of requirements

-The IEC 62485-2 (EN 50272-2 at Cenelec level) for Safety recommendations

Or

Second package for VRLA General Purpose Lead acid batteries:

-The IEC/EN 61056-1: Methods of test

-The IEC/EN 61056-2: Dimensions

-IEC/TR 61056-3: Safety recommendations

Information regarding the potential benefits of using longer life batteries should be provided via technical documentation, user manuals, or manufacturer's websites. This may include the potential to reduce life cycle costs resource consumption. For UPS with no battery monitoring or automatic battery self-test the manufacturer should inform the user that the battery life could be limited by several factors including ambient conditions and the user should check the actual status of the battery manually once a month to make sure the UPS is working properly. The information must include details of how the user could check the battery.

In addition, Task 7 proposed that Base Case 1 UPS products are designed to facilitate the easy replacement of batteries. Clear instructions must be provided supporting battery replacement by technically non-skilled users.

For end users and market surveillance authorities (MSA's) detailed data according to the requirements of a pro-forma technical declaration must be provided to classify the product, justify the claimed conformance of the product with the Ecodesign Regulation requirements, and to confirm the claimed energy label performance indication. The technical pro-forma should be provided as an annex to the harmonised standard supporting the Ecodesign Regulation.

Details of all information sources related to the installation, maintenance and recycling of the product must be provided in the handbooks delivered with the product and at a publicly accessible website provided by the manufacturer.

8.2.5 Critical review of policy options

Different policy implementation mechanisms can be used to assist the realisation of the improvement potential identified in Task 7. Typically this might include:

- Implementing measures under the Ecodesign Directive (Article 15), including setting of minimum efficiency performance standards and information requirements, which should not contradict or conflict with existing legislations or standards.
- Voluntary agreements or other self-regulation options that meet the requirements outlined in the Ecodesign Directive (Article 17) which could include minimum energy efficiency requirements and/or measures relating to batteries or other product requirements, similar to existing voluntary criteria, such as the code of conduct or voluntary eco labels. It is important to note that industry voluntary agreements under Ecodesign do not include other voluntary policy initiative, such as Green Public Procurement, or the European Ecolabel.
- Energy Labelling and standard product information of the consumption of energy and other resources by the products which should be easily recognisable to end-users, simple and concise.
- Green Public Procurement under Directive 2004/17/EC which ensures the possibility of including environmental considerations in the contract award process.
- European Ecolabel (Regulation No (EC) 66/2010) which identifies products and services with a reduced environmental impact throughout whole life cycle, from raw material to disposal/recycling at the end of the life cycle.

It is important that any mix of policy tools adopted ensures complementarity; that there are no contradictions, loopholes or other conflicts. For example, the use of different policy instruments for different types of UPS is not desirable in order to ensure clear and easy to implement requirements.

Therefore two policy options were selected, the Ecodesign Regulation and Energy Labelling. The other options were not selected for the following reasons:

- Voluntary Agreement - Voluntary agreements are intended to be a swifter route to achieving an outcome, but in practice they have not been so. Only two product groups (from the Ecodesign working plan) have implemented voluntary agreements instead of mandatory measures. For smaller UPS products where there are a large number of manufacturers, a voluntary agreement is difficult to implement. Additionally, there is already a voluntary Code of Conduct from JRC[276]. Signatories for the Code of Conduct include the main manufacturers supplying products to the EU market[277]. However, despite being operational for several years, not all products on the market meet its requirements suggesting some reluctance within the sector to work with the Code.
- Green Public Procurement – Green Public Procurement covers public works contracts, public supply contracts and public service contracts. At this stage it is recommended the Commission focuses it efforts and resources on developing a well thought through mandatory policy based on MEPS and Energy Labelling which addresses the market as a whole, rather than diluting its resources developing multiple options. Once MEPS and Energy Label requirements have been adopted, suitable groundwork will have been completed for informing GPP.
- European Ecolabel – UPS are already covered by the EPA Energy Star Product Labelling. The specifications of this label are recognised by the different

[276] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 2.0, 2011
[277] Current list of participants for the code of conduct are available here: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/ac-uninterruptible-power-systems

manufacturers and therefore it is not recommended to implement another label with different specifications and or other requirements. Of note is that the adoption in Europe of the existing Energy Star label is well underway. The scope of the European Ecolabel means it could include additional environmental aspects, for example relating to resource efficiency and end of life. However the proposed Energy Labelling and Ecodesign information requirements address important aspects beyond energy efficiency, including battery monitoring and maintenance and addressing aspects relating to redundancy. As with GPP above, it is recommended at this stage that the Commission focuses it efforts and resources on developing mandatory policies addressing the market as a whole and after these are implemented, considers the need and scope of other policy initiatives.

8.2.5.1 Minimum Efficiency Performance Standards

For the Ecodesign Directive the selected option was the minimum efficiency performance standards (MEPS). The MEPS are based on the high/flat efficiency levels with different efficiencies set of different sizes/topologies using the four base cases.

Different tiers are used over time to provide a transitional period as product performance is improved. The BAU scenario is used until 2014, and then it is assumed that all products meet the levels defined by the Code of Conduct from DG JRC. Almost all products sold in the EU market already achieve such levels, and therefore it will ensure an easy introduction of the efficiency standards. The BAU and 2014 scenarios are only different for Base Case 4 for which the BAU levels were defined using the first version of the CoC[278], to account for the longer lifetime of such products.

Then, the staged implementation is used to increase the level of ambition over time. The BAT levels were obtained from ENERGY STAR database[279], selecting the products (taking into account products with the same size and topology of those considered in each base case) with the highest weighted efficiency (weighted by the proportion of time spent at each load level[280]) were selected The BAT levels were used to Tier 2, which is implemented in 2019. A transition period of six years ensures the needed time to adapt all products to the new levels of efficiency. Additionally, to ensure a smooth transition, intermediate levels are defined to Tier 1, which is implemented in 2017. Such intermediate levels are the mean value between the CoC and BAT levels. The revised efficiency levels are presented in section 8.2.2.1 in Table 102 .

The energy consumption of each base case using the revised efficiency levels was assessed as described in Task 5. Table 103 in Section 8.2.2.1 presents the energy consumption for the revised efficiency levels. It shows that Base Case 1 and Base Case 2 present the highest reduction on the energy consumption, with 91% and 87%, respectively. However, Base Case 3 and Base Case 4 also present a substantial reduction on the energy consumption, with 34% and 24%, respectively.

For Base Case 3 and Base Case 4 the MEPS could also require the use of a multi-mode design. Such design is already available for these products and can easily be implemented without major costs. For this scenario the BAT data from ENERGY STAR for VFI mode and a VFD efficiency of 99% were used. Table 105 in section 8.2.2.1 presents the efficiency levels for multi-mode design options.

The energy consumption of each base case using the revised efficiency levels was assessed using the methodology described in Task 5 and the equation from ENERGY STAR for energy consumption in multi-mode (Table 103 in section 8.2.2.1). As can be seen, the savings are increased from 34% to 46% for Base Case 3 and from 24% to 40% for Base Case 4. Additionally, to Base Case 4 the efficiency allowances to isolation transformers were excluded, to assess the impact exclusively ensured by the UPS. Table 108 in Section 8.2.2.1

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[278] JRC, Code of Conduct on Energy Efficiency and Quality of AC Uninterruptible Power Systems, Version 1.0, 2006
[279] ENERGY STAR Uninterruptible Power Supplies Product List, August 23, 2013, available at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=UPS
[280] ENERGY STAR, Program Requirements for Uninterruptible Power Supplies, 2012.

presents the energy consumption for the revised efficiency levels for multi-mode UPS design option without transformer allowances.

8.2.5.2 Energy Labelling

For the Energy Labelling an A+++ to E scale is proposed (Section 8.2.5.2). The defined levels must consider the different power groups, since products with different power cannot achieve the same efficiency levels. However, it is useful to ensure a synchronization with the Energy Star data and therefore instead of four groups (the four base cases), three power groups were used (Base Case 2 and Base Case 3 are considered as one group).

Additionally, the objective was to ensure synchronization with the MEPS scenario, aligning the labels with the different tiers. Therefore, label E corresponds to the levels defined by the Code of Conduct from JRC (BAU), label D to the intermediate scenario (Tier 1) and label B to the BAT (Tier 2). To ensure a staged implementation and stimulate higher efficiency levels, a transitional label (Label C) between Tier 1 and 2 was adopted.

Table 113 presents the defined efficiency levels for the MEPS scenarios and the corresponding proposed Energy Label level.

Table 113: MEPS efficiency levels and Proposed Energy Label levels

Scenario		Load Levels				Weighted Efficiency	Label Level
		25%	50%	75%	100%		
BAU	BC1 2014	86.0	87.0	88.0	89.0	87.7	E
Tier 1	BC1 Intermediate	91.8	92.8	93.5	94.1	93.2	D
Tier 2	BC1 BAT	97.5	98.6	99.0	99.1	98.7	B
BAU	BC2 2014	85.0	89.0	89.9	90.0	89.7	E
Tier 1	BC2 Intermediate	91.2	93.7	94.3	94.4	94.2	D
Tier 2	BC2 BAT	97.3	98.4	98.7	98.8	98.6	A
BAU	BC3 2014	85.5	91.5	92.5	92.5	92.2	E
Tier 1	BC3 Intermediate	89.9	93.7	93.8	93.4	93.7	D
Tier 2	BC3 BAT	94.3	95.8	95.1	94.2	95.3	B
BAU	BC4 2014	91.5	94.0	94.5	94.5	93.5	E
Tier 1	BC4 Intermediate	91.8	94.6	95.0	95.0	94.0	D
Tier 2	BC4 BAT	94.6	96.1	96.5	96.5	95.8	B

Using such synchronization with the MEPS scenario, the same impacts achieved by the staged introduction of Tier 1 and 2 in years 2017 and 2019 can also be ensured by eliminating products below label D and B, respectively. Therefore, using the proposed Energy Label, the energy consumption for each base case is the same as the presented for the MEPS scenario (section 8.2.2.1 in Table 102) with Base Case 1 presenting the highest reduction on the energy consumption (Base Case 1 - 91%; Base Case 2 - 87%, Base Case 3 - 34%; Base Case 4 - 24%).

The use of an efficiency allowance for VFI topology avoids the need of different Energy Label levels for different topologies, simplifying the use and understanding of the Energy Label. Additionally, it also ensures the assessment (and incentives to the implementation) of the multi-mode design as in the additional multi-mode scenario summarised in Section 8.2.2.2. In the same way, the efficiency allowance for compensation of transformer losses enables the assessment of impacts exclusively ensured by the UPS.

The proposed allowances also ensure options are incentivised which lead to resource savings, despite them not having an impact on the weighted efficiency, such as the AMS and the battery internal resistance monitoring. Only products using multi-mode design, AMS installation or battery internal resistance monitoring can reach the scaling values needed to achieve the A+, A++ and A+++ levels.

UPS manufacturing industry stakeholders have raised concerns over allowances for functionalities that are not clearly defined in the UPS over-arching International Standard IEC 62040-3.

For example;

- Battery internal resistance monitoring, battery condition feedback and automatic internal resistance compensation have various technical solutions with widely differing efficacies.
- AMS are implemented with no standardised installation objective.

These functionalities were not in place at the time of publication of the last version of the IEC 62040-3 and are therefore not covered in the exiting standard. A harmonised standard would have to be mandated by the Commission in support of a UPS ecodesign regulation. This would clearly define the minimum functionality required to justify a specific efficiency allowance. If the harmonised standard is going to take time to develop, guidelines clarifying the definitions and requirement measurements in the absence of a supporting standard can be provided in the interim. For example, the Ecodesign regulation for TVs specified certain parameters not defined in existing standards and these are clarified in supporting Commission guidelines[281] whilst a harmonized standard is developed in response to a Commission Mandate. A similar approach could be used for UPS.

8.3 Sub-task 8.2 Impact Analysis

8.3.1 Environmental savings

The environmental savings achieved with the policy scenarios are mainly due to the electricity consumption reduction. Such savings were assessed for the total stock of UPS from 2014 to 2025 using the proposed energy values in the Minimum Efficiency Performance Standards (Section 8.2.2.1) in the stock model (Task 2). Environmental saving sub-scenarios, such as those associated with suggested allowances in energy labelling, which modify MEPS to encourage resource efficiency, are detailed in section 8.2.5.2 Energy labelling. Where data is available, a sub-scenario resource impact example is given in that section.

Figure 65, Figure 67, Figure 66 and Figure 68 present total electricity consumption through to 2025 for each base case with the BAU and MEPS scenarios. As can be seen, Base Case 1 and Base Case 2 present the highest percentage savings, with 86.4% and 81.0% of savings in 2025, respectively. Due to its higher share of the stock, Base Case 2 also presents the highest absolute savings, with 6.7 TWh/year. The same data is shown in tabular form in Table 125, Table 126, Table 127 and Table 128 (Appendix 9).

[281] http://ec.europa.eu/energy/efficiency/ecodesign/doc/regulations/guidelines_ecodesign_televisions_may_2011.pdf

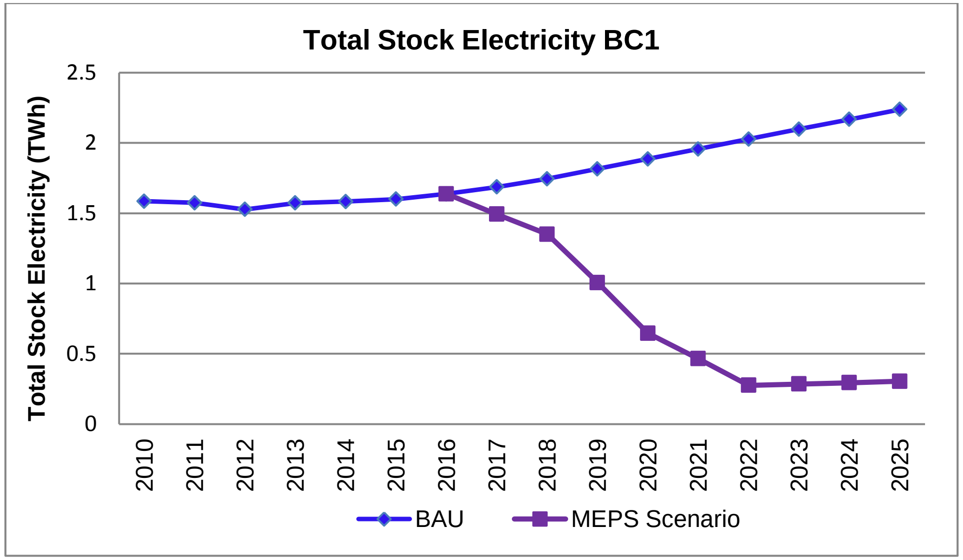


Figure 65: Total stock electricity consumption for the BAU and MEPS scenarios – Base Case 1

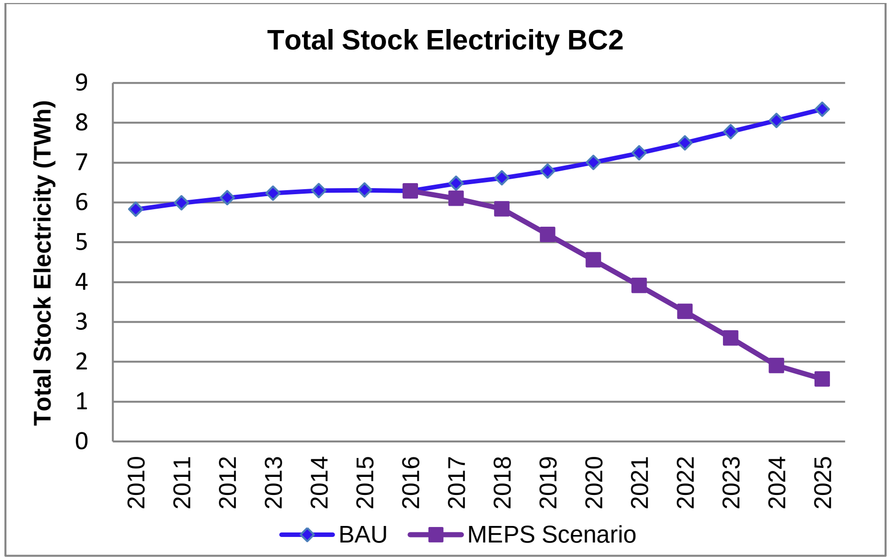


Figure 67: Total stock electricity consumption for the BAU and MEPS scenarios – Base Case 2

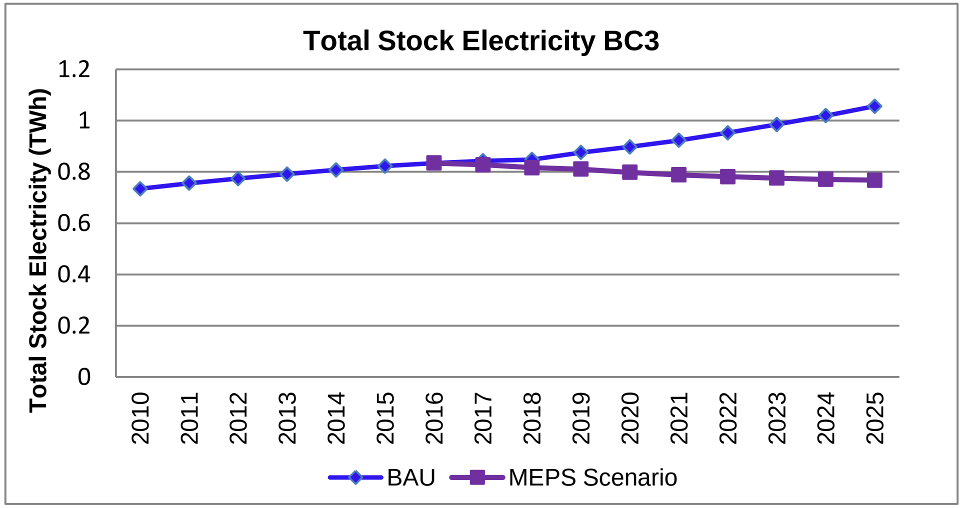


Figure 66: Total stock electricity consumption for the BAU and MEPS scenarios – Base Case 3

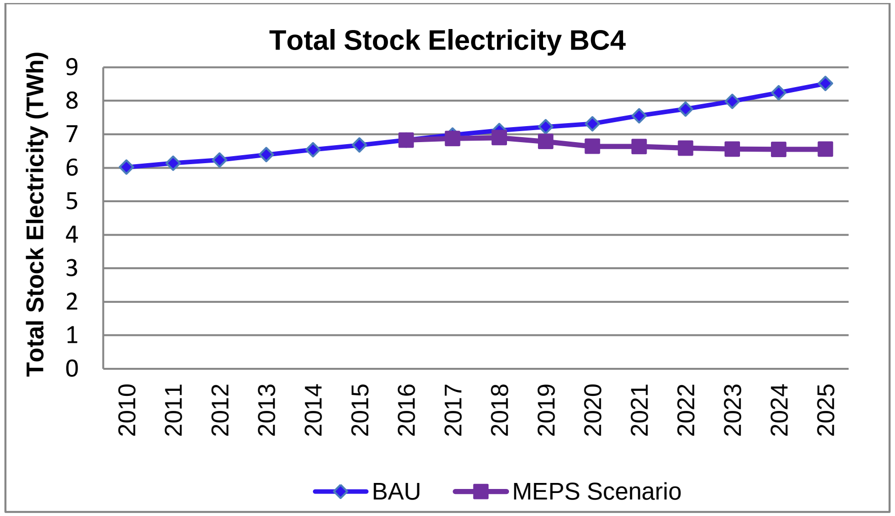


Figure 68: Total stock electricity consumption for the BAU and MEPS scenarios – Base Case 4

Aggregating the impact of the four base cases, the total impact of the MEPS scenario was assessed.

Figure 69 presents total electricity consumption of UPS with the BAU and MEPS scenario. Additionally,

Table 129 (in Appendix 9) shows the annual achieved savings. As can be seen, a total of 10.96 TWh can be reached in 2025, representing a reduction of 54.4%.

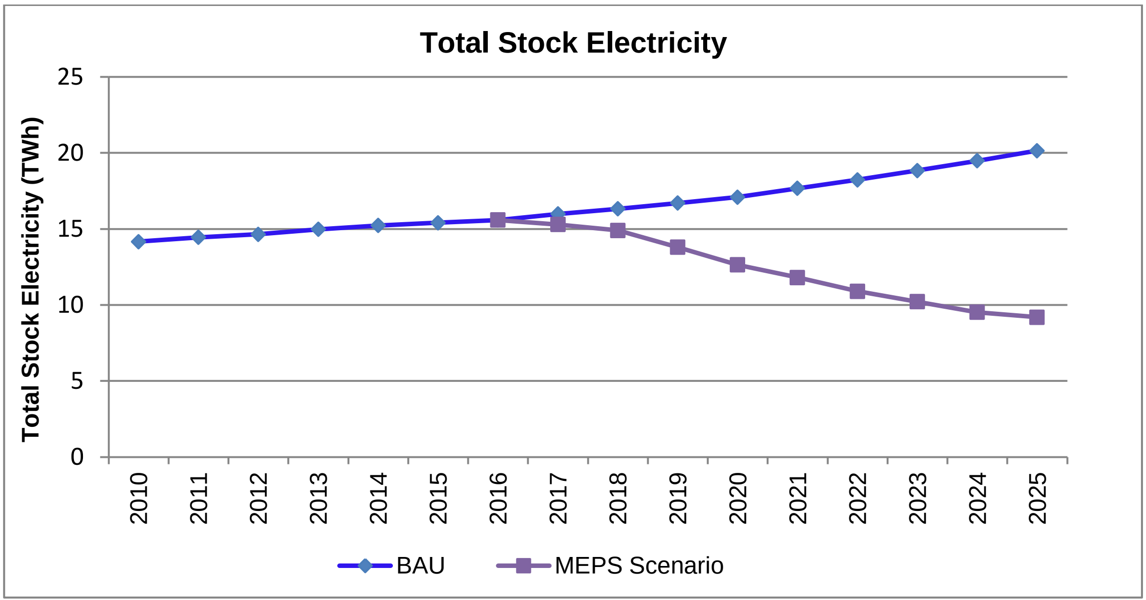


Figure 69: Total stock electricity consumption for the BAU and MEPS scenarios – Total for Base Cases 1-4

An additional scenario where the multi-mode feature was added to the efficiency levels achieved with the BAT was assessed for Base Case 3 and Base Case 4. Figure 70 and Figure 71 present the total electricity consumption through to 2025 for Base Case 3 and Base Case 4, respectively, with the BAU scenario, MEPS scenario and the Multi-mode scenarios. Further details are presented in Table 130 and Table 131 in Appendix 9. As can be seen, with the multi-mode scenario, the savings for Base Case 3 can be increased from 27.4 to 37.0% and the savings for Base Case 4 from 23.1 to 27.5%.

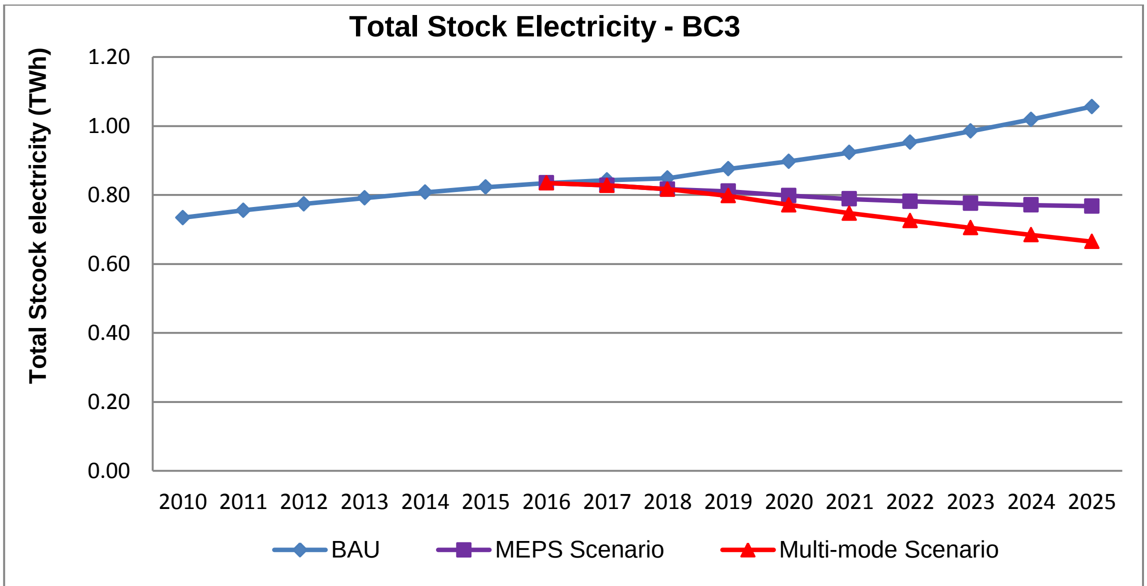


Figure 70: Total stock electricity consumption for the BAU, MEPS and Multi-mode scenarios – Base Case 3

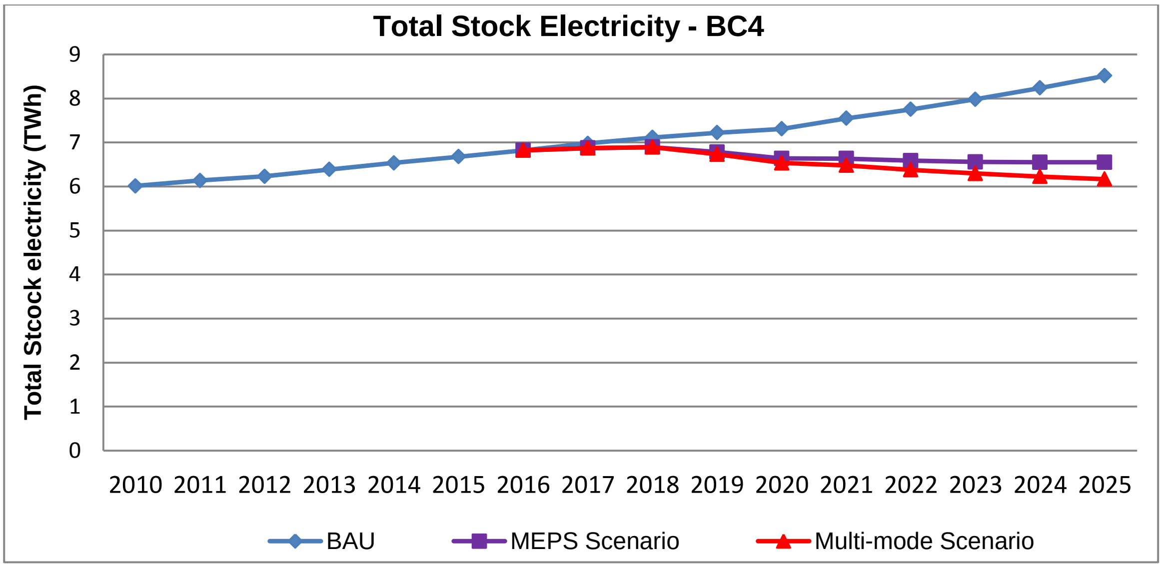


Figure 71: Total stock electricity consumption for the BAU, MEPS and Multi-mode scenarios – Base Case 4

Aggregating the impacts of the four base cases, applying the MEPS scenario to Base Case 1 and Base Case 2 and the Multi-mode scenario to Base Case 3 and Base Case 4, the total impact of the Multi-mode scenario was assessed. Figure 72 presents the evolution of the total electricity consumption of UPS with the BAU, MEPS Scenario and Multi-mode scenario. Table 132 (in Appendix 9) presents the data in tabular form and the annual savings. As can be seen, the savings in 2025 increase from 10.96 to 11.44 TWh, with the percentage of savings increasing from 54.4 to 56.8%.

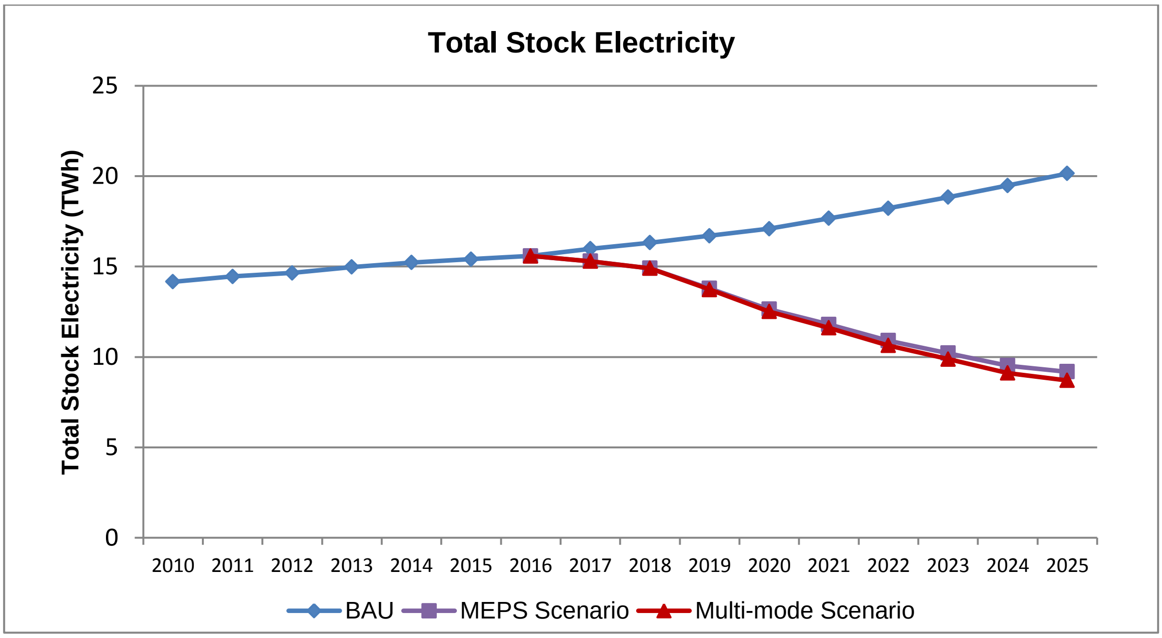


Figure 72: Total stock electricity consumption for the BAU, MEPS and Multi-mode scenarios – Total for Base Cases 1-4

For Base Case 4 an extra scenario was developed where the efficiency allowances for isolation transformers were excluded, to assess the UPS electricity consumption without transformer losses being considered. Figure 73 presents the total electricity consumption for

Base Case 4 for the BAU+Transformerless scenario, MEPS+Transformerless scenario and Multi-mode+Transformerless scenario, which cover the BAU, MEPS and Multi-modes scenarios outlined above, but without the transformer losses for Base Case 4 i.e. Transformerless. By excluding the transformer losses, the percentage of savings achieved in Base Case 4 increase from 23.1 to 32.5% in the MEPS+Transformerless scenario and increase from 27.5 to 38.9% in the Multi-mode+Transformerless scenario. Further details can be found in Table 133 in Appendix 9.

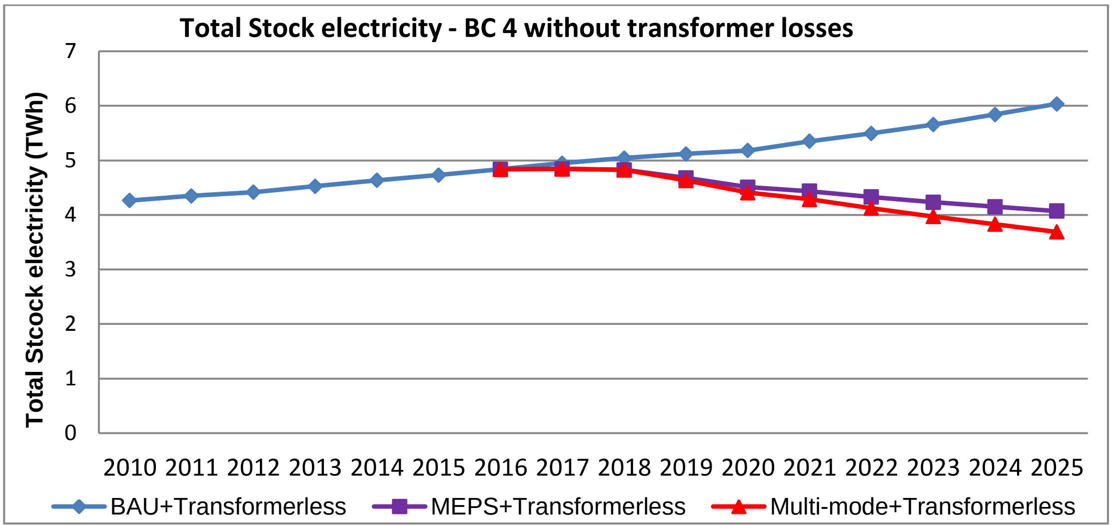


Figure 73: Total stock electricity consumption for the BAU+Transformerless, MEPS+Transformerless and Multi-mode+Transformerless scenarios – Base Case 4

Aggregating the Transformerless Scenarios for Base Case 4 with the MEPS scenario and the Multi-mode scenario for Base Case 1, Base Case 2 and Base Case 3, the total impact was determined and is shown in Figure 74. As can be seen, the savings of 10.96 TWh (MEPS+Transformerless Scenario) and 11.44 TWh (Multi-mode+Transformerless) in 2025 now represent 62% (previously 54.4%) and 64.8% (previously 56.8%). Detailed data are presented in Appendix 9 Table 134.

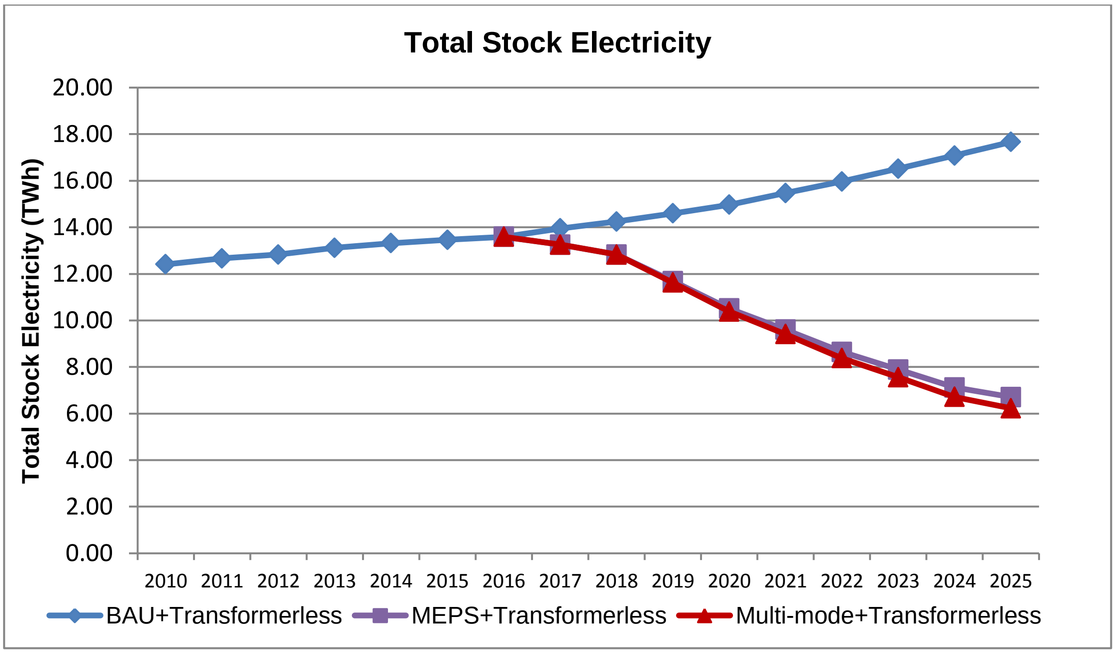


Figure 74: Total stock electricity consumption for the BAU+Transformerless, MEPS+Transformerless and Multi-mode+Transformerless scenarios – Total for Base Cases 1-4

To have a clear picture of the significance of the assessed savings, it helps to compare it with other products. Comparison with transformers[282] is helpful, since both products have their energy consumptions based on losses.

Figure 75 presents the total electricity consumption of transformers and UPS with the BAU+Transformerless and MEPS+Transformerless scenarios. These UPS scenarios are used as transformer based UPS now only make up a relatively small proportion of the market. Additionally, Table 114 presents the same data in tabular form and the annual savings. As can be seen, due to the larger stock and individual consumption, transformers present a much higher total electricity consumption. However, the UPS present a much higher potential of savings percentage, which can reach 64.8% in 2025, whereas the savings for transformers are just 17.2%. Therefore, despite the much lower energy consumption, with the MEPS+Transformerless Scenario (as described in Section 8.2.2.2) the UPS can reach 65.5% of the energy savings projected to transformers (11.44 TWh to UPS and 17.47 TWh to transformers in 2025).

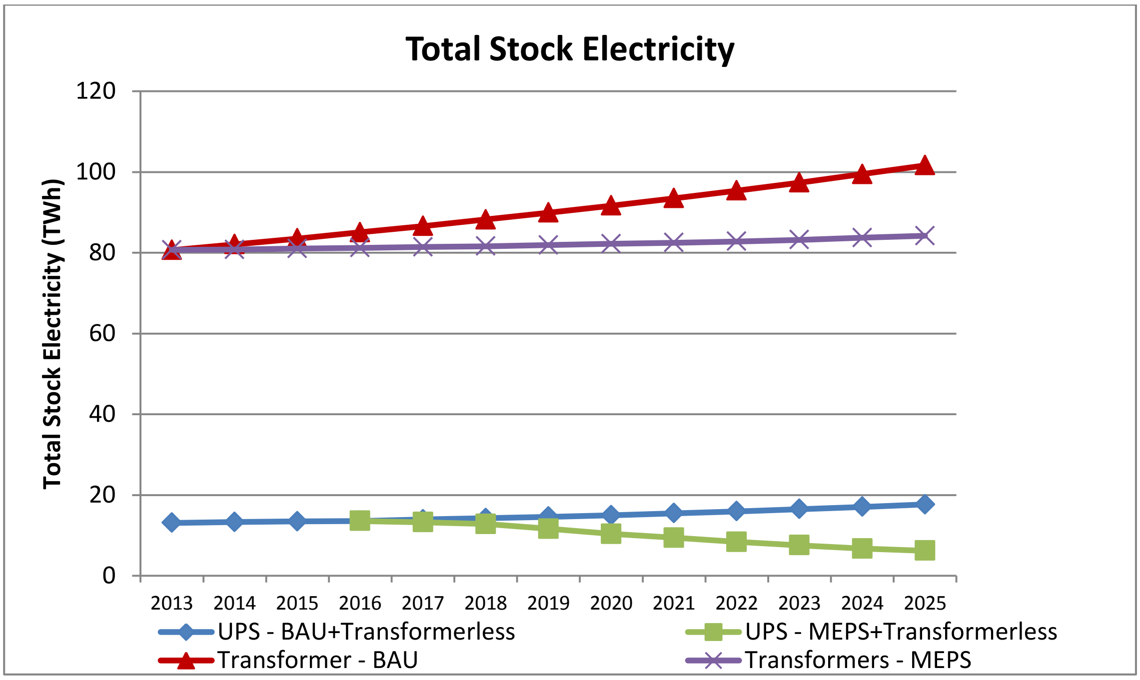


Figure 75: Total stock electricity consumption for the BAU+Transformerless and MEPS+Transformerless scenarios for UPS and the BAU and MEPS data for transformers UPS

Table 114: Total stock electricity consumption and savings for the for the BAU+Transformerless and MEPS+Transformerless scenarios for UPS and the BAU and MEPS data for transformers

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
UPS												
BAU+ Transformerless Scenario (TWh)	13.32	13.46	13.60	13.95	14.25	14.60	14.97	15.47	15.97	16.51	17.08	17.67
MEPS+ Transformerless Scenario (TWh)	13.32	13.46	13.60	13.26	12.83	11.63	10.38	9.41	8.38	7t.56	6.72	6.23

[282] http://www.eceee.org/ecodesign/products/distribution_power_transformers/Final_report_Feb2011

Savings (TWh)	0.00	0.00	0.00	0.69	1.42	2.97	4.59	6.06	7.59	8.96	10.37	11.44
Savings (%)	0.0%	0.0%	0.0%	5.0%	9.9%	20.4%	30.6%	39.2%	47.5%	54.2%	60.7%	64.8%
Transformers												
BAU (TWh)	82.07	83.53	85.04	86.61	88.23	89.91	91.67	93.49	95.40	97.39	99.48	101.67
MEPS (TWh)	80.8	81.0	81.2	81.4	81.6	81.9	82.2	82.5	82.8	83.2	83.7	84.2
Savings (TWh)	1.27	2.53	3.84	5.21	6.63	8.01	9.47	10.99	12.60	14.19	15.78	17.47
Savings (%)	1.6%	3.0%	4.5%	6.0%	7.5%	8.9%	10.3%	11.8%	13.2%	14.6%	15.9%	17.2%

8.3.2 Impacts from labelling

Due to data limitations it is difficult to model the environmental savings and economic impacts of the Energy Label, however example saving scenarios have been included where relevant e.g. reducing the number of units when using AMS functionality in Section 8.2.3.4.

8.3.3 Economic impacts

The stock model developed to assess the energy impact of the policy scenarios also enables the economic impacts, in terms of expenditure to be assessed. For the main MEPS policy scenario outlined in Section 8.2.2, the impact on annual expenditure has been analysed.

The life cycle costs, summarised in Table 115 have been informed by stakeholder feedback and are used as the inputs for this analysis, together with the sales data calculated in Task 2.

Table 115: Life cycle costs per product for MEPS scenario

		Life Cycle Costs Per Product (Euros)					
		Purchase Cost	Installation	Electricity	Repair and Maintenance	TOTAL	Percentage Change in LCC compared to BAU
BAU	BC1	180	0	166	0	346	-
Tier 1	BC1 Intermediate	180	0	91	0	271	22
Tier 2	BC1 BAT	180	0	16	0	196	43
BAU	BC2	643	308	1 698	241	2 890	-
Tier 1	BC2 Intermediate	643	308	958	241	2 150	26
Tier 2	BC2 BAT	643	308	219	241	1 411	51
BAU	BC3	3 502	503	3 478	1 138	8 621	-
Tier 1	BC3 Intermediate	3 502	503	2 882	1 138	8 025	7
Tier 2	BC3 BAT	3 502	503	2 313	1 138	7 456	14
BAU	BC4	28 800	1 220	56 548	45 936	132 504	-
	BC4 2014	28 800	1 220	50 060	45 936	126 016	5
Tier 1	BC4 Intermediate	28 800	1 220	47 192	45 936	123 148	7
Tier 2	BC4 BAT	28 800	1 220	38 109	45 936	114 065	14

The data in Table 115 clearly shows that changes in life cycle costs at the product level relate to electricity expenditure, which is as expected given that the MEPS focus on improving energy efficiency. The annual life cycle costs of all UPS purchased has been calculated for each base case and is shown in Figure 76, Figure 78, Figure 77 and Figure 79. In these Figures it is assumed that:

- Purchase and installation costs are incurred in the year of the product sale; and
- Electricity and repair and maintenance costs are divided by lifetime and spread over the product's lifetime.

Figure 80 presents the life cycle costs for all products in the Base Cases s1 to 4.

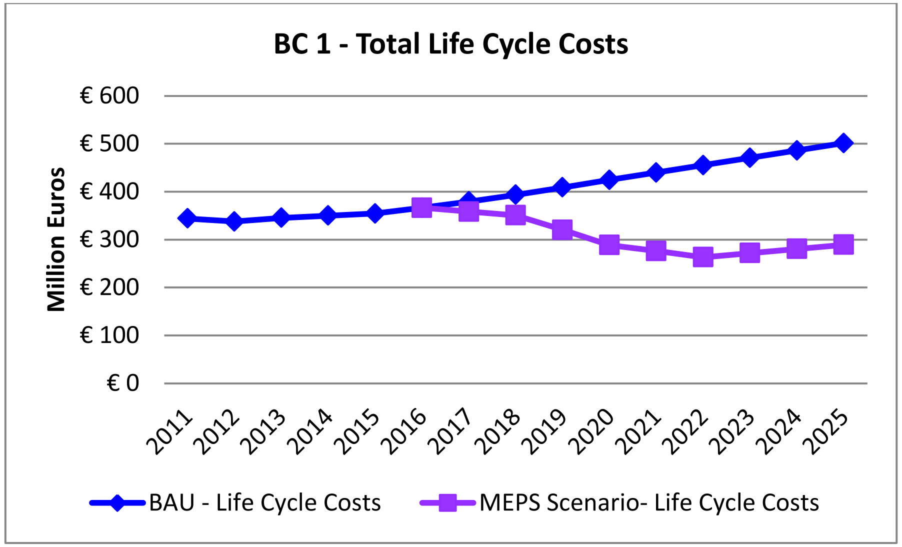


Figure 76: Expenditure for Base Case 1

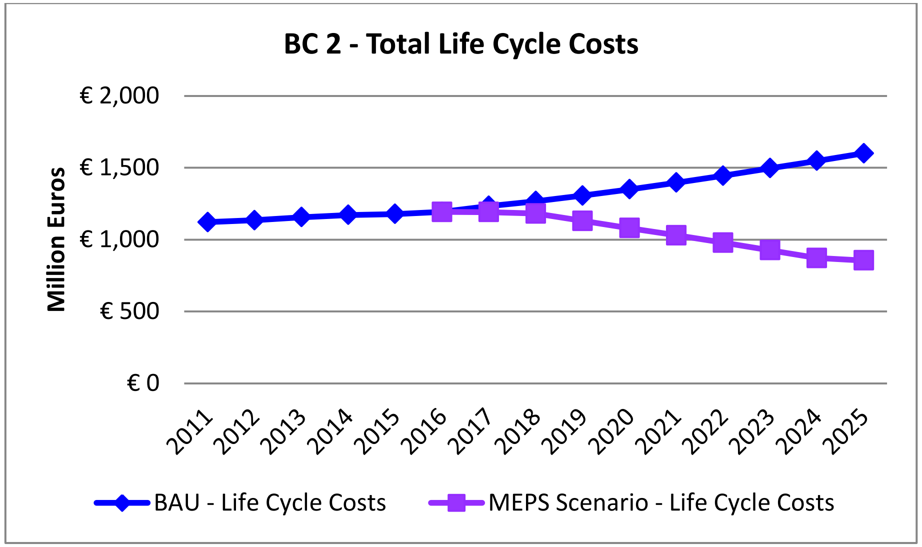


Figure 78: Expenditure for Base Case 2

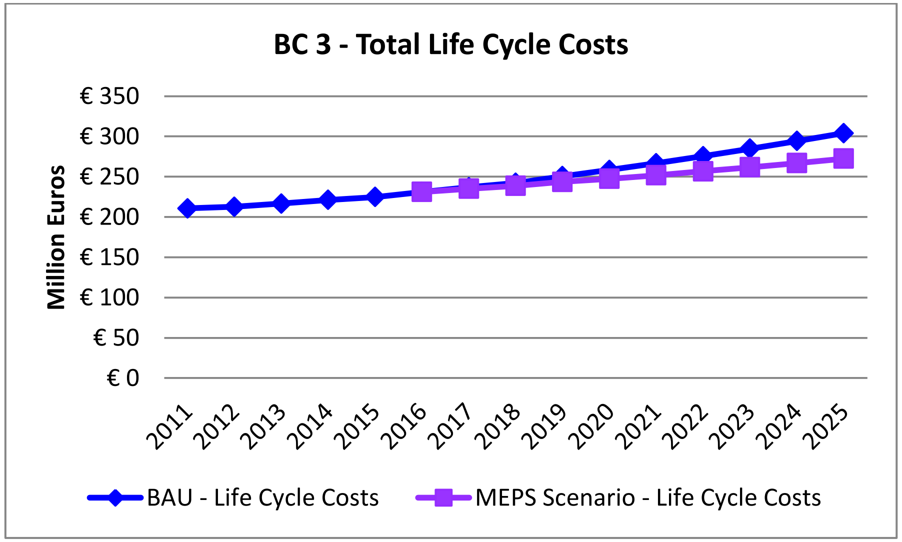


Figure 77: Expenditure for Base Case 3

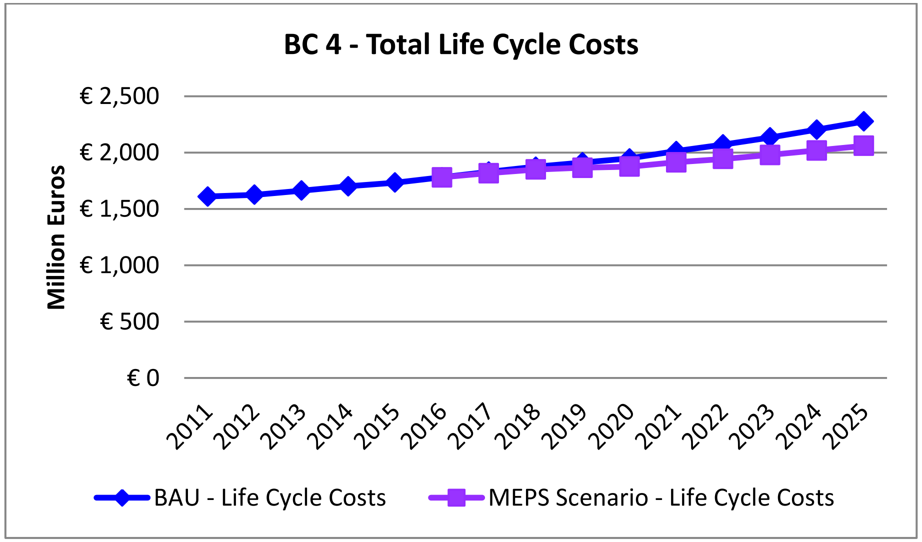


Figure 79: Expenditure for Base Case 4

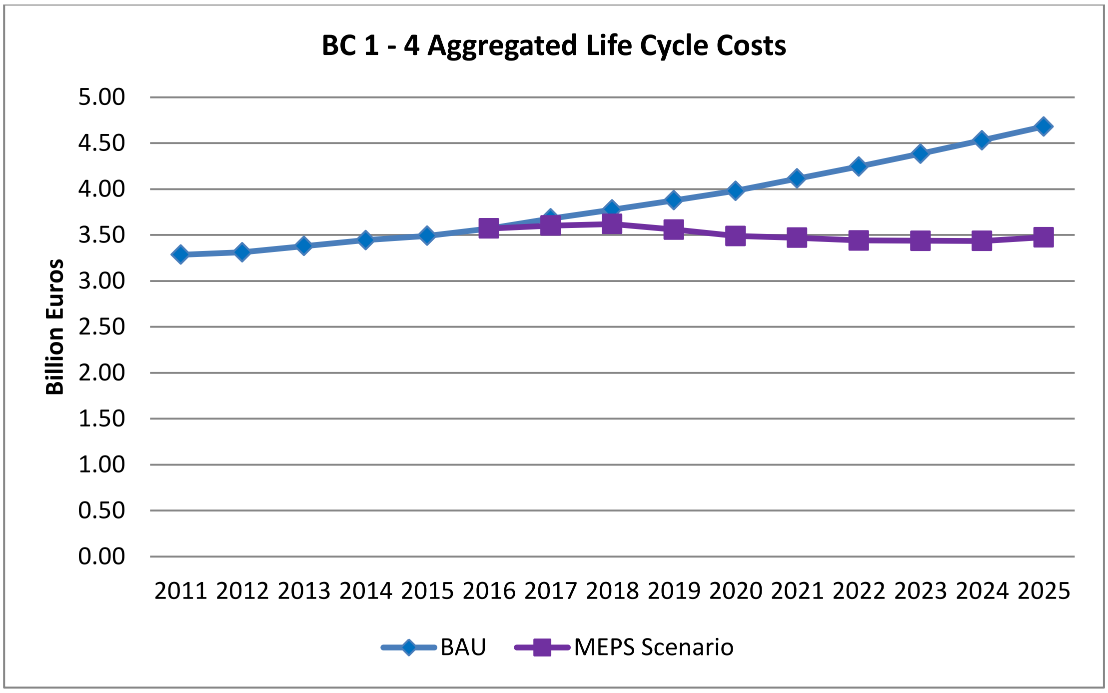


Figure 80: Aggregated Life Cycle Costs for Bases Cases 1-4

The introduction of the MEPS scenario results is reduced life cycle costs for each base case over the period 2011 – 2025, with the aggregated total life cycle costs for Base Cases 1-4 reducing from €4.68 billion per year under business as usual to €3.48 billion per year under the MEPS scenario in 2025. This is a reduction of approximately 26%. Under the MEPS scenario total expenditure in 2025 would be only slightly above 2011 expenditure (€3.48 billion compared to €3.29 billion), despite the large increase (29%) in the stock of Base Case1-4 products in 2025 compared to 2011.

For the alternative scenarios incorporating multi-mode or transformerless designs, the same trends will be observed, as energy efficiency and the reduction in energy costs is the main factor affecting life cycle costs.

As outlined in Task 7, it is understood from stakeholder feedback that the costs of improving products to meet existing BAT efficiency levels is minimal, and can be achieved mainly through improved energy management controls. To achieve improvements above existing BAT would incur significant additional costs as different components would need to be used including larger semi-conductors. This has therefore not been considered as part of the design or policy options.

Current variations in product price is understood to be a commercial marketing issue enabling the distinction between for example, entry level and premium models, rather than a reflection of the long term manufacturing costs, which will reduce as products become established and production levels increase.

8.3.3.1 Further Observations on Economic Impacts

The economic impact of the proposed policy options will be limited, as the majority of manufacturing of UPS product takes places outside the EU e.g. in terms of manufacturing activities and the associated jobs.

Some proposed features such as battery monitoring and remote data transmission could create new businesses connected with UPS maintenance. Since the technology for such features is only in development at present, detailed data of the economic impacts of the respective proposal is not available yet.

The life cycle cost saving to consumers is significant reaching €1.2 billion per year in 2025 (or 26% compared to BAU).

8.4 Sub-task 8.3 – Sensitivity Analysis of Main Parameters

Energy consumption is the key environmental impact for UPS; therefore the sensitivity analysis is focused firstly on the main cost parameter that is affected by the energy consumption, the electricity rate and secondly lifetime which will affect energy consumption over the lifetime of the product.

The sensitivity analysis is undertaken at two levels, firstly at the product level by considering the design options outlined in Task 7, and whether changes to the parameters identified affect the ranking of the design option, and secondly for the change in lifetime, at the market level for the MEPS scenario outlined in Section 8.2.2.1, to understand the significance of any changes in terms of overall saving potential. A reminder of the different design options and their reference numbers is provided in Table 116.

Table 116: Summary of design options from Task 7

BC	Flat Efficiency Intermediate	Flat Efficient BAT	Multimode (CoC)	Multimode (BAT)	Longlife Battery
1	Option 1A	Option 1B	n/a	n/a	n/a
2	Option 2A	Option 2B	n/a	n/a	Option 2E
3	Option 3A	Option 3B	Option 3C	Option 3D	Option 3E
4	Option 4A	Option 4B	Option 4C	Option 4D	Option 4E

8.4.1 Electricity price

For the base cases, an average electricity price of 0.11 Euros/kWh is used in line with the MEErP methodology. The MEErP methodology indicates that there are variations in the electricity price between Member States; therefore the lowest (Bulgaria) and highest (Cyprus) rates[283] have been used to undertake this sensitivity analysis to provide an indication of changes in life cycle costs for the different design options identified in Task 7. Table 117 summarises the minimum and maximum levels used for this analysis compared to the base case.

Table 117: Minimum and maximum electricity prices used for sensitivity analysis

	Average used in base cases	Minimum	Maximum
Electricity price (Euro/kWh)	0.11	0.06	0.15
Percentage change	N/A	-45%	+27%

The results of the sensitivity analysis for changes in the electricity price on life cycle costs are show in Figure 81, Figure 83, Figure 82 and Figure 84 for each base case.

The graphs show, as expected, that life cycle costs decrease and increase in response to lower and higher electricity prices. As no other changes are made to the underpinning assumptions, the changes in electricity price do not alter the ranking of the various design options. This can be clearly seen in the graphs.

From the analysis we conclude that the electricity price does not affect our conclusions. Whether we had used a higher or lower price we would have drawn the same conclusions and be making the same recommendations regarding MEPS and an Energy Label.

283 MEErP 2011 Methodology Report Part 1: Methods, Table 2, Page 46 - http://www.meerp.eu/downloads/MEErP%20Methodology%20Part%201%20Final.pdf

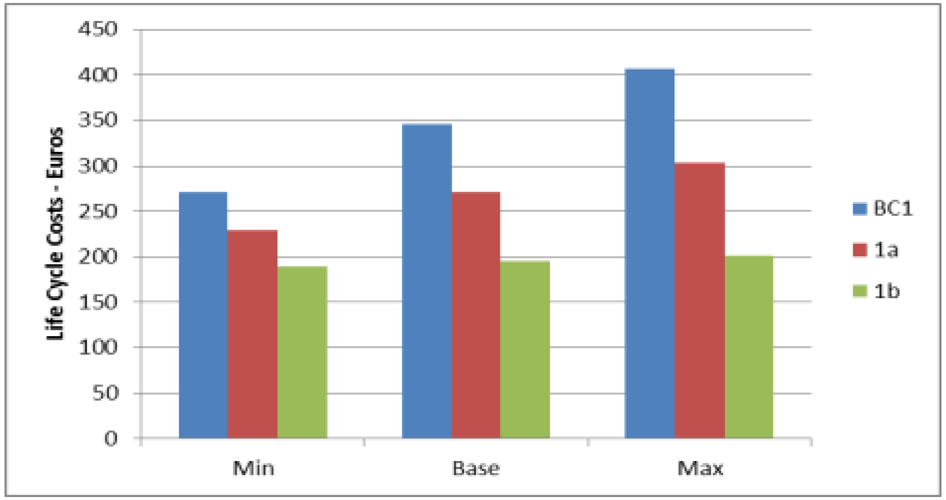


Figure 81: Impact of changes in electricity prices on product life cycle costs for Base Case 1 (Below 1.5 kVA) design options

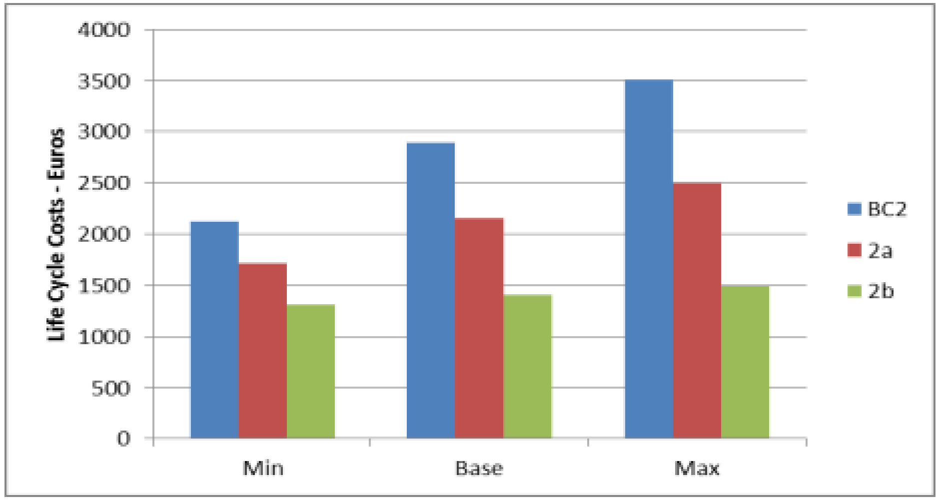


Figure 83: Impact of changes in electricity prices on product life cycle costs for Base Case 2 (1.5 – 5 kVA) design options

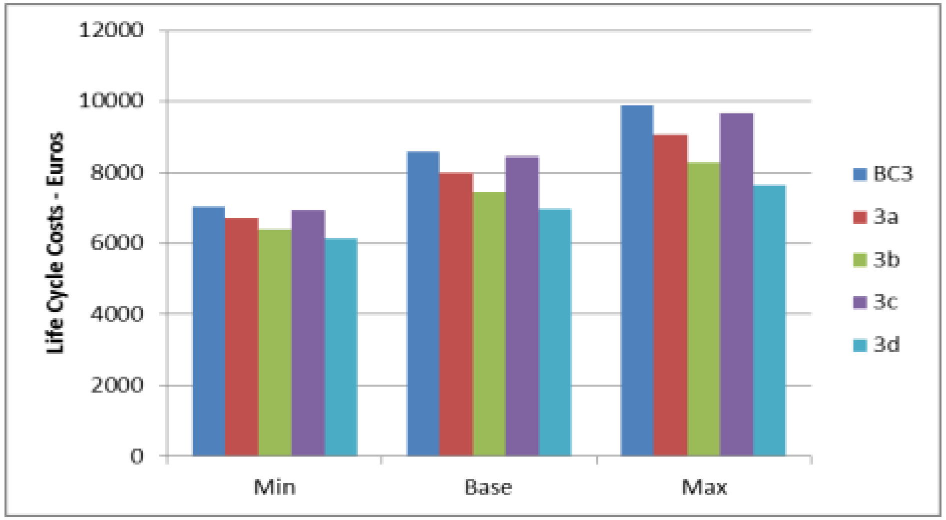


Figure 82: Impact of changes in electricity prices on product life cycle costs for Base Case 3 (5.1 – 10 kVA) design options

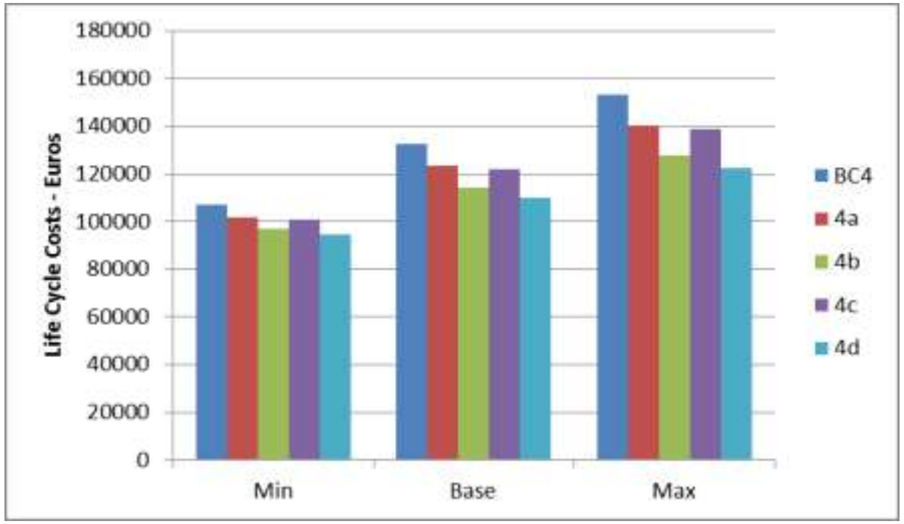


Figure 84: Impact of changes in electricity prices on product life cycle costs for Base Case 4 (10.1 – 200 kVA) design options

8.4.2 Product Lifetime

For all base cases, average product lifetimes were informed by stakeholders. The lifetime of the product is important, as it affects not only the life cycle costs, but also the energy consumption of the product over its lifetime. Sensitivity analysis on lifetime has been undertaken by varying the lifetime of each base case by 25%. Table 118 summarises the minimum and maximum levels used for this analysis compared to the base case.

Table 118: Minimum and maximum lifetimes used for sensitivity analysis

Base Case	Average used in base cases	Minimum	Maximum
1	4	3	5
2	8	6	10
3	10	7.5	12.5
4	12	9	15

The results of the lifetime sensitivity analysis are show in Figure 85, Figure 87, Figure 86 and Figure 88 for each base case on a per product basis.

The results of the lifetime sensitivity analysis on primary energy consumption are show in Figure 89, Figure 90, Figure 91, and Figure 92 for each base case. The results of this sensitivity analysis show that, as expected, that life cycle costs and energy consumption decrease or increase in response to lower or higher lifetimes. However, changes in lifetime do not alter the ranking of the design options in terms of life cycle costs or energy consumption at the product level, with the same profile seen across the design options observed for the base case, minimum and maximum lifetime scenarios.

Changes in lifetime will affect the replacement rate of products and therefore the stock for a given year. This has implications for the total stock energy consumption for a given year, and the rate at which new products are brought onto the market as old products are replaced, which affect when savings are realised.

Using the stock model developed to assess the MEPS scenario, a sensitivity analysis has been undertaken to assess the impact of the changes in product lifetime. For the MEPS scenario[284] outlined in Section 8.2.2.1, the lifetime has been changed to assess the impact this will have on overall energy consumption and the saving potential between the BAU scenario and policy scenario. Apart from lifetime and the implications this has for stock and subsequent energy consumption for a given year, no other parameters have been changed.

Table 119 summarises the results from the sensitivity analysis, comparing them to those outlined in Table 134 for the BAU+Transformerless and MEPS+Transformerless scenarios.

Table 119: Total stock electricity consumption for different lifetimes - 2025

	Base Cases	Minimum	Maximum
BAU+Transformerless (TWh)	17.67	13.82	21.25
MEPS+Transformerless - (TWh)	6.71	4.58	9.48
Difference (TWh)	10.96	9.24	11.77
Percentage saving	62%	67%	55%

This analysis indicates that changing the lifetime of the products by -/+25% results in a decrease in total stock electricity consumption of 3.85 TWh or an increase of 3.58 TWh for BAU+Transformerless scenario and a decrease of 2.13 TWh or increase of 2.77 TWh for the MEPS+Transformerless scenario. The percentage saving calculated between the business

[284] Includes BC4 without transformer losses, as per the results in Table 134 and Figure 74

as usual and policy scenario changes slightly in response to the change in lifetime. This is a reflection on the rate at which products will be replaced. With a shorter lifetime products will be replaced quicker, resulting in a higher percentage saving as better performing products replace old stock, whereas for a longer lifetime, older products will remain in the stock for longer, reducing the percentage saving for a given year.

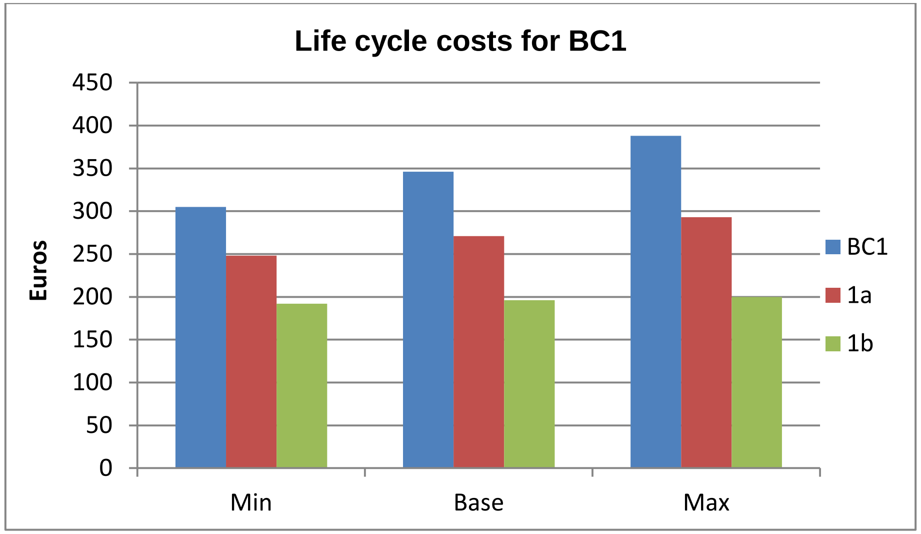


Figure 85: Impact of changes in lifetime on product life cycle costs for Base Case 1 (Below 1.5 kVA) design options

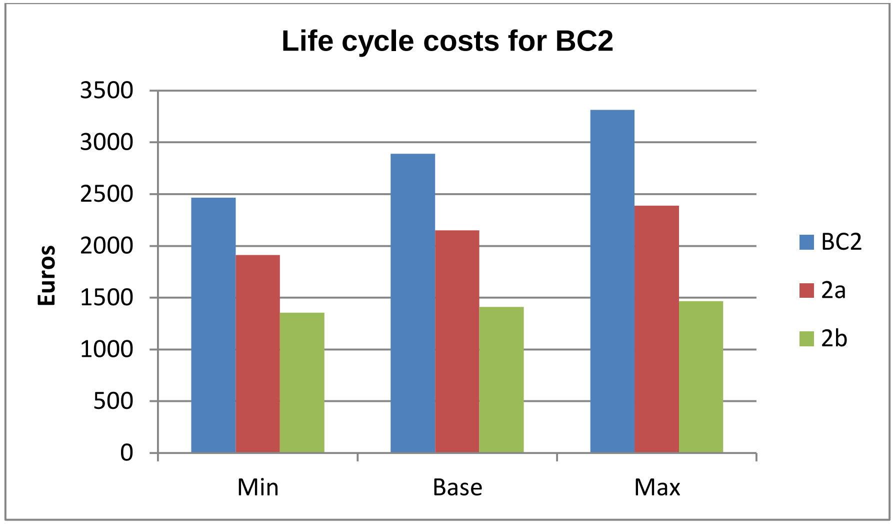


Figure 87: Impact of changes in lifetime on product life cycle costs for Base Case 2 (1.5 – 5 kVA) design options

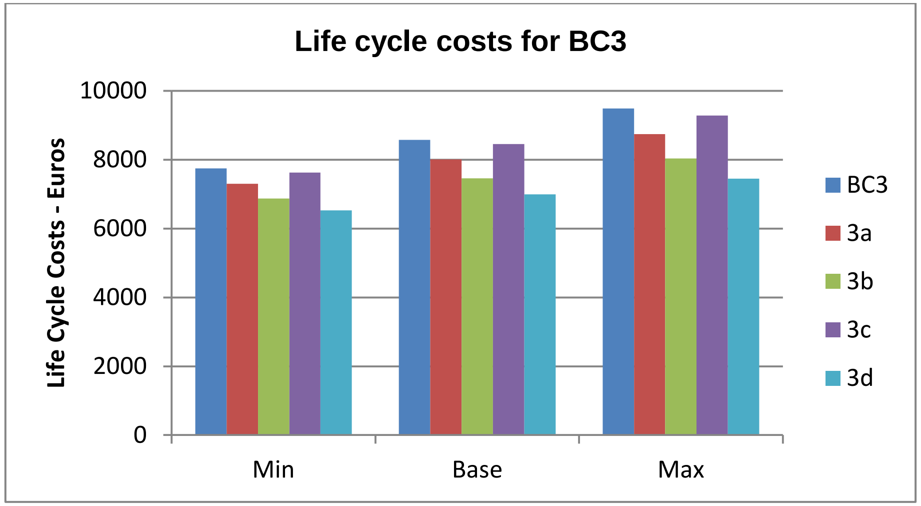


Figure 86: Impact of changes in lifetime on product life cycle costs for Base Case 3 (5.1 – 10 kVA) design options

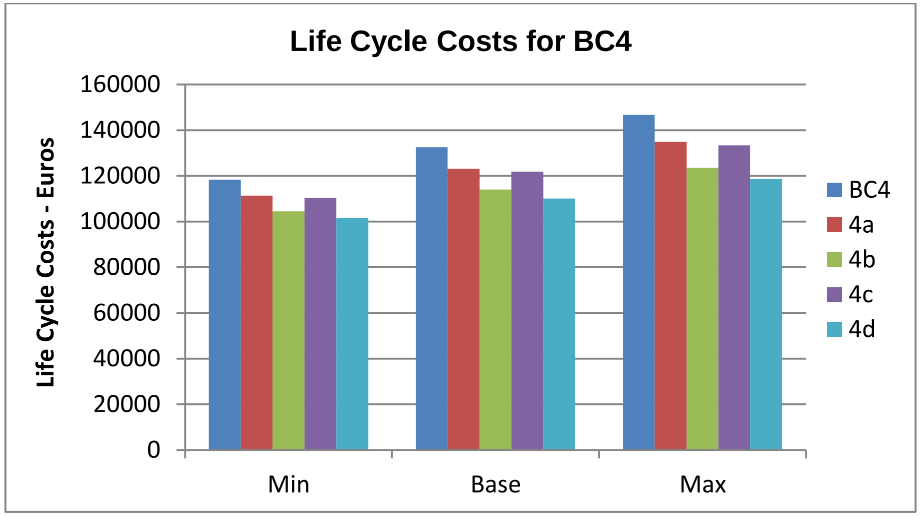


Figure 88: Impact of changes in lifetime on product life cycle costs for Base Case 4 (10.1 – 200 kVA) design options

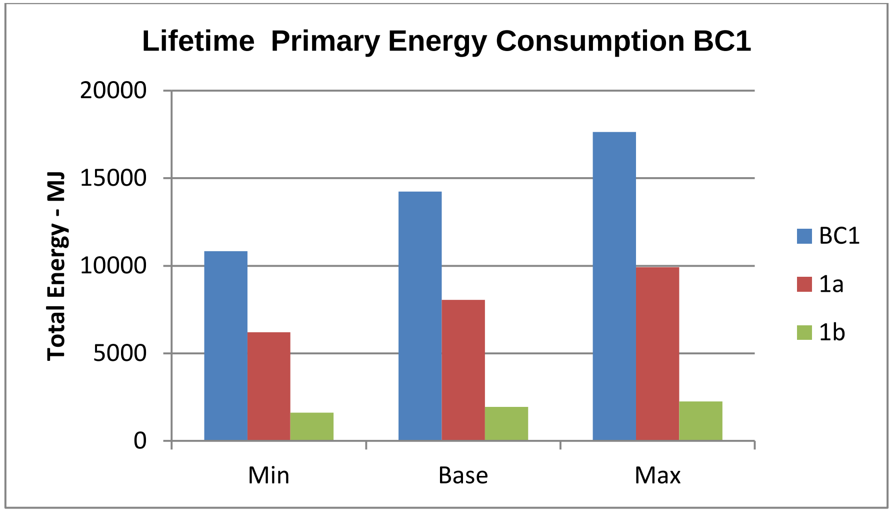


Figure 89: Impact of changes in lifetime on product primary energy consumption for Base Case 1 (Below 1.5 kVA) design options

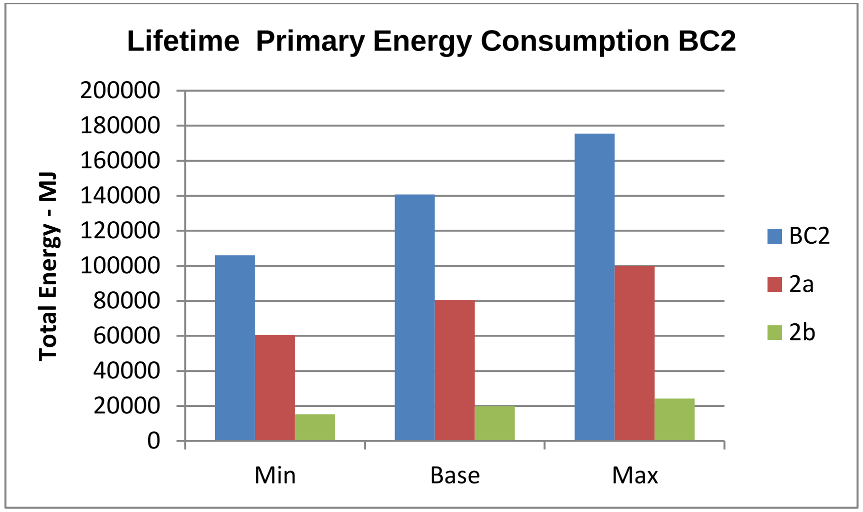


Figure 91: Impact of changes in lifetime on product primary energy consumption for Base Case 2 (1.5 – 5 kVA) design options

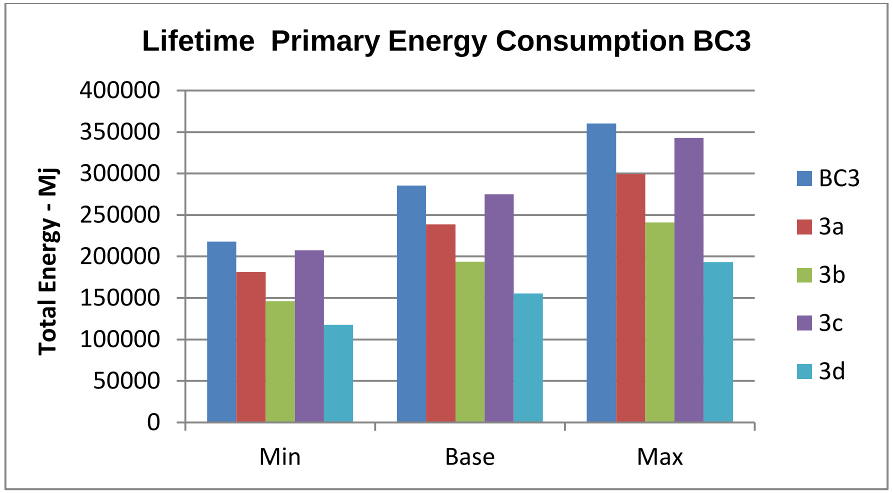


Figure 90: Impact of changes in lifetime on product primary energy consumption for Base Case 3 (5.1 – 10 kVA) design options

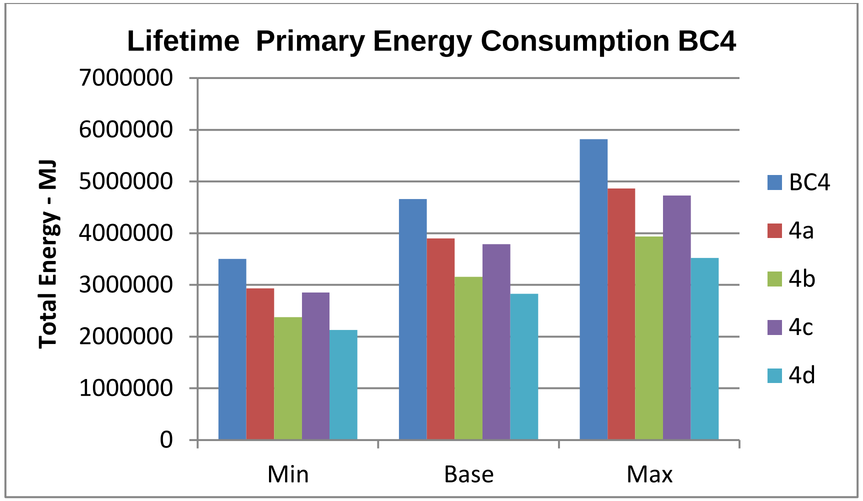


Figure 92: Impact of changes in lifetime on product primary energy consumption for Base Case 4 (10.1 – 200 kVA) design options

8.4.3 Timing of MEPS Tiers

In the MEPS policy scenarios identified in Section 8.2.2.1, improvements to product energy efficiency are implemented in 2017 and 2019 on a two tier basis. These dates were chosen on the basis that 2017 would be the earliest date at which Regulation would be likely and that BAT products are already available on the market in 2013, which will have been designed two to three years previously, allowing sufficient time for these to become the standard in 2019. Sensitivity analysis has been undertaken to understand the implications of delaying the tiers by a further two years to 2019 and 2021 respectively.

The results of this analysis are summarised in Table 120 for the MEPS+Transformerless scenario[285]. This clearly shows that delaying the implementation of improvements will delay when savings start to be realised and implications on the savings achieved for a given year. For example, in 2025 savings of 10.96 TWh were calculated when implementing the MEPS+Transformerless scenario in 2017 and 2019, compared to 9.22 TWh if it is implemented in 2019 and 2021.

Table 120: Impact on total electricity consumption of delaying implementation of policy scenario tiers by two years

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
2017/2019 Scenario												
BAU+Transformerless (TWh)	13.32	13.46	13.60	13.95	14.25	14.60	14.97	15.47	15.97	16.51	17.08	17.67
MEPS+Transformerless (TWh)	13.32	13.46	13.60	13.26	12.83	11.69	10.51	9.60	8.64	7.89	7.12	6.71
Savings (TWh)	0.00	0.00	0.00	0.69	1.42	2.91	4.46	5.87	7.33	8.62	9.96	10.96
Savings (%)	0.0%	0.0%	0.0%	5.0%	9.9%	19.9%	29.8%	37.9%	45.9%	52.2%	58.3%	62.0%
2019/2021 Scenario												
BAU+Transformerless (TWh)	13.32	13.46	13.60	13.95	14.25	14.60	14.97	15.47	15.97	16.51	17.08	17.67
MEPS+Transformerless (TWh)	13.32	13.46	13.60	13.95	14.25	13.85	13.44	12.34	11.18	10.22	9.24	8.44
Savings (TWh)	0.00	0.00	0.00	0.00	0.00	0.75	1.53	3.13	4.79	6.29	7.84	9.22
Savings (%)	0.0%	0.0%	0.0%	0.0%	0.0%	5.1%	10.2%	20.2%	30.0%	38.1%	45.9%	52.2%

8.5 Conclusions

The scope and definition for the policy options outlined covers most UPS products, with an exception made for products not based on standard components or topology i.e. bespoke.

The analysis of the policy options focuses on minimum efficiency performance standards (MEPS) and an Energy Label for UPS. A voluntary agreement was not considered appropriate as it would be difficult to manage given there are a significant number of manufacturers.

The MEPS policy option implements efficiency requirements for different UPS sizes and topologies using a tiered approach to implement improvements in line with product design cycles. The efficiencies reflect developments in flat efficiency and multi-mode functionality. The proposed Energy Label includes 'allowances' for certain design features to incentivise resource efficient design.

[285] Includes BC4 without transformer losses, as per the results in Table 134

The implementation dates selected are 2017 and 2019; however these can be amended depending on the timescales of any proposed Consultation Forum and Regulatory Committee.

The most significant environmental improvement resulting from the MEPS policy option is the reduction in electricity consumption, with reductions of over 60% identified for the UPS market as a whole, depending on the scenario chosen. Improvements in other environmental parameters, in particular those influenced by energy consumption are also observed. Table 121 summarises the potential energy consumption savings for the different scenarios.

Table 121: Summary of potential savings (TWh) compared to relevant business as usual scenarios by 2020 and 2025

Scenario name	2020	2025
MEPS or **MEPS+Transformerless**	4.46	10.96
Multi-Mode or **Multi-Mode+Transformerless**	4.59	11.44

The MEPS scenario results in lower life cycle costs, as a result of lower electricity consumption. Aggregated life cycle costs for Base Cases 1-4 reduces from €4.68 billion under business as usual to €3.48 billion under the MEPS scenario in 2025. Other economic impacts related to the implementation of MEPS are limited, as the design options used to implement the MEPS do not affect product price and the majority of manufacturing is outside of the EU.

Additional aspects under any potential Ecodesign regulation should focus on the provision of information relating to the optimum operating conditions for the UPS and its battery, the benefits of longer life batteries, information on the monitoring and checking the battery and clear instructions regarding battery replacement. The design of products to facilitate ease of battery replacement should be considered, in particular for the smaller UPS products, in order to increase their lifetime.

The energy labelling policy option provides a mechanism to address other aspects of UPS design, which would be difficult to include as part of Ecodesign requirements. The labelling scenario focuses on the energy efficiency of the products, but enables allowances to be added to influence the label category depending on the features the product. This includes proposals for allowances related to transformer losses, AMS functionality, compensation for VFI topology and a resource impact bonus for the use of battery internal resistance monitoring and correction. Due to data limitations it is difficult to model the environmental savings and economic impacts of the label, however example saving scenarios have been included where relevant e.g. reducing the number of units when using AMS functionality. The basic functionality of the product would remain the same, with allowances made for these specific aspects.

Appendices

Appendix 1 – International Standards and Existing Labels

International standards

EN 62040-1:2008 Uninterruptible power systems (UPS). General and safety requirements for UPS

Scope

applies to **uninterruptible power systems** (**UPS**) with an electrical energy storage device in the DC link. It is used with IEC 60950-1, which is referred to in this standard as "RD" (reference document).

*NOTE **UPS** applications generally make use of a chemical battery as the energy storage device. Alternative devices may be suitable, and as such, where "battery" appears in the text of this standard, where applicable, this may be understood as "energy storage device".*

When a clause is referred to by the phrase "The definitions or the provisions of item/RD apply", this phrase is intended to mean that the definitions or provisions in that clause of IEC 60950-1 apply, except any which are clearly inapplicable to **uninterruptible power systems**. National requirements additional to those in IEC 60950-1 apply and are found as notes under relevant clauses of the RD.

The primary function of the **UPS** covered by this standard is to ensure continuity of an alternating power source. The **UPS** may also serve to improve the quality of the power source by keeping it within specified characteristics.

This standard is applicable to **UPS** which are movable, stationary, fixed or for building-in, for use in low-voltage distribution systems and intended to be installed in any **operator** accessible area or in **restricted access locations** as applicable. It specifies requirements to ensure safety for the **operator** and layman who may come into contact with the equipment and, where specifically stated, for the **service person**.

This standard is intended to ensure the safety of installed **UPS**, both as a single **UPS** unit or as a system of interconnected **UPS** units, subject to installing, operating and maintaining the **UPS** in the manner prescribed by the manufacturer.

This standard does not cover **UPS** based on rotating machines.

Electromagnetic compatibility (EMC) requirements and definitions are given in IEC 62040-2.

Specific applications

Even if this standard does not cover all types of **UPS**, it may be taken as a guide for such equipment. Requirements additional to those specified in this standard may be necessary for specific applications, e.g. related to **UPS** that operate:

- while exposed to extremes of temperature; to excessive dust, moisture, or vibration; to flammable gases; to corrosive or to explosive atmospheres;
- where ingress of water and foreign objects are possible;

NOTE 1 Annex H provides guidance on such requirements and on relevant testing.

- in vehicles, on board ships or aircraft, in tropical countries, or at elevations greater than 1,000 m;

*NOTE 2 Guidance for performance of **UPS** operating at elevations greater than 1 000 m is provided in 4.1.1 of IEC 62040-3.*

- with trapezoidal output waveforms and long run times (greater than 30 min);

NOTE 3 In addition to complying with 5.3.1.2 of IEC 62040-3, voltage distortion tests for the purpose of load compatibility should also be performed.

- subject to transient over voltages exceeding those of overvoltage category II according to IEC 60664;

*NOTE 4 Subclause G.2.1/RD provides guidance for additional protection against transient over voltages at the mains supply to the **UPS**. Where such additional protection is an integral part of the equipment insulation requirements, creepage distances and clearance distances from the mains through to the load side of the additional protection may be judged as category III or IV as required. All further downstream insulation requirements, creepage distances, and clearance distances on the load side of the additional protection may be judged as category I or II as required.*

- in electromedical applications with the **UPS** located within 1,5 m of the patient contact area;
- in systems classified as emergency power systems by an authority having jurisdiction.

Terms and definitions

uninterruptible power system UPS

Combination of convertors, switches and energy storage devices (such as batteries), constituting a power system for maintaining continuity of load power in case of input power failure

*NOTE Continuity of load power occurs when voltage and frequency are within rated steady-state and transient tolerance bands and with distortion and interruptions within the limits specified for the load. Input power failure occurs when voltage and frequency are outside rated steady-state and transient tolerance bands or with distortion or interruptions outside the limits specified for the **UPS**.*

INTERNATIONAL STANDARD

IEC 62040-3 Apply to movable, stationary and fixed UPS that deliver single or 3-phase fixed frequency AC. not exceeding 1,000VA and incorporate an energy storage system connected through a DC link

Edition 2.0 2010-11 FINAL DRAFT

Scope

This International Standard applies to movable, stationary and fixed electronic **uninterruptible power systems** (UPS) that deliver single or three-phase fixed frequency AC output voltage not exceeding 1000 V DC and that incorporate an **energy storage system**, generally connected through a DC link.

This standard is intended to specify performance and test requirements of a complete UPS and not of individual **UPS functional units**. The individual UPS functional units are dealt with in IEC publications referred to in the bibliography that apply so far that they are not in contradiction with this standard. The primary function of the UPS covered by this standard is to ensure continuity of an AC power source. The UPS may also serve to improve the quality of the power source by keeping it within specified characteristics. UPS have been developed over a wide range of power, from less than hundred watts to several megawatts, to meet requirements for availability and quality of power to a variety of loads. Refer to Annexes A and B for information on typical UPS configurations and topologies.

This standard also covers UPS test and performance when power switches form integral part of a UPS and are associated with its output. Included are interrupters, bypass switches, isolating switches, and tie switches. These switches interact with other functional units of the UPS to maintain **continuity of load power**.

This standard does not cover

- conventional AC input and output distribution boards or DC boards and their associated switches (e.g. switches for batteries, rectifier output or inverter input);
- stand-alone static transfer systems covered by IEC 62310-3;
- systems wherein the output voltage is derived from a rotating machine.

Existing Labels

Energy Star[286] for (UPS):

A device intended to maintain continuity of power to electrical loads in the event of a disruption to expected utility power supply. The ride-through time of a UPS varies from seconds to tens of minutes. UPS design offer a range of features, from acting as a temporary power source to the load during a power disruption, to conditioning the power reaching the load under normal operation. UPSs contain energy storage mechanisms to supply power to the attached load in the event of full disruption from the utility.

Current draft definition for Energy Star [287]

International Electrical Commission (IEC) standard IEC 62040-31 specifications:

A) (UPS): Combination of convertors, switches, and energy storage devices (such as batteries) constituting a power system for maintaining continuity of load power in case of input power failure.

1) Power conversion mechanism:

   i) Static UPS: solid-state power electronic components provide the output voltage.

   ii) Rotary UPS: UPS where one or more electrical rotating machines provide the output voltage.

2) Power Output:

   i) Ac-output UPS: supplies power with a continuous flow that periodically reverses direction.

   ii) Dc-output UPS/Rectifier: supplies power with a continuous flow that is unidirectional (Includes individual dc rectifier units and entire frames or systems, consisting of rectifier modules, controllers, and supporting components).

Note*:* Dc-output UPSs are also known as rectifiers (a product that converts Ac to Dc to supply a load and an energy storage mechanism).The term “Dc-output UPS/Rectifier” is used because a “rectifier” may also refer to an Ac-output component.

Note: To avoid confusion EPA removed the terms: "Consumer UPS," “Commercial UPS,” "Data Centre UPS," “Industrial UPS,” “Cable TV UPS,” “Safety UPS,” and “Utility UPS” since the minimum average efficiency requirements are based solely on output power not application. The qualification criteria in Section 3 no longer reference terms related to application. Where application is relevant to the scope of the specification, EPA has included additional descriptions of included and excluded products in Section 2.

Included Products

[286] www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies

[287] www.energystar.gov/ia/partners/prod_development/new_specs/downloads/uninterruptible_power_supplies/UPS_V1_Draft3_ES_Specification.pdf?8038-ad27

i) Products that meet the definition of an UPS including Static, Rotary, Ac-output, Dc-output UPSs/Rectifiers are eligible for ENERGY STAR qualification, Products eligible include: Consumer - desktop computers and peripherals and home entertainment devices such as TVs, set top boxes, DVRs, Blu-ray and DVD players;

ii) Commercial - small business and branch office ICT equipment such as servers, network switches and routers, and small storage arrays;

iii) Data Centre - large installations of information and communication technology equipment such as enterprise servers, networking equipment, and large storage arrays; and,

iv) Telecommunications Dc-output UPSs/Rectifiers - telecommunication network systems - central or at a remote wireless/cellular site.

Excluded Products

Products covered under other ENERGY STAR product specifications are not eligible under this specification. www.energystar.gov/products.

The following products are not eligible for qualification under this specification:

i) Products that are inside a computer or product (e.g., battery-supplemented power supplies or backup for modems, security systems, etc.);

ii) Industrial UPSs designed to protect industrial manufacturing operations;

iii) Utility UPSs designed as part of electrical transmission and distribution (e.g. substation or neighbourhood UPSs);

iv) Cable TV (CATV) UPSs that power the cable signal distribution system outside plant equipment and connected to the cable itself. The “cable” may be metallic wire, fibre-optic or wireless

v) UPSs designed to comply with specific UL safety standards, such as emergency lighting, or medical diagnostic equipment.

Appendix 2 – Sales data

This annex presents UPS sales in number of units for 1995 - 2025. The data is categorised by Member State for different sizes of UPS.

1995	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	24,930.70	17,212.28	6,920.51	441.90	228.38	127.63
Belgium	18,597.76	12,839.99	5,162.55	329.64	170.37	95.21
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	10,394.83	7,176.65	2,885.50	184.25	95.22	53.21
Denmark	22,057.33	15,228.50	6,122.89	390.97	202.06	112.92
Estonia	2,496.73	1,723.76	693.07	44.25	22.87	12.78
Finland	16,141.57	11,144.22	4,480.74	286.11	147.87	82.63
France	131,414.36	90,729.16	36,479.30	2,329.31	1,203.85	672.74
Germany	179,501.03	123,928.45	49,827.67	3,181.65	1,644.36	918.91
Greece	10,986.41	7,585.07	3,049.72	194.73	100.64	56.24
Hungary	13,099.18	9,043.74	3,636.20	232.18	120.00	67.06
Ireland	15,296.46	10,560.76	4,246.14	271.13	140.13	78.31
Italy	112,568.44	77,717.84	31,247.86	1,995.27	1,031.21	576.26
Latvia	3,094.17	2,136.23	858.91	54.84	28.34	15.84
Lithuania	4,719.42	3,258.31	1,310.06	83.65	43.23	24.16
Luxembourg	2,191.91	1,513.31	608.45	38.85	20.08	11.22
Malta	-	-	-	-	-	-
Netherlands	43,776.62	30,223.60	12,151.95	775.94	401.03	224.10
Poland	28,818.20	19,896.23	7,999.64	510.80	264.00	147.53
Portugal	25,099.72	17,328.98	6,967.43	444.89	229.93	128.49
Romania	11,577.99	7,993.50	3,213.93	205.22	106.06	59.27
Slovakia	3,295.92	2,275.52	914.91	58.42	30.19	16.87
Slovenia	-	-	-	-	-	-
Spain	64,566.28	44,576.90	17,922.95	1,144.44	591.47	330.53
Sweden	24,508.14	16,920.55	6,803.21	434.41	224.51	125.46
United Kingdom	159,640.98	110,216.97	44,314.72	2,829.63	1,462.43	817.24
Total EU27	**928,774.17**	**641,230.53**	**257,818.30**	**16,462.49**	**8,508.24**	**4,754.61**

1996	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	26,177.23	18,072.90	7,266.53	463.99	239.80	134.01
Belgium	19,527.65	13,481.99	5,420.68	346.13	178.89	99.97
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	10,914.58	7,535.48	3,029.78	193.46	99.99	55.87
Denmark	23,160.20	15,989.92	6,429.04	410.51	212.16	118.56
Estonia	2,621.57	1,809.94	727.72	46.47	24.02	13.42
Finland	16,948.65	11,701.44	4,704.77	300.41	155.26	86.76
France	137,985.08	95,265.62	38,303.26	2,445.78	1,264.04	706.38
Germany	188,476.08	130,124.87	52,319.05	3,340.73	1,726.58	964.85
Greece	11,535.73	7,964.33	3,202.20	204.47	105.68	59.05
Hungary	13,754.14	9,495.93	3,818.01	243.79	126.00	70.41
Ireland	16,061.29	11,088.80	4,458.45	284.69	147.13	82.22
Italy	118,196.87	81,603.73	32,810.25	2,095.04	1,082.77	605.08
Latvia	3,248.88	2,243.04	901.86	57.59	29.76	16.63
Lithuania	4,955.39	3,421.23	1,375.57	87.83	45.39	25.37
Luxembourg	2,301.50	1,588.97	638.87	40.79	21.08	11.78
Malta	-	-	-	-	-	-
Netherlands	45,965.45	31,734.78	12,759.54	814.74	421.08	235.31
Poland	30,259.11	20,891.05	8,399.62	536.34	277.20	154.90
Portugal	26,354.71	18,195.43	7,315.80	467.14	241.43	134.92
Romania	12,156.88	8,393.18	3,374.63	215.48	111.37	62.23
Slovakia	3,460.72	2,389.30	960.66	61.34	31.70	17.72
Slovenia	-	-	-	-	-	-
Spain	67,794.60	46,805.74	18,819.09	1,201.66	621.05	347.06
Sweden	25,733.55	17,766.58	7,143.37	456.13	235.74	131.74
United Kingdom	167,623.03	115,727.82	46,530.46	2,971.11	1,535.55	858.10
Total EU27	**975,212.87**	**673,292.06**	**270,709.22**	**17,285.61**	**8,933.65**	**4,992.34**

1997	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	27,486.10	18,976.54	7,629.86	487.19	251.79	140.71
Belgium	20,504.03	14,156.09	5,691.71	363.43	187.83	104.96
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	11,460.30	7,912.25	3,181.26	203.13	104.98	58.67
Denmark	24,318.21	16,789.42	6,750.49	431.04	222.77	124.49
Estonia	2,752.65	1,900.44	764.11	48.79	25.22	14.09
Finland	17,796.08	12,286.51	4,940.01	315.43	163.02	91.10
France	144,884.33	100,028.90	40,218.42	2,568.07	1,327.24	741.70
Germany	197,899.89	136,631.11	54,935.00	3,507.77	1,812.91	1,013.09
Greece	12,112.52	8,362.54	3,362.31	214.69	110.96	62.01
Hungary	14,441.85	9,970.73	4,008.91	255.98	132.30	73.93
Ireland	16,864.35	11,643.24	4,681.37	298.92	154.49	86.33
Italy	124,106.71	85,683.92	34,450.77	2,199.79	1,136.91	635.33
Latvia	3,411.32	2,355.19	946.95	60.47	31.25	17.46
Lithuania	5,203.16	3,592.29	1,444.35	92.23	47.66	26.64
Luxembourg	2,416.58	1,668.42	670.82	42.83	22.14	12.37
Malta	-	-	-	-	-	-
Netherlands	48,263.72	33,321.52	13,397.52	855.47	442.13	247.07
Poland	31,772.06	21,935.60	8,819.60	563.16	291.05	162.65
Portugal	27,672.44	19,105.20	7,681.59	490.49	253.50	141.66
Romania	12,764.73	8,812.84	3,543.36	226.25	116.93	65.35
Slovakia	3,633.75	2,508.76	1,008.69	64.41	33.29	18.60
Slovenia	-	-	-	-	-	-
Spain	71,184.33	49,146.03	19,760.05	1,261.74	652.10	364.41
Sweden	27,020.23	18,654.91	7,500.54	478.93	247.52	138.32
United Kingdom	176,004.18	121,514.21	48,856.98	3,119.67	1,612.33	901.01
Total EU27	**1,023,973.52**	**706,956.66**	**284,244.68**	**18,149.89**	**9,380.34**	**5,241.95**

1998	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	28,860.40	19,925.37	8,011.35	511.55	264.38	147.74
Belgium	21,529.23	14,863.89	5,976.30	381.60	197.22	110.21
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	12,033.32	8,307.87	3,340.33	213.29	110.23	61.60
Denmark	25,534.12	17,628.89	7,088.01	452.59	233.91	130.71
Estonia	2,890.28	1,995.46	802.31	51.23	26.48	14.80
Finland	18,685.89	12,900.83	5,187.01	331.21	171.18	95.66
France	152,128.55	105,030.34	42,229.34	2,696.47	1,393.61	778.78
Germany	207,794.88	143,462.67	57,681.75	3,683.16	1,903.55	1,063.75
Greece	12,718.14	8,780.67	3,530.43	225.43	116.51	65.11
Hungary	15,163.94	10,469.26	4,209.36	268.78	138.91	77.63
Ireland	17,707.57	12,225.40	4,915.44	313.87	162.21	90.65
Italy	130,312.04	89,968.11	36,173.30	2,309.78	1,193.75	667.10
Latvia	3,581.89	2,472.95	994.30	63.49	32.81	18.34
Lithuania	5,463.32	3,771.91	1,516.56	96.84	50.05	27.97
Luxembourg	2,537.41	1,751.84	704.36	44.98	23.24	12.99
Malta	-	-	-	-	-	-
Netherlands	50,676.91	34,987.60	14,067.40	898.25	464.24	259.43
Poland	33,360.67	23,032.38	9,260.58	591.32	305.61	170.78
Portugal	29,056.06	20,060.46	8,065.67	515.02	266.17	148.74
Romania	13,402.97	9,253.48	3,720.53	237.57	122.78	68.61
Slovakia	3,815.44	2,634.20	1,059.13	67.63	34.95	19.53
Slovenia	-	-	-	-	-	-
Spain	74,743.54	51,603.33	20,748.05	1,324.83	684.70	382.63
Sweden	28,371.24	19,587.65	7,875.57	502.88	259.90	145.24
United Kingdom	184,804.39	127,589.92	51,299.83	3,275.65	1,692.94	946.06
Total EU27	**1,075,172.19**	**742,304.49**	**298,456.91**	**19,057.39**	**9,849.35**	**5,504.05**

1999	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	30,303.42	20,921.64	8,411.92	537.13	277.60	155.13
Belgium	22,605.69	15,607.09	6,275.11	400.69	207.08	115.72
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	12,634.99	8,723.26	3,507.34	223.95	115.75	64.68
Denmark	26,810.82	18,510.33	7,442.41	475.22	245.61	137.25
Estonia	3,034.79	2,095.24	842.43	53.79	27.80	15.54
Finland	19,620.18	13,545.87	5,446.36	347.77	179.73	100.44
France	159,734.98	110,281.86	44,340.81	2,831.30	1,463.29	817.72
Germany	218,184.62	150,635.80	60,565.84	3,867.31	1,998.73	1,116.94
Greece	13,354.05	9,219.71	3,706.95	236.70	122.33	68.36
Hungary	15,922.14	10,992.73	4,419.82	282.22	145.86	81.51
Ireland	18,592.95	12,836.67	5,161.21	329.56	170.32	95.18
Italy	136,827.65	94,466.52	37,981.97	2,425.27	1,253.44	700.45
Latvia	3,760.98	2,596.60	1,044.01	66.66	34.45	19.25
Lithuania	5,736.49	3,960.50	1,592.39	101.68	52.55	29.37
Luxembourg	2,664.28	1,839.43	739.58	47.22	24.41	13.64
Malta	-	-	-	-	-	-
Netherlands	53,210.75	36,736.98	14,770.77	943.16	487.45	272.40
Poland	35,028.70	24,184.00	9,723.61	620.88	320.89	179.32
Portugal	30,508.87	21,063.48	8,468.95	540.77	279.48	156.18
Romania	14,073.11	9,716.15	3,906.55	249.45	128.92	72.04
Slovakia	4,006.21	2,765.91	1,112.08	71.01	36.70	20.51
Slovenia	-	-	-	-	-	-
Spain	78,480.72	54,183.50	21,785.45	1,391.07	718.94	401.76
Sweden	29,789.80	20,567.04	8,269.35	528.02	272.90	152.50
United Kingdom	194,044.61	133,969.41	53,864.82	3,439.43	1,777.59	993.36
Total EU27	**1,128,930.80**	779,419.72	313,379.76	20,010.26	10,341.82	5,779.25

2000	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	31,818.59	21,967.72	8,832.52	563.98	291.48	162.89
Belgium	23,735.98	16,387.44	6,588.87	420.72	217.44	121.51
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	13,266.73	9,159.42	3,682.71	235.15	121.53	67.92
Denmark	28,151.36	19,435.85	7,814.53	498.98	257.89	144.11
Estonia	3,186.53	2,200.00	884.55	56.48	29.19	16.31
Finland	20,601.19	14,223.17	5,718.68	365.16	188.72	105.46
France	167,721.73	115,795.95	46,557.85	2,972.86	1,536.45	858.61
Germany	229,093.86	158,167.59	63,594.13	4,060.68	2,098.66	1,172.78
Greece	14,021.75	9,680.69	3,892.30	248.54	128.45	71.78
Hungary	16,718.24	11,542.36	4,640.81	296.33	153.15	85.58
Ireland	19,522.59	13,478.50	5,419.27	346.04	178.84	99.94
Italy	143,669.03	99,189.85	39,881.07	2,546.53	1,316.11	735.47
Latvia	3,949.03	2,726.43	1,096.21	70.00	36.18	20.22
Lithuania	6,023.31	4,158.53	1,672.01	106.76	55.18	30.83
Luxembourg	2,797.49	1,931.40	776.56	49.59	25.63	14.32
Malta	-	-	-	-	-	-
Netherlands	55,871.29	38,573.83	15,509.30	990.32	511.82	286.02
Poland	36,780.13	25,393.20	10,209.79	651.93	336.93	188.29
Portugal	32,034.31	22,116.66	8,892.40	567.81	293.46	163.99
Romania	14,776.77	10,201.96	4,101.88	261.92	135.37	75.65
Slovakia	4,206.53	2,904.21	1,167.69	74.56	38.53	21.53
Slovenia	-	-	-	-	-	-
Spain	82,404.76	56,892.67	22,874.73	1,460.62	754.89	421.85
Sweden	31,279.29	21,595.39	8,682.81	554.42	286.54	160.13
United Kingdom	203,746.84	140,667.88	56,558.06	3,611.41	1,866.47	1,043.03
Total EU27	**1,185,377.34**	**818,390.70**	**329,048.74**	**21,010.77**	**10,858.91**	**6,068.21**

2001	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	28,432.49	19,629.94	7,892.57	503.96	260.46	145.55
Belgium	21,210.02	14,643.51	5,887.69	375.95	194.30	108.58
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	11,854.90	8,184.69	3,290.80	210.13	108.60	60.69
Denmark	25,155.53	17,367.51	6,982.92	445.88	230.44	128.78
Estonia	2,847.42	1,965.88	790.42	50.47	26.08	14.58
Finland	18,408.83	12,709.55	5,110.11	326.30	168.64	94.24
France	149,872.96	103,473.07	41,603.22	2,656.49	1,372.94	767.23
Germany	204,713.94	141,335.57	56,826.52	3,628.55	1,875.33	1,047.98
Greece	12,529.57	8,650.48	3,478.08	222.09	114.78	64.14
Hungary	14,939.11	10,314.04	4,146.94	264.80	136.85	76.48
Ireland	17,445.02	12,044.13	4,842.56	309.21	159.81	89.31
Italy	128,379.93	88,634.17	35,636.97	2,275.53	1,176.05	657.21
Latvia	3,528.78	2,436.29	979.55	62.55	32.33	18.06
Lithuania	5,382.32	3,715.98	1,494.08	95.40	49.31	27.55
Luxembourg	2,499.79	1,725.87	693.92	44.31	22.90	12.80
Malta	-	-	-	-	-	-
Netherlands	49,925.53	34,468.84	13,858.82	884.93	457.35	255.58
Poland	32,866.03	22,690.88	9,123.28	582.55	301.08	168.25
Portugal	28,625.25	19,763.02	7,946.08	507.38	262.23	146.54
Romania	13,204.24	9,116.28	3,665.36	234.04	120.96	67.60
Slovakia	3,758.87	2,595.14	1,043.42	66.63	34.43	19.24
Slovenia	-	-	-	-	-	-
Spain	73,635.33	50,838.22	20,440.42	1,305.18	674.55	376.96
Sweden	27,950.58	19,297.23	7,758.80	495.42	256.05	143.09
United Kingdom	182,064.32	125,698.16	50,539.21	3,227.08	1,667.84	932.03
Total EU27	**1,059,230.77**	**731,298.45**	**294,031.73**	**18,774.83**	**9,703.32**	**5,422.44**

2002	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	29,609.20	20,442.35	8,219.21	524.82	271.24	151.58
Belgium	22,087.82	15,249.54	6,131.35	391.51	202.34	113.07
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	12,345.53	8,523.42	3,426.99	218.82	113.09	63.20
Denmark	26,196.61	18,086.28	7,271.91	464.33	239.98	134.11
Estonia	2,965.27	2,047.24	823.13	52.56	27.16	15.18
Finland	19,170.70	13,235.55	5,321.59	339.80	175.62	98.14
France	156,075.61	107,755.41	43,325.01	2,766.43	1,429.77	798.99
Germany	213,186.23	147,184.89	59,178.34	3,778.72	1,952.94	1,091.35
Greece	13,048.12	9,008.49	3,622.03	231.28	119.53	66.80
Hungary	15,557.38	10,740.89	4,318.57	275.75	142.52	79.64
Ireland	18,167.00	12,542.59	5,042.98	322.01	166.42	93.00
Italy	133,693.06	92,302.39	37,111.84	2,369.70	1,224.72	684.41
Latvia	3,674.82	2,537.12	1,020.09	65.14	33.66	18.81
Lithuania	5,605.07	3,869.77	1,555.91	99.35	51.35	28.69
Luxembourg	2,603.24	1,797.29	722.63	46.14	23.85	13.33
Malta	-	-	-	-	-	-
Netherlands	51,991.75	35,895.37	14,432.38	921.55	476.28	266.16
Poland	34,226.23	23,629.97	9,500.85	606.66	313.54	175.21
Portugal	29,809.94	20,580.94	8,274.94	528.38	273.08	152.60
Romania	13,750.71	9,493.56	3,817.06	243.73	125.97	70.39
Slovakia	3,914.44	2,702.55	1,086.61	69.38	35.86	20.04
Slovenia	-	-	-	-	-	-
Spain	76,682.81	52,942.21	21,286.37	1,359.20	702.47	392.56
Sweden	29,107.35	20,095.86	8,079.90	515.93	266.64	149.01
United Kingdom	189,599.24	130,900.31	52,630.83	3,360.64	1,736.87	970.60
Total EU27	**1,103,068.11**	**761,563.98**	**306,200.53**	**19,551.84**	**10,104.90**	**5,646.86**

2003	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	30,785.91	21,254.75	8,545.86	545.68	282.02	157.60
Belgium	22,965.62	15,855.58	6,375.02	407.06	210.38	117.57
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	12,836.16	8,862.15	3,563.19	227.52	117.59	65.71
Denmark	27,237.70	18,805.05	7,560.91	482.79	249.52	139.44
Estonia	3,083.11	2,128.60	855.84	54.65	28.24	15.78
Finland	19,932.57	13,761.55	5,533.08	353.30	182.60	102.04
France	162,278.25	112,037.75	45,046.80	2,876.38	1,486.59	830.74
Germany	221,658.52	153,034.20	61,530.16	3,928.89	2,030.55	1,134.72
Greece	13,566.67	9,366.50	3,765.97	240.47	124.28	69.45
Hungary	16,175.65	11,167.75	4,490.20	286.71	148.18	82.81
Ireland	18,888.98	13,041.05	5,243.39	334.81	173.04	96.70
Italy	139,006.19	95,970.60	38,586.71	2,463.88	1,273.40	711.60
Latvia	3,820.86	2,637.94	1,060.63	67.72	35.00	19.56
Lithuania	5,827.82	4,023.56	1,617.74	103.30	53.39	29.83
Luxembourg	2,706.70	1,868.72	751.35	47.98	24.80	13.86
Malta	-	-	-	-	-	-
Netherlands	54,057.96	37,321.90	15,005.94	958.18	495.21	276.73
Poland	35,586.42	24,569.05	9,878.43	630.77	326.00	182.17
Portugal	30,994.62	21,398.85	8,603.79	549.38	283.93	158.67
Romania	14,297.18	9,870.85	3,968.75	253.42	130.97	73.19
Slovakia	4,070.00	2,809.95	1,129.79	72.14	37.28	20.84
Slovenia	-	-	-	-	-	-
Spain	79,730.28	55,046.20	22,132.32	1,413.22	730.39	408.16
Sweden	30,264.11	20,894.50	8,401.01	536.43	277.24	154.93
United Kingdom	197,134.16	136,102.45	54,722.45	3,494.20	1,805.89	1,009.17
Total EU27	**1,146,905.45**	**791,829.51**	**318,369.34**	**20,328.86**	**10,506.48**	**5,871.27**

2004	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	31,962.61	22,067.16	8,872.50	566.54	292.80	163.62
Belgium	23,843.41	16,461.62	6,618.69	422.62	218.42	122.06
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	13,326.78	9,200.88	3,699.38	236.22	122.08	68.22
Denmark	28,278.79	19,523.82	7,849.90	501.24	259.05	144.77
Estonia	3,200.95	2,209.96	888.55	56.74	29.32	16.39
Finland	20,694.44	14,287.55	5,744.57	366.81	189.58	105.94
France	168,480.90	116,320.09	46,768.59	2,986.32	1,543.41	862.49
Germany	230,130.82	158,883.52	63,881.98	4,079.06	2,108.16	1,178.09
Greece	14,085.22	9,724.51	3,909.91	249.66	129.03	72.11
Hungary	16,793.92	11,594.61	4,661.82	297.67	153.84	85.97
Ireland	19,610.96	13,539.51	5,443.80	347.60	179.65	100.39
Italy	144,319.33	99,638.82	40,061.58	2,558.05	1,322.07	738.80
Latvia	3,966.91	2,738.77	1,101.17	70.31	36.34	20.31
Lithuania	6,050.58	4,177.35	1,679.58	107.25	55.43	30.97
Luxembourg	2,810.16	1,940.15	780.07	49.81	25.74	14.39
Malta	-	-	-	-	-	-
Netherlands	56,124.18	38,748.43	15,579.50	994.80	514.14	287.31
Poland	36,946.61	25,508.14	10,256.01	654.88	338.46	189.14
Portugal	32,179.31	22,216.76	8,932.65	570.38	294.79	164.73
Romania	14,843.65	10,248.14	4,120.45	263.10	135.98	75.99
Slovakia	4,225.57	2,917.35	1,172.97	74.90	38.71	21.63
Slovenia	-	-	-	-	-	-
Spain	82,777.75	57,150.19	22,978.27	1,467.23	758.30	423.76
Sweden	31,420.87	21,693.14	8,722.12	556.93	287.84	160.85
United Kingdom	204,669.07	141,304.60	56,814.06	3,627.75	1,874.92	1,047.75
Total EU27	**1,190,742.79**	**822,095.03**	**330,538.14**	**21,105.87**	**10,908.06**	**6,095.68**

2005	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	33,139.32	22,879.56	9,199.14	587.39	303.58	169.65
Belgium	24,721.21	17,067.65	6,862.36	438.18	226.46	126.55
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	13,817.41	9,539.61	3,835.57	244.91	126.58	70.73
Denmark	29,319.87	20,242.59	8,138.90	519.69	268.59	150.10
Estonia	3,318.80	2,291.32	921.26	58.83	30.40	16.99
Finland	21,456.31	14,813.55	5,956.05	380.31	196.56	109.84
France	174,683.54	120,602.43	48,490.38	3,096.26	1,600.23	894.24
Germany	238,603.11	164,732.83	66,233.81	4,229.23	2,185.78	1,221.46
Greece	14,603.77	10,082.52	4,053.86	258.85	133.78	74.76
Hungary	17,412.19	12,021.46	4,833.45	308.63	159.51	89.14
Ireland	20,332.94	14,037.97	5,644.22	360.40	186.26	104.09
Italy	149,632.46	103,307.03	41,536.46	2,652.23	1,370.74	766.00
Latvia	4,112.95	2,839.60	1,141.71	72.90	37.68	21.06
Lithuania	6,273.33	4,331.14	1,741.41	111.19	57.47	32.11
Luxembourg	2,913.61	2,011.57	808.79	51.64	26.69	14.92
Malta	-	-	-	-	-	-
Netherlands	58,190.40	40,174.96	16,153.07	1,031.42	533.07	297.89
Poland	38,306.81	26,447.22	10,633.58	678.99	350.92	196.10
Portugal	33,363.99	23,034.68	9,261.51	591.38	305.64	170.80
Romania	15,390.13	10,625.42	4,272.14	272.79	140.98	78.79
Slovakia	4,381.13	3,024.76	1,216.16	77.66	40.13	22.43
Slovenia	-	-	-	-	-	-
Spain	85,825.22	59,254.18	23,824.21	1,521.25	786.22	439.36
Sweden	32,577.64	22,491.77	9,043.22	577.44	298.43	166.77
United Kingdom	212,203.99	146,506.74	58,905.68	3,761.31	1,943.94	1,086.32
Total EU27	**1,234,580.13**	**852,360.56**	**342,706.94**	**21,882.89**	**11,309.64**	**6,320.09**

2006	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	35,408.17	25,148.41	9,199.14	587.39	303.58	169.65
Belgium	24,721.21	17,067.65	6,862.36	438.18	226.46	126.55
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	13,817.41	9,539.61	3,835.57	244.91	126.58	70.73
Denmark	29,319.87	20,242.59	8,138.90	519.69	268.59	150.10
Estonia	3,318.80	2,291.32	921.26	58.83	30.40	16.99
Finland	21,456.31	14,813.55	5,956.05	380.31	196.56	109.84
France	174,683.54	120,602.43	48,490.38	3,096.26	1,600.23	894.24
Germany	238,603.11	164,732.83	66,233.81	4,229.23	2,185.78	1,221.46
Greece	14,603.77	10,082.52	4,053.86	258.85	133.78	74.76
Hungary	17,412.19	12,021.46	4,833.45	308.63	159.51	89.14
Ireland	20,332.94	14,037.97	5,644.22	360.40	186.26	104.09
Italy	149,632.46	103,307.03	41,536.46	2,652.23	1,370.74	766.00
Latvia	4,112.95	2,839.60	1,141.71	72.90	37.68	21.06
Lithuania	6,273.33	4,331.14	1,741.41	111.19	57.47	32.11
Luxembourg	2,913.61	2,011.57	808.79	51.64	26.69	14.92
Malta	-	-	-	-	-	-
Netherlands	58,190.40	40,174.96	16,153.07	1,031.42	533.07	297.89
Poland	38,306.81	26,447.22	10,633.58	678.99	350.92	196.10
Portugal	33,363.99	23,034.68	9,261.51	591.38	305.64	170.80
Romania	15,390.13	10,625.42	4,272.14	272.79	140.98	78.79
Slovakia	4,381.13	3,024.76	1,216.16	77.66	40.13	22.43
Slovenia	-	-	-	-	-	-
Spain	85,825.22	59,254.18	23,824.21	1,521.25	786.22	439.36
Sweden	32,577.64	22,491.77	9,043.22	577.44	298.43	166.77
United Kingdom	212,203.99	146,506.74	58,905.68	3,761.31	1,943.94	1,086.32
Total EU27	**1,234,580.13**	**852,360.56**	**342,706.94**	**21,882.89**	**11,309.64**	**6,320.09**

2007	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	39,711.84	27,417.26	11,023.60	703.89	363.79	203.29
Belgium	29,624.17	20,452.68	8,223.37	525.09	271.38	151.65
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,557.82	11,431.60	4,596.28	293.49	151.68	84.76
Denmark	35,134.88	24,257.30	9,753.09	622.76	321.86	179.86
Estonia	3,977.01	2,745.75	1,103.98	70.49	36.43	20.36
Finland	25,711.73	17,751.51	7,137.32	455.74	235.54	131.62
France	209,328.50	144,521.49	58,107.47	3,710.34	1,917.60	1,071.60
Germany	285,925.23	197,404.27	79,369.95	5,068.01	2,619.28	1,463.72
Greece	17,500.13	12,082.18	4,857.86	310.19	160.31	89.59
Hungary	20,865.54	14,405.68	5,792.06	369.84	191.14	106.82
Ireland	24,365.57	16,822.12	6,763.63	431.88	223.21	124.73
Italy	179,309.04	123,795.90	49,774.37	3,178.25	1,642.60	917.92
Latvia	4,928.67	3,402.78	1,368.15	87.36	45.15	25.23
Lithuania	7,517.52	5,190.13	2,086.79	133.25	68.87	38.48
Luxembourg	3,491.47	2,410.53	969.20	61.89	31.98	17.87
Malta	-	-	-	-	-	-
Netherlands	69,731.29	48,142.85	19,356.70	1,235.98	638.79	356.97
Poland	45,904.19	31,692.49	12,742.54	813.65	420.52	234.99
Portugal	39,981.07	27,603.14	11,098.34	708.66	366.26	204.67
Romania	18,442.45	12,732.76	5,119.44	326.89	168.95	94.41
Slovakia	5,250.04	3,624.65	1,457.36	93.06	48.09	26.88
Slovenia	-	-	-	-	-	-
Spain	102,846.93	71,006.06	28,549.27	1,822.96	942.15	526.50
Sweden	39,038.76	26,952.56	10,836.76	691.96	357.62	199.85
United Kingdom	254,290.38	175,563.40	70,588.43	4,507.29	2,329.48	1,301.77
Total EU27	**1,479,434.23**	**1,021,409.11**	**410,675.96**	**26,222.92**	**13,552.68**	**7,573.56**

2008	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	42,998.10	29,686.11	11,935.84	762.14	393.89	220.12
Belgium	32,075.64	22,145.19	8,903.87	568.54	293.84	164.20
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	17,928.02	12,377.60	4,976.64	317.77	164.23	91.78
Denmark	38,042.38	26,264.66	10,560.18	674.30	348.50	194.75
Estonia	4,306.12	2,972.97	1,195.34	76.33	39.45	22.04
Finland	27,839.45	19,220.50	7,727.95	493.45	255.03	142.52
France	226,650.98	156,481.02	62,916.02	4,017.38	2,076.29	1,160.28
Germany	309,586.29	213,739.99	85,938.02	5,487.41	2,836.03	1,584.84
Greece	18,948.31	13,082.01	5,259.86	335.86	173.58	97.00
Hungary	22,592.22	15,597.79	6,271.37	400.45	206.96	115.65
Ireland	26,381.88	18,214.19	7,323.34	467.62	241.68	135.05
Italy	194,147.34	134,040.33	53,893.33	3,441.25	1,778.53	993.88
Latvia	5,336.53	3,684.37	1,481.37	94.59	48.89	27.32
Lithuania	8,139.61	5,619.63	2,259.47	144.27	74.56	41.67
Luxembourg	3,780.40	2,610.01	1,049.40	67.01	34.63	19.35
Malta	-	-	-	-	-	-
Netherlands	75,501.74	52,126.80	20,958.52	1,338.27	691.65	386.51
Poland	49,702.88	34,315.13	13,797.02	880.98	455.31	254.44
Portugal	43,289.61	29,887.37	12,016.76	767.31	396.56	221.61
Romania	19,968.61	13,786.43	5,543.08	353.94	182.93	102.22
Slovakia	5,684.49	3,924.60	1,577.96	100.76	52.07	29.10
Slovenia	-	-	-	-	-	-
Spain	111,357.78	76,881.99	30,911.79	1,973.81	1,020.12	570.07
Sweden	42,269.31	29,182.96	11,733.53	749.22	387.22	216.39
United Kingdom	275,333.57	190,091.73	76,429.81	4,880.28	2,522.25	1,409.49
Total EU27	**1,601,861.27**	**1,105,933.38**	**444,660.47**	**28,392.93**	**14,674.20**	**8,200.29**

2009	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	34,398.48	23,748.89	9,548.67	609.71	315.11	176.09
Belgium	25,660.51	17,716.15	7,123.10	454.83	235.07	131.36
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	14,342.42	9,902.08	3,981.31	254.22	131.39	73.42
Denmark	30,433.91	21,011.73	8,448.14	539.44	278.80	155.80
Estonia	3,444.90	2,378.38	956.27	61.06	31.56	17.64
Finland	22,271.56	15,376.40	6,182.36	394.76	204.02	114.01
France	181,320.78	125,184.82	50,332.81	3,213.90	1,661.03	928.22
Germany	247,669.03	170,991.99	68,750.42	4,389.92	2,268.83	1,267.87
Greece	15,158.65	10,465.61	4,207.89	268.69	138.86	77.60
Hungary	18,073.78	12,478.23	5,017.10	320.36	165.57	92.52
Ireland	21,105.51	14,571.35	5,858.67	374.09	193.34	108.04
Italy	155,317.87	107,232.27	43,114.67	2,753.00	1,422.82	795.11
Latvia	4,269.22	2,947.49	1,185.09	75.67	39.11	21.86
Lithuania	6,511.69	4,495.70	1,807.58	115.42	59.65	33.33
Luxembourg	3,024.32	2,088.00	839.52	53.61	27.70	15.48
Malta	-	-	-	-	-	-
Netherlands	60,401.39	41,701.44	16,766.82	1,070.61	553.32	309.21
Poland	39,762.31	27,452.10	11,037.61	704.79	364.25	203.55
Portugal	34,631.69	23,909.90	9,613.41	613.85	317.25	177.29
Romania	15,974.89	11,029.14	4,434.47	283.15	146.34	81.78
Slovakia	4,547.60	3,139.68	1,262.37	80.61	41.66	23.28
Slovenia	-	-	-	-	-	-
Spain	89,086.22	61,505.59	24,729.43	1,579.05	816.09	456.05
Sweden	33,815.45	23,346.36	9,386.83	599.38	309.77	173.11
United Kingdom	220,266.86	152,073.39	61,143.85	3,904.22	2,017.80	1,127.60
Total EU27	**1,281,489.02**	**884,746.71**	**355,728.37**	**22,714.35**	**11,739.36**	**6,560.23**

2010	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	38,698.29	26,717.50	10,742.25	685.93	354.50	198.11
Belgium	28,868.08	19,930.67	8,013.49	511.69	264.45	147.78
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,135.22	11,139.84	4,478.97	286.00	147.81	82.60
Denmark	34,238.14	23,638.19	9,504.16	606.87	313.65	175.27
Estonia	3,875.51	2,675.67	1,075.80	68.69	35.50	19.84
Finland	25,055.50	17,298.45	6,955.15	444.11	229.53	128.26
France	203,985.88	140,832.92	56,624.42	3,615.64	1,868.66	1,044.25
Germany	278,627.66	192,365.99	77,344.22	4,938.67	2,552.43	1,426.36
Greece	17,053.48	11,773.81	4,733.87	302.27	156.22	87.30
Hungary	20,333.00	14,038.01	5,644.23	360.40	186.26	104.09
Ireland	23,743.69	16,392.77	6,591.01	420.86	217.51	121.55
Italy	174,732.60	120,636.30	48,504.00	3,097.13	1,600.68	894.50
Latvia	4,802.88	3,315.93	1,333.23	85.13	44.00	24.59
Lithuania	7,325.65	5,057.67	2,033.53	129.85	67.11	37.50
Luxembourg	3,402.36	2,349.00	944.46	60.31	31.17	17.42
Malta	-	-	-	-	-	-
Netherlands	67,951.57	46,914.12	18,862.67	1,204.44	622.49	347.86
Poland	44,732.60	30,883.62	12,417.32	792.88	409.78	229.00
Portugal	38,960.65	26,898.63	10,815.08	690.58	356.91	199.45
Romania	17,971.75	12,407.79	4,988.77	318.55	164.63	92.00
Slovakia	5,116.04	3,532.14	1,420.16	90.68	46.87	26.19
Slovenia	-	-	-	-	-	-
Spain	100,222.00	69,193.79	27,820.61	1,776.43	918.11	513.06
Sweden	38,042.38	26,264.66	10,560.18	674.30	348.50	194.75
United Kingdom	247,800.21	171,082.56	68,786.83	4,392.25	2,270.03	1,268.55
Total EU27	**1,441,675.15**	**995,340.04**	**400,194.42**	**25,553.64**	**13,206.78**	**7,380.26**

2011	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	38,601.43	26,650.63	10,715.37	684.21	353.62	197.61
Belgium	28,795.82	19,880.79	7,993.43	510.40	263.79	147.41
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,094.83	11,111.96	4,467.76	285.28	147.44	82.39
Denmark	34,152.45	23,579.03	9,480.37	605.35	312.86	174.83
Estonia	3,865.81	2,668.98	1,073.11	68.52	35.41	19.79
Finland	24,992.79	17,255.15	6,937.75	443.00	228.95	127.94
France	203,475.33	140,480.43	56,482.69	3,606.59	1,863.98	1,041.64
Germany	277,930.28	191,884.52	77,150.63	4,926.30	2,546.04	1,422.79
Greece	17,010.80	11,744.34	4,722.03	301.52	155.83	87.08
Hungary	20,282.11	14,002.87	5,630.11	359.50	185.80	103.83
Ireland	23,684.27	16,351.74	6,574.51	419.80	216.96	121.25
Italy	174,295.26	120,334.36	48,382.60	3,089.38	1,596.67	892.26
Latvia	4,790.86	3,307.63	1,329.89	84.92	43.89	24.53
Lithuania	7,307.31	5,045.01	2,028.44	129.52	66.94	37.41
Luxembourg	3,393.84	2,343.13	942.10	60.16	31.09	17.37
Malta	-	-	-	-	-	-
Netherlands	67,781.49	46,796.70	18,815.46	1,201.42	620.93	346.99
Poland	44,620.63	30,806.32	12,386.24	790.90	408.76	228.42
Portugal	38,863.13	26,831.31	10,788.01	688.85	356.01	198.95
Romania	17,926.77	12,376.73	4,976.29	317.75	164.22	91.77
Slovakia	5,103.24	3,523.30	1,416.61	90.45	46.75	26.12
Slovenia	-	-	-	-	-	-
Spain	99,971.16	69,020.61	27,750.98	1,771.99	915.81	511.77
Sweden	37,947.17	26,198.92	10,533.75	672.61	347.62	194.26
United Kingdom	247,179.99	170,654.36	68,614.66	4,381.26	2,264.35	1,265.37
Total EU27	**1,438,066.77**	**992,848.80**	**399,192.77**	**25,489.68**	**13,173.73**	**7,361.79**

2012	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	38,338.53	26,469.12	10,642.39	679.55	351.21	196.26
Belgium	28,599.71	19,745.39	7,938.99	506.93	261.99	146.41
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	15,985.22	11,036.28	4,437.33	283.34	146.44	81.83
Denmark	33,919.85	23,418.44	9,415.81	601.23	310.73	173.64
Estonia	3,839.48	2,650.80	1,065.80	68.05	35.17	19.66
Finland	24,822.57	17,137.63	6,890.49	439.98	227.39	127.07
France	202,089.53	139,523.66	56,098.01	3,582.03	1,851.29	1,034.54
Germany	276,037.40	190,577.66	76,625.19	4,892.75	2,528.70	1,413.10
Greece	16,894.94	11,664.36	4,689.87	299.46	154.77	86.49
Hungary	20,143.97	13,907.50	5,591.76	357.05	184.53	103.12
Ireland	23,522.96	16,240.38	6,529.74	416.94	215.49	120.42
Italy	173,108.20	119,514.80	48,053.08	3,068.34	1,585.80	886.18
Latvia	4,758.23	3,285.10	1,320.84	84.34	43.59	24.36
Lithuania	7,257.55	5,010.65	2,014.62	128.64	66.48	37.15
Luxembourg	3,370.73	2,327.17	935.68	59.75	30.88	17.26
Malta	-	-	-	-	-	-
Netherlands	67,319.86	46,477.98	18,687.31	1,193.24	616.70	344.63
Poland	44,316.74	30,596.51	12,301.88	785.51	405.97	226.87
Portugal	38,598.45	26,648.57	10,714.54	684.16	353.59	197.59
Romania	17,804.67	12,292.44	4,942.40	315.59	163.10	91.15
Slovakia	5,068.48	3,499.31	1,406.96	89.84	46.43	25.95
Slovenia	-	-	-	-	-	-
Spain	99,290.29	68,550.53	27,561.98	1,759.92	909.57	508.29
Sweden	37,688.72	26,020.49	10,462.01	668.03	345.26	192.94
United Kingdom	245,496.54	169,492.09	68,147.35	4,351.42	2,248.93	1,256.75
Total EU27	**1,428,272.61**	**986,086.86**	**396,474.01**	**25,316.08**	**13,084.01**	**7,311.65**

2013	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	38,872.13	26,867.96	10,802.75	689.79	356.50	155.13
Belgium	28,997.76	20,042.91	8,058.61	514.57	265.94	115.72
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,207.70	11,202.57	4,504.20	287.61	148.64	64.68
Denmark	34,391.95	23,771.31	9,557.69	610.29	315.41	137.25
Estonia	3,892.92	2,690.74	1,081.86	69.08	35.70	15.54
Finland	25,168.05	17,395.87	6,994.32	446.61	230.82	100.44
France	204,902.23	141,626.02	56,943.30	3,636.00	1,879.18	817.72
Germany	279,879.31	193,449.31	77,779.78	4,966.48	2,566.80	1,116.94
Greece	17,130.09	11,840.12	4,760.53	303.97	157.10	68.36
Hungary	20,424.34	14,117.06	5,676.02	362.43	187.31	81.51
Ireland	23,850.36	16,485.09	6,628.13	423.23	218.73	95.18
Italy	175,517.53	121,315.67	48,777.15	3,114.57	1,609.69	700.45
Latvia	4,824.45	3,334.60	1,340.74	85.61	44.25	19.25
Lithuania	7,358.56	5,086.15	2,044.98	130.58	67.49	29.37
Luxembourg	3,417.64	2,362.23	949.78	60.65	31.34	13.64
Malta	-	-	-	-	-	-
Netherlands	68,256.82	47,178.32	18,968.89	1,211.22	625.99	272.40
Poland	44,933.54	31,057.54	12,487.24	797.35	412.09	179.32
Portugal	39,135.67	27,050.12	10,875.99	694.47	358.92	156.18
Romania	18,052.48	12,477.66	5,016.87	320.34	165.56	72.04
Slovakia	5,139.03	3,552.04	1,428.16	91.19	47.13	20.51
Slovenia	-	-	-	-	-	-
Spain	100,672.22	69,583.46	27,977.29	1,786.44	923.28	401.76
Sweden	38,213.28	26,412.57	10,619.65	678.10	350.46	152.50
United Kingdom	248,913.38	172,046.02	69,174.21	4,416.98	2,282.81	993.36
Total EU27	**1,448,151.42**	**1,000,945.34**	**402,448.13**	**25,697.55**	**13,281.16**	**5,779.25**

2014	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	39,739.51	27,436.37	11,031.29	704.38	364.04	203.44
Belgium	29,644.81	20,466.93	8,229.10	525.45	271.57	151.76
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,569.36	11,439.57	4,599.49	293.69	151.79	84.82
Denmark	35,159.36	24,274.21	9,759.88	623.20	322.09	179.99
Estonia	3,979.79	2,747.67	1,104.75	70.54	36.46	20.37
Finland	25,729.65	17,763.88	7,142.29	456.06	235.70	131.72
France	209,474.37	144,622.20	58,147.96	3,712.93	1,918.94	1,072.35
Germany	286,124.48	197,541.84	79,425.26	5,071.55	2,621.11	1,464.74
Greece	17,512.33	12,090.60	4,861.24	310.41	160.43	89.65
Hungary	20,880.08	14,415.72	5,796.10	370.10	191.28	106.89
Ireland	24,382.55	16,833.84	6,768.35	432.18	223.36	124.82
Italy	179,434.00	123,882.17	49,809.06	3,180.46	1,643.74	918.56
Latvia	4,932.10	3,405.15	1,369.10	87.42	45.18	25.25
Lithuania	7,522.76	5,193.75	2,088.24	133.34	68.91	38.51
Luxembourg	3,493.90	2,412.21	969.87	61.93	32.01	17.89
Malta	-	-	-	-	-	-
Netherlands	69,779.89	48,176.40	19,370.19	1,236.85	639.23	357.22
Poland	45,936.18	31,714.58	12,751.42	814.22	420.81	235.16
Portugal	40,008.93	27,622.38	11,106.07	709.16	366.51	204.81
Romania	18,455.30	12,741.63	5,123.00	327.12	169.06	94.48
Slovakia	5,253.70	3,627.18	1,458.37	93.12	48.13	26.89
Slovenia	-	-	-	-	-	-
Spain	102,918.60	71,055.54	28,569.16	1,824.23	942.81	526.86
Sweden	39,065.96	26,971.34	10,844.31	692.44	357.87	199.99
United Kingdom	254,467.58	175,685.75	70,637.62	4,510.43	2,331.11	1,302.68
Total EU27	**1,480,465.19**	**1,022,120.89**	**410,962.14**	**26,241.19**	**13,562.13**	**7,578.84**

2015	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	40,268.77	27,801.77	11,178.20	713.76	368.89	206.14
Belgium	30,039.63	20,739.51	8,338.70	532.45	275.18	153.78
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	16,790.03	11,591.92	4,660.74	297.60	153.81	85.95
Denmark	35,627.63	24,597.50	9,889.87	631.50	326.37	182.39
Estonia	4,032.79	2,784.26	1,119.46	71.48	36.94	20.64
Finland	26,072.32	18,000.47	7,237.41	462.13	238.84	133.47
France	212,264.21	146,548.31	58,922.39	3,762.38	1,944.49	1,086.63
Germany	289,935.16	200,172.75	80,483.06	5,139.09	2,656.01	1,484.24
Greece	17,745.56	12,251.63	4,925.99	314.54	162.56	90.84
Hungary	21,158.17	14,607.71	5,873.29	375.03	193.82	108.31
Ireland	24,707.28	17,058.04	6,858.49	437.94	226.34	126.48
Italy	181,823.74	125,532.06	50,472.43	3,222.82	1,665.64	930.80
Latvia	4,997.79	3,450.50	1,387.34	88.59	45.78	25.58
Lithuania	7,622.95	5,262.92	2,116.05	135.12	69.83	39.02
Luxembourg	3,540.43	2,444.33	982.79	62.75	32.43	18.12
Malta	-	-	-	-	-	-
Netherlands	70,709.23	48,818.02	19,628.17	1,253.32	647.75	361.98
Poland	46,547.97	32,136.96	12,921.25	825.06	426.41	238.29
Portugal	40,541.78	27,990.26	11,253.99	718.60	371.39	207.54
Romania	18,701.09	12,911.33	5,191.23	331.48	171.32	95.74
Slovakia	5,323.67	3,675.49	1,477.80	94.36	48.77	27.25
Slovenia	-	-	-	-	-	-
Spain	104,289.29	72,001.87	28,949.65	1,848.52	955.37	533.88
Sweden	39,586.25	27,330.55	10,988.74	701.66	362.64	202.65
United Kingdom	257,856.65	178,025.57	71,578.39	4,570.50	2,362.15	1,320.03
Total EU27	**1,500,182.39**	**1,035,733.75**	**416,435.44**	**26,590.68**	**13,742.75**	**7,679.77**

2016	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	42,001.42	28,998.00	11,659.17	744.47	384.76	215.01
Belgium	31,332.15	21,631.88	8,697.49	555.36	287.03	160.40
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	17,512.46	12,090.69	4,861.28	310.41	160.43	89.65
Denmark	37,160.58	25,655.86	10,315.40	658.67	340.42	190.23
Estonia	4,206.31	2,904.06	1,167.63	74.56	38.53	21.53
Finland	27,194.14	18,774.98	7,548.82	482.02	249.12	139.21
France	221,397.33	152,853.87	61,457.66	3,924.26	2,028.16	1,133.38
Germany	302,410.24	208,785.61	83,946.02	5,360.21	2,770.30	1,548.11
Greece	18,509.10	12,778.78	5,137.94	328.07	169.56	94.75
Hungary	22,068.54	15,236.24	6,126.00	391.16	202.16	112.97
Ireland	25,770.36	17,791.99	7,153.59	456.78	236.08	131.92
Italy	189,647.10	130,933.35	52,644.11	3,361.49	1,737.30	970.85
Latvia	5,212.83	3,598.97	1,447.03	92.40	47.75	26.69
Lithuania	7,950.94	5,489.37	2,207.10	140.93	72.84	40.70
Luxembourg	3,692.77	2,549.51	1,025.08	65.45	33.83	18.90
Malta	-	-	-	-	-	-
Netherlands	73,751.65	50,918.52	20,472.71	1,307.25	675.62	377.55
Poland	48,550.80	33,519.72	13,477.21	860.56	444.76	248.54
Portugal	42,286.18	29,194.60	11,738.21	749.52	387.37	216.47
Romania	19,505.75	13,466.87	5,414.60	345.74	178.69	99.85
Slovakia	5,552.73	3,833.63	1,541.38	98.42	50.87	28.43
Slovenia	-	-	-	-	-	-
Spain	108,776.56	75,099.91	30,195.27	1,928.06	996.47	556.85
Sweden	41,289.53	28,506.51	11,461.56	731.86	378.24	211.37
United Kingdom	268,951.48	185,685.50	74,658.21	4,767.16	2,463.79	1,376.82
Total EU27	**1,564,730.95**	**1,080,298.41**	**434,353.46**	**27,734.80**	**14,334.06**	**8,010.21**

2017	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	43,734.07	30,194.23	12,140.14	775.18	400.64	223.88
Belgium	32,624.67	22,524.24	9,056.28	578.27	298.87	167.01
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	18,234.88	12,589.46	5,061.82	323.21	167.04	93.35
Denmark	38,693.54	26,714.22	10,740.93	685.84	354.46	198.08
Estonia	4,379.83	3,023.86	1,215.80	77.63	40.12	22.42
Finland	28,315.96	19,549.49	7,860.22	501.90	259.39	144.96
France	230,530.45	159,159.42	63,992.92	4,086.14	2,111.83	1,180.14
Germany	314,885.32	217,398.47	87,408.98	5,581.33	2,884.58	1,611.97
Greece	19,272.64	13,305.93	5,349.89	341.61	176.55	98.66
Hungary	22,978.92	15,864.77	6,378.72	407.30	210.50	117.63
Ireland	26,833.45	18,525.95	7,448.69	475.62	245.81	137.37
Italy	197,470.45	136,334.63	54,815.80	3,500.16	1,808.97	1,010.90
Latvia	5,427.87	3,747.43	1,506.72	96.21	49.72	27.79
Lithuania	8,278.93	5,715.82	2,298.15	146.74	75.84	42.38
Luxembourg	3,845.10	2,654.68	1,067.36	68.15	35.22	19.68
Malta	-	-	-	-	-	-
Netherlands	76,794.07	53,019.02	21,317.25	1,361.17	703.49	393.13
Poland	50,553.62	34,902.48	14,033.17	896.06	463.11	258.80
Portugal	44,030.57	30,398.94	12,222.44	780.44	403.35	225.40
Romania	20,310.40	14,022.41	5,637.96	360.00	186.06	103.97
Slovakia	5,781.79	3,991.78	1,604.97	102.48	52.97	29.60
Slovenia	-	-	-	-	-	-
Spain	113,263.83	78,197.94	31,440.89	2,007.60	1,037.58	579.82
Sweden	42,992.82	29,682.47	11,934.37	762.05	393.85	220.09
United Kingdom	280,046.31	193,345.44	77,738.02	4,963.81	2,565.43	1,433.62
Total EU27	**1,629,279.50**	**1,124,863.07**	**452,271.49**	**28,878.92**	**14,925.37**	**8,340.65**

2018	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	45,466.72	31,390.46	12,621.10	805.90	416.51	232.75
Belgium	33,917.18	23,416.60	9,415.07	601.18	310.71	173.63
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	18,957.31	13,088.23	5,262.36	336.02	173.66	97.05
Denmark	40,226.49	27,772.58	11,166.47	713.01	368.50	205.93
Estonia	4,553.35	3,143.66	1,263.96	80.71	41.71	23.31
Finland	29,437.78	20,323.99	8,171.63	521.78	269.67	150.70
France	239,663.57	165,464.98	66,528.18	4,248.03	2,195.49	1,226.89
Germany	327,360.40	226,011.33	90,871.93	5,802.45	2,998.86	1,675.83
Greece	20,036.18	13,833.09	5,561.84	355.14	183.55	102.57
Hungary	23,889.29	16,493.29	6,631.43	423.44	218.84	122.29
Ireland	27,896.53	19,259.91	7,743.79	494.46	255.55	142.81
Italy	205,293.81	141,735.92	56,987.48	3,638.83	1,880.64	1,050.95
Latvia	5,642.91	3,895.90	1,566.42	100.02	51.69	28.89
Lithuania	8,606.93	5,942.27	2,389.20	152.56	78.85	44.06
Luxembourg	3,997.44	2,759.85	1,109.65	70.85	36.62	20.46
Malta	-	-	-	-	-	-
Netherlands	79,836.48	55,119.52	22,161.80	1,415.10	731.36	408.70
Poland	52,556.45	36,285.25	14,589.14	931.56	481.45	269.05
Portugal	45,774.97	31,603.28	12,706.67	811.36	419.33	234.33
Romania	21,115.05	14,577.94	5,861.33	374.26	193.43	108.09
Slovakia	6,010.85	4,149.93	1,668.55	106.54	55.06	30.77
Slovenia	-	-	-	-	-	-
Spain	117,751.10	81,295.98	32,686.51	2,087.13	1,078.68	602.79
Sweden	44,696.10	30,858.42	12,407.18	792.24	409.45	228.81
United Kingdom	291,141.15	201,005.37	80,817.83	5,160.47	2,667.06	1,490.42
Total EU27	**1,693,828.06**	**1,169,427.73**	**470,189.51**	**30,023.04**	**15,516.69**	**8,671.09**

2019	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	47,199.37	32,586.69	13,102.07	836.61	432.38	241.62
Belgium	35,209.70	24,308.96	9,773.86	624.09	322.55	180.25
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	19,679.74	13,586.99	5,462.90	348.82	180.28	100.75
Denmark	41,759.44	28,830.94	11,592.00	740.18	382.55	213.78
Estonia	4,726.87	3,263.45	1,312.13	83.78	43.30	24.20
Finland	30,559.59	21,098.50	8,483.03	541.67	279.95	156.44
France	248,796.69	171,770.53	69,063.44	4,409.91	2,279.16	1,273.65
Germany	339,835.48	234,624.19	94,334.89	6,023.57	3,113.14	1,739.69
Greece	20,799.72	14,360.24	5,773.79	368.67	190.54	106.48
Hungary	24,799.67	17,121.82	6,884.14	439.57	227.18	126.96
Ireland	28,959.61	19,993.87	8,038.90	513.31	265.29	148.25
Italy	213,117.17	147,137.20	59,159.17	3,777.49	1,952.31	1,090.99
Latvia	5,857.95	4,044.36	1,626.11	103.83	53.66	29.99
Lithuania	8,934.92	6,168.72	2,480.24	158.37	81.85	45.74
Luxembourg	4,149.77	2,865.03	1,151.93	73.55	38.01	21.24
Malta	-	-	-	-	-	-
Netherlands	82,878.90	57,220.02	23,006.34	1,469.03	759.23	424.28
Poland	54,559.27	37,668.01	15,145.10	967.06	499.80	279.30
Portugal	47,519.37	32,807.62	13,190.90	842.28	435.31	243.26
Romania	21,919.71	15,133.48	6,084.69	388.53	200.80	112.21
Slovakia	6,239.92	4,308.07	1,732.14	110.60	57.16	31.94
Slovenia	-	-	-	-	-	-
Spain	122,238.37	84,394.01	33,932.13	2,166.67	1,119.79	625.77
Sweden	46,399.38	32,034.38	12,880.00	822.43	425.05	237.53
United Kingdom	302,235.98	208,665.30	83,897.65	5,357.12	2,768.70	1,547.21
Total EU27	**1,758,376.62**	**1,213,992.39**	**488,107.54**	**31,167.16**	**16,108.00**	**9,001.53**

2020	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	48,932.02	33,782.92	13,583.03	867.32	448.25	250.49
Belgium	36,502.22	25,201.33	10,132.65	647.00	334.39	186.86
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	20,402.17	14,085.76	5,663.43	361.63	186.90	104.44
Denmark	43,292.40	29,889.30	12,017.53	767.36	396.59	221.62
Estonia	4,900.39	3,383.25	1,360.30	86.86	44.89	25.09
Finland	31,681.41	21,873.01	8,794.44	561.55	290.22	162.18
France	257,929.81	178,076.09	71,598.70	4,571.80	2,362.82	1,320.40
Germany	352,310.56	243,237.05	97,797.84	6,244.69	3,227.42	1,803.56
Greece	21,563.26	14,887.39	5,985.74	382.21	197.54	110.39
Hungary	25,710.05	17,750.35	7,136.85	455.71	235.52	131.62
Ireland	30,022.70	20,727.83	8,334.00	532.15	275.03	153.69
Italy	220,940.52	152,538.49	61,330.85	3,916.16	2,023.97	1,131.04
Latvia	6,072.99	4,192.83	1,685.80	107.64	55.63	31.09
Lithuania	9,262.91	6,395.16	2,571.29	164.18	84.85	47.42
Luxembourg	4,302.11	2,970.20	1,194.22	76.25	39.41	22.02
Malta	-	-	-	-	-	-
Netherlands	85,921.31	59,320.52	23,850.89	1,522.95	787.10	439.85
Poland	56,562.10	39,050.77	15,701.07	1,002.56	518.15	289.55
Portugal	49,263.76	34,011.96	13,675.12	873.20	451.29	252.19
Romania	22,724.36	15,689.02	6,308.05	402.79	208.17	116.33
Slovakia	6,468.98	4,466.22	1,795.72	114.66	59.26	33.12
Slovenia	-	-	-	-	-	-
Spain	126,725.64	87,492.05	35,177.76	2,246.21	1,160.90	648.74
Sweden	48,102.67	33,210.33	13,352.81	852.62	440.66	246.25
United Kingdom	313,330.82	216,325.23	86,977.46	5,553.78	2,870.34	1,604.01
Total EU27	**1,822,925.18**	**1,258,557.05**	**506,025.57**	**32,311.28**	**16,699.31**	**9,331.97**

2021	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	50,664.67	34,979.15	14,064.00	898.03	464.12	259.36
Belgium	37,794.74	26,093.69	10,491.44	669.91	346.23	193.48
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	21,124.59	14,584.53	5,863.97	374.43	193.52	108.14
Denmark	44,825.35	30,947.66	12,443.06	794.53	410.63	229.47
Estonia	5,073.91	3,503.05	1,408.46	89.93	46.48	25.97
Finland	32,803.23	22,647.52	9,105.84	581.44	300.50	167.93
France	267,062.93	184,381.64	74,133.97	4,733.68	2,446.49	1,367.16
Germany	364,785.64	251,849.91	101,260.80	6,465.81	3,341.70	1,867.42
Greece	22,326.80	15,414.54	6,197.69	395.74	204.53	114.30
Hungary	26,620.42	18,378.88	7,389.56	471.85	243.86	136.28
Ireland	31,085.78	21,461.79	8,629.10	550.99	284.77	159.14
Italy	228,763.88	157,939.77	63,502.54	4,054.83	2,095.64	1,171.09
Latvia	6,288.03	4,341.29	1,745.49	111.46	57.60	32.19
Lithuania	9,590.91	6,621.61	2,662.34	170.00	87.86	49.10
Luxembourg	4,454.44	3,075.37	1,236.51	78.95	40.81	22.80
Malta	-	-	-	-	-	-
Netherlands	88,963.73	61,421.02	24,695.43	1,576.88	814.97	455.43
Poland	58,564.93	40,433.53	16,257.03	1,038.06	536.50	299.81
Portugal	51,008.16	35,216.30	14,159.35	904.12	467.27	261.12
Romania	23,529.02	16,244.56	6,531.42	417.05	215.54	120.45
Slovakia	6,698.04	4,624.36	1,859.31	118.72	61.36	34.29
Slovenia	-	-	-	-	-	-
Spain	131,212.91	90,590.08	36,423.38	2,325.74	1,202.00	671.71
Sweden	49,805.95	34,386.29	13,825.63	882.81	456.26	254.97
United Kingdom	324,425.65	223,985.16	90,057.27	5,750.43	2,971.97	1,660.81
Total EU27	**1,887,473.73**	**1,303,121.71**	**523,943.59**	**33,455.40**	**17,290.62**	**9,662.41**

2022	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	52,397.32	36,175.38	14,544.97	928.74	480.00	268.23
Belgium	39,087.26	26,986.05	10,850.23	692.82	358.07	200.10
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	21,847.02	15,083.30	6,064.51	387.24	200.13	111.84
Denmark	46,358.31	32,006.02	12,868.60	821.70	424.68	237.32
Estonia	5,247.43	3,622.85	1,456.63	93.01	48.07	26.86
Finland	33,925.05	23,422.03	9,417.25	601.32	310.78	173.67
France	276,196.06	190,687.20	76,669.23	4,895.57	2,530.15	1,413.91
Germany	377,260.72	260,462.77	104,723.76	6,686.93	3,455.98	1,931.28
Greece	23,090.35	15,941.70	6,409.65	409.28	211.52	118.20
Hungary	27,530.80	19,007.41	7,642.27	487.98	252.20	140.94
Ireland	32,148.87	22,195.74	8,924.20	569.84	294.51	164.58
Italy	236,587.23	163,341.06	65,674.22	4,193.50	2,167.31	1,211.14
Latvia	6,503.07	4,489.76	1,805.19	115.27	59.57	33.29
Lithuania	9,918.90	6,848.06	2,753.39	175.81	90.86	50.78
Luxembourg	4,606.78	3,180.54	1,278.79	81.65	42.20	23.58
Malta	-	-	-	-	-	-
Netherlands	92,006.15	63,521.52	25,539.97	1,630.81	842.84	471.00
Poland	60,567.75	41,816.29	16,812.99	1,073.56	554.84	310.06
Portugal	52,752.56	36,420.64	14,643.58	935.04	483.25	270.05
Romania	24,333.67	16,800.09	6,754.78	431.31	222.91	124.57
Slovakia	6,927.10	4,782.51	1,922.89	122.78	63.46	35.46
Slovenia	-	-	-	-	-	-
Spain	135,700.18	93,688.12	37,669.00	2,405.28	1,243.11	694.68
Sweden	51,509.23	35,562.24	14,298.44	913.00	471.86	263.69
United Kingdom	335,520.48	231,645.09	93,137.09	5,947.09	3,073.61	1,717.61
Total EU27	**1,952,022.29**	**1,347,686.37**	**541,861.62**	**34,599.52**	**17,881.93**	**9,992.84**

2023	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	54,129.97	37,371.62	15,025.93	959.45	495.87	277.10
Belgium	40,379.78	27,878.41	11,209.02	715.73	369.91	206.71
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	22,569.45	15,582.06	6,265.05	400.04	206.75	115.54
Denmark	47,891.26	33,064.38	13,294.13	848.87	438.72	245.17
Estonia	5,420.95	3,742.65	1,504.80	96.09	49.66	27.75
Finland	35,046.86	24,196.54	9,728.65	621.20	321.05	179.41
France	285,329.18	196,992.75	79,204.49	5,057.45	2,613.82	1,460.66
Germany	389,735.80	269,075.63	108,186.71	6,908.05	3,570.26	1,995.15
Greece	23,853.89	16,468.85	6,621.60	422.81	218.52	122.11
Hungary	28,441.17	19,635.93	7,894.98	504.12	260.54	145.60
Ireland	33,211.95	22,929.70	9,219.30	588.68	304.25	170.02
Italy	244,410.59	168,742.35	67,845.90	4,332.17	2,238.98	1,251.19
Latvia	6,718.12	4,638.22	1,864.88	119.08	61.54	34.39
Lithuania	10,246.89	7,074.51	2,844.43	181.63	93.87	52.46
Luxembourg	4,759.11	3,285.72	1,321.08	84.36	43.60	24.36
Malta	-	-	-	-	-	-
Netherlands	95,048.56	65,622.02	26,384.52	1,684.73	870.71	486.58
Poland	62,570.58	43,199.05	17,368.96	1,109.06	573.19	320.31
Portugal	54,496.96	37,624.98	15,127.80	965.96	499.23	278.98
Romania	25,138.33	17,355.63	6,978.14	445.58	230.29	128.69
Slovakia	7,156.17	4,940.65	1,986.48	126.84	65.56	36.63
Slovenia	-	-	-	-	-	-
Spain	140,187.45	96,786.15	38,914.62	2,484.82	1,284.22	717.65
Sweden	53,212.52	36,738.20	14,771.26	943.19	487.46	272.41
United Kingdom	346,615.32	239,305.02	96,216.90	6,143.74	3,175.25	1,774.40
Total EU27	**2,016,570.85**	**1,392,251.04**	**559,779.64**	**35,743.64**	**18,473.24**	**10,323.28**

2024	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	55,846.75	38,567.85	15,506.90	990.16	495.87	285.97
Belgium	41,660.46	28,770.77	11,567.81	738.64	369.91	213.33
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	23,285.26	16,080.83	6,465.59	412.85	206.75	119.24
Denmark	49,410.18	34,122.74	13,719.66	876.04	438.72	253.01
Estonia	5,592.87	3,862.45	1,552.97	99.16	49.66	28.64
Finland	36,158.40	24,971.05	10,040.06	641.09	321.05	185.16
France	294,378.63	203,298.31	81,739.75	5,219.33	2,613.82	1,507.42
Germany	402,096.60	277,688.49	111,649.67	7,129.17	3,570.26	2,059.01
Greece	24,610.43	16,996.00	6,833.55	436.34	218.52	126.02
Hungary	29,343.21	20,264.46	8,147.69	520.26	260.54	150.26
Ireland	34,265.29	23,663.66	9,514.40	607.52	304.25	175.46
Italy	252,162.28	174,143.63	70,017.59	4,470.84	2,238.98	1,291.24
Latvia	6,931.19	4,786.69	1,924.57	122.89	61.54	35.49
Lithuania	10,571.88	7,300.96	2,935.48	187.44	93.87	54.14
Luxembourg	4,910.05	3,390.89	1,363.37	87.06	43.60	25.14
Malta	-	-	-	-	-	-
Netherlands	98,063.11	67,722.52	27,229.06	1,738.66	870.71	502.15
Poland	64,555.06	44,581.82	17,924.92	1,144.56	573.19	330.57
Portugal	56,225.37	38,829.32	15,612.03	996.88	499.23	287.91
Romania	25,935.61	17,911.17	7,201.51	459.84	230.29	132.81
Slovakia	7,383.13	5,098.80	2,050.06	130.90	65.56	37.81
Slovenia	-	-	-	-	-	-
Spain	144,633.62	99,884.18	40,160.24	2,564.35	1,284.22	740.62
Sweden	54,900.20	37,914.15	15,244.07	973.38	487.46	281.13
United Kingdom	357,608.51	246,964.95	99,296.71	6,340.40	3,175.25	1,831.20
Total EU27	**2,081,119.41**	**1,436,815.70**	**577,697.67**	**36,887.77**	**19,064.55**	**10,653.72**

2025	Total	Below 1.5 kVA	1.5 - 5 kVA	5.1 - 10 kVA	10.1 kVA - 200 kVA	Above 200 kVA
Austria	57,563.53	39,764.08	15,987.86	1,020.87	495.87	294.84
Belgium	42,941.14	29,663.14	11,926.60	761.55	369.91	219.95
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	24,001.06	16,579.60	6,666.13	425.65	206.75	122.93
Denmark	50,929.09	35,181.10	14,145.20	903.21	438.72	260.86
Estonia	5,764.80	3,982.25	1,601.13	102.24	49.66	29.53
Finland	37,269.95	25,745.55	10,351.46	660.97	321.05	190.90
France	303,428.09	209,603.86	84,275.01	5,381.22	2,613.82	1,554.17
Germany	414,457.40	286,301.35	115,112.62	7,350.29	3,570.26	2,122.87
Greece	25,366.98	17,523.15	7,045.50	449.88	218.52	129.93
Hungary	30,245.24	20,892.99	8,400.40	536.39	260.54	154.92
Ireland	35,318.64	24,397.62	9,809.50	626.37	304.25	180.90
Italy	259,913.96	179,544.92	72,189.27	4,609.51	2,238.98	1,331.29
Latvia	7,144.26	4,935.15	1,984.27	126.70	61.54	36.59
Lithuania	10,896.87	7,527.41	3,026.53	193.25	93.87	55.81
Luxembourg	5,060.99	3,496.06	1,405.65	89.76	43.60	25.92
Malta	-	-	-	-	-	-
Netherlands	101,077.65	69,823.02	28,073.61	1,792.59	870.71	517.72
Poland	66,539.54	45,964.58	18,480.89	1,180.06	573.19	340.82
Portugal	57,953.79	40,033.66	16,096.26	1,027.80	499.23	296.84
Romania	26,732.89	18,466.71	7,424.87	474.10	230.29	136.93
Slovakia	7,610.09	5,256.95	2,113.65	134.96	65.56	38.98
Slovenia	-	-	-	-	-	-
Spain	149,079.78	102,982.22	41,405.86	2,643.89	1,284.22	763.59
Sweden	56,587.88	39,090.11	15,716.88	1,003.57	487.46	289.85
United Kingdom	368,601.71	254,624.89	102,376.53	6,537.05	3,175.25	1,888.00
Total EU27	**2,145,667.96**	**1,481,380.36**	**595,615.70**	**38,031.89**	**19,655.86**	**10,984.16**

Appendix 3 – Stock data

This annex presents UPS stock in number of units for 2010 - 2025. The data is categorised by Member State for different sizes of UPS

2010	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	199,937.42	107,569.76	79,979.23	6,135.71	3,740.17	2,512.55
Belgium	149,148.96	80,244.69	59,662.76	4,577.10	2,790.09	1,874.31
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	83,363.74	44,851.12	33,347.27	2,558.28	1,559.46	1,047.61
Denmark	176,893.78	95,171.89	70,761.28	5,428.54	3,309.10	2,222.97
Estonia	20,023.10	10,772.77	8,009.67	614.47	374.57	251.62
Finland	129,451.01	69,646.86	51,783.16	3,972.61	2,421.60	1,626.77
France	1,053,907.40	567,020.24	421,585.41	32,342.45	19,715.15	13,244.15
Germany	1,439,549.40	774,502.25	575,850.43	44,177.08	26,929.25	18,090.40
Greece	88,108.01	47,403.62	35,245.08	2,703.87	1,648.21	1,107.23
Hungary	105,051.86	56,519.70	42,022.98	3,223.85	1,965.18	1,320.16
Ireland	122,673.47	66,000.43	49,072.00	3,764.62	2,294.82	1,541.60
Italy	902,768.27	485,704.80	361,126.54	27,704.27	16,887.84	11,344.82
Latvia	24,814.40	13,350.57	9,926.29	761.51	464.20	311.84
Lithuania	37,848.49	20,363.13	15,140.20	1,161.50	708.02	475.63
Luxembourg	17,578.52	9,457.54	7,031.78	539.45	328.84	220.90
Malta	-	-	-	-	-	-
Netherlands	351,076.55	188,885.20	140,438.10	10,773.88	6,567.49	4,411.88
Poland	231,114.10	124,343.35	92,450.56	7,092.46	4,323.39	2,904.34
Portugal	201,292.93	108,299.04	80,521.46	6,177.30	3,765.53	2,529.59
Romania	92,852.29	49,956.12	37,142.89	2,849.46	1,736.96	1,166.85
Slovakia	26,432.40	14,221.09	10,573.52	811.16	494.46	332.17
Slovenia	-	-	-	-	-	-
Spain	517,804.02	278,587.44	207,132.64	15,890.44	9,686.42	6,507.09
Sweden	196,548.65	105,746.54	78,623.65	6,031.71	3,676.78	2,469.97
United Kingdom	1,280,277.22	688,811.09	512,138.17	39,289.31	23,949.79	16,088.87
Total EU27	**7,448,515.99**	**4,007,429.24**	**2,979,565.08**	**228,581.02**	**139,337.33**	**93,603.32**

2011	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	201,660.16	106,803.12	82,148.74	6,315.95	3,816.19	2,576.16
Belgium	150,434.08	79,672.80	61,281.17	4,711.56	2,846.79	1,921.76
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	84,082.03	44,531.47	34,251.85	2,633.43	1,591.16	1,074.13
Denmark	178,417.97	94,493.61	72,680.75	5,588.01	3,376.36	2,279.24
Estonia	20,195.63	10,695.99	8,226.94	632.52	382.18	257.99
Finland	130,566.41	69,150.50	53,187.83	4,089.31	2,470.82	1,667.95
France	1,062,988.28	562,979.18	433,021.30	33,292.55	20,115.85	13,579.40
Germany	1,451,953.13	768,982.49	591,470.90	45,474.84	27,476.57	18,548.33
Greece	88,867.19	47,065.78	36,201.14	2,783.30	1,681.71	1,135.26
Hungary	105,957.03	56,116.90	43,162.90	3,318.55	2,005.12	1,353.57
Ireland	123,730.47	65,530.05	50,403.12	3,875.21	2,341.46	1,580.63
Italy	910,546.88	482,243.26	370,922.43	28,518.12	17,231.07	11,632.00
Latvia	25,028.21	13,255.42	10,195.55	783.88	473.63	319.73
Lithuania	38,174.60	20,218.01	15,550.89	1,195.62	722.41	487.67
Luxembourg	17,729.98	9,390.14	7,222.52	555.30	335.52	226.50
Malta	-	-	-	-	-	-
Netherlands	354,101.56	187,539.05	144,247.61	11,090.38	6,700.97	4,523.56
Poland	233,105.47	123,457.17	94,958.37	7,300.81	4,411.26	2,977.86
Portugal	203,027.34	107,527.21	82,705.68	6,358.77	3,842.06	2,593.62
Romania	93,652.34	49,600.09	38,150.43	2,933.17	1,772.26	1,196.38
Slovakia	26,660.16	14,119.74	10,860.34	834.99	504.51	340.58
Slovenia	-	-	-	-	-	-
Spain	522,265.63	276,601.99	212,751.30	16,357.24	9,883.28	6,671.81
Sweden	198,242.19	104,992.90	80,756.38	6,208.90	3,751.51	2,532.49
United Kingdom	1,291,308.60	683,902.04	526,030.38	40,443.49	24,436.55	16,496.14
Total EU27	**7,512,695.33**	**3,978,868.93**	**3,060,388.51**	**235,295.88**	**142,169.24**	**95,972.77**

2012	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	200,483.07	103,586.13	83,918.63	6,470.68	3,875.92	2,631.71
Belgium	149,556.00	77,273.00	62,601.47	4,826.98	2,891.35	1,963.20
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	83,591.24	43,190.15	34,989.80	2,697.94	1,616.06	1,097.29
Denmark	177,376.54	91,647.39	74,246.65	5,724.90	3,429.20	2,328.40
Estonia	20,077.74	10,373.82	8,404.18	648.02	388.16	263.56
Finland	129,804.29	67,067.63	54,333.75	4,189.49	2,509.49	1,703.92
France	1,056,783.62	546,021.82	442,350.72	34,108.14	20,430.68	13,872.25
Germany	1,443,478.08	745,820.16	604,214.10	46,588.87	27,906.60	18,948.34
Greece	88,348.47	45,648.13	36,981.09	2,851.48	1,708.03	1,159.74
Hungary	105,338.56	54,426.61	44,092.84	3,399.85	2,036.50	1,382.76
Ireland	123,008.25	63,556.24	51,489.05	3,970.14	2,378.11	1,614.71
Italy	905,232.01	467,717.73	378,913.93	29,216.75	17,500.75	11,882.85
Latvia	24,882.12	12,856.16	10,415.21	803.08	481.04	326.62
Lithuania	37,951.78	19,609.03	15,885.94	1,224.91	733.72	498.19
Luxembourg	17,626.49	9,107.30	7,378.13	568.90	340.77	231.38
Malta	-	-	-	-	-	-
Netherlands	352,034.67	181,890.23	147,355.42	11,362.07	6,805.85	4,621.11
Poland	231,744.83	119,738.55	97,004.24	7,479.66	4,480.30	3,042.08
Portugal	201,842.27	104,288.41	84,487.57	6,514.55	3,902.19	2,649.56
Romania	93,105.70	48,106.10	38,972.38	3,005.03	1,800.00	1,222.19
Slovakia	26,504.54	13,694.44	11,094.33	855.45	512.41	347.92
Slovenia	-	-	-	-	-	-
Spain	519,217.16	268,270.53	217,335.02	16,757.96	10,037.97	6,815.69
Sweden	197,085.05	101,830.44	82,496.28	6,361.00	3,810.22	2,587.11
United Kingdom	1,283,771.23	663,302.40	537,363.67	41,434.26	24,819.01	16,851.89
Total EU27	**7,468,843.71**	**3,859,022.41**	**3,126,324.38**	**241,060.12**	**144,394.33**	**98,042.47**

2013	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	205,497.37	106,705.21	85,522.23	6,614.79	3,971.96	2,683.19
Belgium	153,296.56	79,599.76	63,797.72	4,934.49	2,962.99	2,001.60
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	85,681.95	44,490.64	35,658.42	2,758.03	1,656.10	1,118.75
Denmark	181,812.93	94,406.98	75,665.43	5,852.40	3,514.17	2,373.94
Estonia	20,579.91	10,686.19	8,564.78	662.45	397.78	268.71
Finland	133,050.84	69,087.10	55,372.02	4,282.79	2,571.67	1,737.25
France	1,083,214.96	562,463.03	450,803.64	34,867.77	20,936.92	14,143.60
Germany	1,479,581.07	768,277.48	615,760.08	47,626.46	28,598.08	19,318.98
Greece	90,558.16	47,022.63	37,687.76	2,914.99	1,750.35	1,182.42
Hungary	107,973.20	56,065.45	44,935.41	3,475.57	2,086.96	1,409.81
Ireland	126,084.83	65,469.97	52,472.96	4,058.56	2,437.03	1,646.30
Italy	927,872.88	481,801.13	386,154.63	29,867.44	17,934.39	12,115.29
Latvia	25,504.45	13,243.27	10,614.23	820.97	492.96	333.01
Lithuania	38,901.00	20,199.47	16,189.50	1,252.19	751.90	507.93
Luxembourg	18,067.35	9,381.53	7,519.12	581.57	349.21	235.91
Malta	-	-	-	-	-	-
Netherlands	360,839.45	187,367.11	150,171.24	11,615.12	6,974.48	4,711.50
Poland	237,541.03	123,343.98	98,857.90	7,646.24	4,591.31	3,101.59
Portugal	206,890.57	107,428.63	86,102.05	6,659.63	3,998.88	2,701.38
Romania	95,434.37	49,554.62	39,717.10	3,071.95	1,844.60	1,246.09
Slovakia	27,167.45	14,106.79	11,306.33	874.50	525.11	354.73
Slovenia	-	-	-	-	-	-
Spain	532,203.36	276,348.40	221,488.09	17,131.17	10,286.69	6,949.01
Sweden	202,014.37	104,896.64	84,072.70	6,502.67	3,904.63	2,637.71
United Kingdom	1,315,879.78	683,275.03	547,632.20	42,357.05	25,433.98	17,181.52
Total EU27	**7,655,647.84**	**3,975,221.04**	**3,186,065.57**	**246,428.80**	**147,972.17**	**99,960.24**

2014	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	207,415.10	107,424.07	86,442.15	6,752.63	4,064.76	2,731.50
Belgium	154,727.15	80,136.02	64,483.96	5,037.32	3,032.22	2,037.64
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	86,481.55	44,790.38	36,041.98	2,815.50	1,694.80	1,138.90
Denmark	183,509.63	95,042.99	76,479.32	5,974.36	3,596.28	2,416.68
Estonia	20,771.96	10,758.18	8,656.91	676.25	407.07	273.55
Finland	134,292.49	69,552.54	55,967.63	4,372.04	2,631.76	1,768.53
France	1,093,323.69	566,252.31	455,652.67	35,594.38	21,426.09	14,398.23
Germany	1,493,388.75	773,453.32	622,383.46	48,618.94	29,266.25	19,666.78
Greece	91,403.27	47,339.42	38,093.15	2,975.74	1,791.25	1,203.71
Hungary	108,980.82	56,443.16	45,418.76	3,547.99	2,135.72	1,435.19
Ireland	127,261.47	65,911.04	53,037.39	4,143.14	2,493.97	1,675.94
Italy	936,531.93	485,047.00	390,308.27	30,489.85	18,353.41	12,333.40
Latvia	25,742.46	13,332.49	10,728.41	838.07	504.48	339.01
Lithuania	39,264.03	20,335.56	16,363.64	1,278.28	769.47	517.08
Luxembourg	18,235.95	9,444.73	7,600.00	593.69	357.37	240.15
Malta	-	-	-	-	-	-
Netherlands	364,206.86	188,629.39	151,786.55	11,857.16	7,137.44	4,796.32
Poland	239,757.80	124,174.94	99,921.26	7,805.58	4,698.58	3,157.42
Portugal	208,821.31	108,152.37	87,028.20	6,798.41	4,092.31	2,750.02
Romania	96,324.98	49,888.47	40,144.32	3,135.97	1,887.70	1,268.53
Slovakia	27,420.98	14,201.83	11,427.94	892.72	537.37	361.11
Slovenia	-	-	-	-	-	-
Spain	537,169.96	278,210.14	223,870.51	17,488.17	10,527.03	7,074.11
Sweden	203,899.59	105,603.33	84,977.03	6,638.18	3,995.86	2,685.20
United Kingdom	1,328,159.77	687,878.21	553,522.77	43,239.73	26,028.22	17,490.84
Total EU27	**7,727,091.51**	**4,002,001.89**	**3,220,336.27**	**251,564.12**	**151,429.40**	**101,759.83**

2015	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	208,977.34	108,575.22	86,596.75	6,879.00	4,151.63	2,774.76
Belgium	155,892.55	80,994.75	64,599.29	5,131.58	3,097.02	2,069.91
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	87,132.93	45,270.34	36,106.44	2,868.19	1,731.02	1,156.93
Denmark	184,891.82	96,061.46	76,616.10	6,086.17	3,673.13	2,454.95
Estonia	20,928.42	10,873.46	8,672.39	688.91	415.77	277.88
Finland	135,303.98	70,297.85	56,067.72	4,453.86	2,688.00	1,796.54
France	1,101,558.54	572,320.20	456,467.60	36,260.49	21,884.00	14,626.25
Germany	1,504,636.88	781,741.55	623,496.58	49,528.80	29,891.71	19,978.24
Greece	92,091.71	47,846.71	38,161.28	3,031.42	1,829.53	1,222.77
Hungary	109,801.66	57,047.99	45,499.99	3,614.39	2,181.36	1,457.92
Ireland	128,220.00	66,617.34	53,132.24	4,220.67	2,547.27	1,702.48
Italy	943,585.84	490,244.70	391,006.33	31,060.44	18,745.65	12,528.72
Latvia	25,936.35	13,475.36	10,747.59	853.76	515.26	344.38
Lithuania	39,559.76	20,553.47	16,392.91	1,302.21	785.91	525.27
Luxembourg	18,373.31	9,545.94	7,613.59	604.80	365.01	243.96
Malta	-	-	-	-	-	-
Netherlands	366,950.05	190,650.72	152,058.02	12,079.06	7,289.97	4,872.28
Poland	241,563.64	125,505.59	100,099.97	7,951.66	4,799.00	3,207.43
Portugal	210,394.14	109,311.32	87,183.84	6,925.64	4,179.77	2,793.57
Romania	97,050.50	50,423.07	40,216.12	3,194.65	1,928.04	1,288.62
Slovakia	27,627.51	14,354.01	11,448.38	909.43	548.86	366.83
Slovenia	-	-	-	-	-	-
Spain	541,215.90	281,191.41	224,270.90	17,815.45	10,752.01	7,186.15
Sweden	205,435.36	106,734.96	85,129.01	6,762.41	4,081.26	2,727.73
United Kingdom	1,338,163.40	695,249.43	554,512.73	44,048.92	26,584.48	17,767.84
Total EU27	**7,785,291.56**	**4,044,886.84**	**3,226,095.75**	**256,271.91**	**154,665.67**	**103,371.38**

2016	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	211,489.82	111,104.10	86,320.08	6,977.83	4,243.59	2,844.22
Belgium	157,766.79	82,881.24	64,392.90	5,205.31	3,165.63	2,121.72
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	88,180.50	46,324.76	35,991.08	2,909.40	1,769.36	1,185.89
Denmark	187,114.72	98,298.88	76,371.33	6,173.61	3,754.50	2,516.41
Estonia	21,180.03	11,126.72	8,644.68	698.81	424.98	284.84
Finland	136,930.69	71,935.19	55,888.59	4,517.85	2,747.54	1,841.51
France	1,114,802.25	585,650.41	455,009.24	36,781.45	22,368.75	14,992.40
Germany	1,522,726.67	799,949.50	621,504.58	50,240.39	30,553.84	20,478.37
Greece	93,198.90	48,961.13	38,039.36	3,074.98	1,870.06	1,253.38
Hungary	111,121.77	58,376.73	45,354.62	3,666.32	2,229.68	1,494.42
Ireland	129,761.55	68,168.95	52,962.49	4,281.31	2,603.69	1,745.10
Italy	954,930.29	501,663.24	389,757.11	31,506.69	19,160.88	12,842.37
Latvia	26,248.17	13,789.22	10,713.26	866.02	526.68	353.00
Lithuania	40,035.38	21,032.19	16,340.54	1,320.92	803.32	538.42
Luxembourg	18,594.20	9,768.28	7,589.27	613.49	373.10	250.06
Malta	-	-	-	-	-	-
Netherlands	371,361.78	195,091.26	151,572.21	12,252.60	7,451.45	4,994.25
Poland	244,467.89	128,428.80	99,780.16	8,065.90	4,905.30	3,287.72
Portugal	212,923.64	111,857.34	86,905.30	7,025.14	4,272.36	2,863.50
Romania	98,217.30	51,597.50	40,087.63	3,240.55	1,970.75	1,320.87
Slovakia	27,959.67	14,688.34	11,411.81	922.49	561.02	376.02
Slovenia	-	-	-	-	-	-
Spain	547,722.78	287,740.78	223,554.38	18,071.40	10,990.18	7,366.04
Sweden	207,905.24	109,220.98	84,857.03	6,859.56	4,171.66	2,796.01
United Kingdom	1,354,251.73	711,442.84	552,741.12	44,681.78	27,173.36	18,212.63
Total EU27	**7,878,891.77**	**4,139,098.39**	**3,215,788.74**	**259,953.81**	**158,091.68**	**105,959.15**

2017	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	217,648.21	114,430.37	88,911.55	7,049.13	4,340.64	2,916.53
Belgium	162,360.82	85,362.56	66,326.08	5,258.49	3,238.03	2,175.66
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	90,748.24	47,711.65	37,071.59	2,939.13	1,809.83	1,216.04
Denmark	192,563.33	101,241.78	78,664.11	6,236.68	3,840.37	2,580.38
Estonia	21,796.78	11,459.84	8,904.21	705.95	434.70	292.08
Finland	140,918.00	74,088.82	57,566.46	4,564.01	2,810.38	1,888.33
France	1,147,264.31	603,183.81	468,669.34	37,157.26	22,880.35	15,373.55
Germany	1,567,067.13	823,898.66	640,163.14	50,753.71	31,252.64	20,998.99
Greece	95,912.77	50,426.94	39,181.36	3,106.39	1,912.83	1,285.25
Hungary	114,357.54	60,124.43	46,716.24	3,703.78	2,280.68	1,532.41
Ireland	133,540.09	70,209.82	54,552.51	4,325.06	2,663.24	1,789.46
Italy	982,737.01	516,682.21	401,458.24	31,828.60	19,599.11	13,168.86
Latvia	27,012.50	14,202.05	11,034.89	874.87	538.72	361.97
Lithuania	41,201.17	21,661.86	16,831.10	1,334.41	821.69	552.10
Luxembourg	19,135.65	10,060.73	7,817.11	619.76	381.63	256.42
Malta	-	-	-	-	-	-
Netherlands	382,175.51	200,931.97	156,122.65	12,377.79	7,621.88	5,121.22
Poland	251,586.58	132,273.75	102,775.72	8,148.31	5,017.49	3,371.31
Portugal	219,123.79	115,206.17	89,514.34	7,096.92	4,370.07	2,936.30
Romania	101,077.31	53,142.24	41,291.13	3,273.66	2,015.82	1,354.45
Slovakia	28,773.83	15,128.08	11,754.41	931.92	573.85	385.57
Slovenia	-	-	-	-	-	-
Spain	563,671.98	296,355.26	230,265.84	18,256.04	11,241.53	7,553.31
Sweden	213,959.26	112,490.87	87,404.57	6,929.65	4,267.07	2,867.09
United Kingdom	1,393,686.35	732,742.26	569,335.29	45,138.30	27,794.84	18,675.65
Total EU27	**8,108,318.15**	**4,263,016.12**	**3,312,331.86**	**262,609.81**	**161,707.41**	**108,652.95**

2018	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	223,682.89	118,384.47	90,790.40	7,092.88	4,423.47	2,991.68
Belgium	166,862.56	88,312.23	67,727.66	5,291.14	3,299.81	2,231.73
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	93,264.39	49,360.30	37,854.98	2,957.37	1,844.36	1,247.38
Denmark	197,902.49	104,740.15	80,326.42	6,275.40	3,913.64	2,646.88
Estonia	22,401.13	11,855.83	9,092.37	710.33	443.00	299.61
Finland	144,825.19	76,648.92	58,782.93	4,592.34	2,864.01	1,936.99
France	1,179,074.23	624,026.59	478,573.10	37,387.91	23,316.92	15,769.70
Germany	1,610,516.82	852,368.15	653,690.85	51,068.75	31,848.97	21,540.10
Greece	98,572.12	52,169.43	40,009.33	3,125.68	1,949.32	1,318.37
Hungary	117,528.30	62,202.01	47,703.43	3,726.77	2,324.20	1,571.90
Ireland	137,242.72	72,635.89	55,705.29	4,351.90	2,714.06	1,835.57
Italy	1,009,985.13	534,535.96	409,941.72	32,026.17	19,973.08	13,508.20
Latvia	27,761.47	14,692.79	11,268.07	880.30	549.00	371.30
Lithuania	42,343.55	22,410.38	17,186.77	1,342.69	837.37	566.33
Luxembourg	19,666.22	10,408.37	7,982.30	623.61	388.91	263.03
Malta	-	-	-	-	-	-
Netherlands	392,771.99	207,875.09	159,421.78	12,454.62	7,767.31	5,253.19
Poland	258,562.26	136,844.42	104,947.54	8,198.89	5,113.23	3,458.18
Portugal	225,199.39	119,187.07	91,405.92	7,140.97	4,453.46	3,011.96
Romania	103,879.85	54,978.55	42,163.68	3,293.98	2,054.29	1,389.36
Slovakia	29,571.64	15,650.83	12,002.80	937.70	584.80	395.51
Slovenia	-	-	-	-	-	-
Spain	579,300.78	306,595.70	235,131.74	18,369.36	11,456.03	7,747.95
Sweden	219,891.66	116,377.95	89,251.58	6,972.66	4,348.49	2,940.97
United Kingdom	1,432,328.76	758,061.88	581,366.30	45,418.49	28,325.19	19,156.90
Total EU27	**8,333,135.53**	**4,410,322.96**	**3,382,326.96**	**264,239.92**	**164,792.93**	**111,452.77**

2019	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	231,228.00	123,169.39	93,177.10	7,319.78	4,492.06	3,069.68
Belgium	172,491.05	91,881.68	69,508.09	5,460.39	3,350.98	2,289.91
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	96,410.32	51,355.37	38,850.11	3,051.98	1,872.96	1,279.90
Denmark	204,578.00	108,973.59	82,438.04	6,476.14	3,974.33	2,715.89
Estonia	23,156.75	12,335.02	9,331.39	733.05	449.87	307.42
Finland	149,710.33	79,746.96	60,328.22	4,739.25	2,908.42	1,987.49
France	1,218,845.92	649,248.81	491,153.86	38,583.91	23,678.48	16,180.86
Germany	1,664,841.63	886,819.59	670,875.11	52,702.40	32,342.83	22,101.70
Greece	101,897.09	54,278.04	41,061.09	3,225.66	1,979.55	1,352.74
Hungary	121,492.68	64,716.12	48,957.46	3,845.98	2,360.23	1,612.88
Ireland	141,872.10	75,571.73	57,169.68	4,491.12	2,756.14	1,883.43
Italy	1,044,053.22	556,141.10	420,718.29	33,050.66	20,282.79	13,860.39
Latvia	28,697.90	15,286.65	11,564.29	908.46	557.51	380.98
Lithuania	43,771.85	23,316.17	17,638.58	1,385.65	850.35	581.10
Luxembourg	20,329.59	10,829.06	8,192.14	643.56	394.94	269.89
Malta	-	-	-	-	-	-
Netherlands	406,020.70	216,277.09	163,612.67	12,853.03	7,887.75	5,390.15
Poland	267,283.90	142,375.46	107,706.41	8,461.17	5,192.52	3,548.34
Portugal	232,795.65	124,004.43	93,808.81	7,369.40	4,522.51	3,090.49
Romania	107,383.85	57,200.70	43,272.08	3,399.35	2,086.14	1,425.58
Slovakia	30,569.13	16,283.41	12,318.33	967.70	593.87	405.82
Slovenia	-	-	-	-	-	-
Spain	598,841.34	318,987.84	241,312.89	18,956.98	11,633.67	7,949.95
Sweden	227,308.89	121,081.77	91,597.83	7,195.71	4,415.92	3,017.65
United Kingdom	1,480,643.05	788,701.61	596,649.28	46,871.39	28,764.41	19,656.36
Total EU27	**8,614,222.92**	**4,588,581.60**	**3,471,241.73**	**272,692.74**	**167,348.24**	**114,358.62**

2020	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	239,270.17	127,954.31	96,117.75	7,501.17	4,546.42	3,150.53
Belgium	178,490.34	95,451.13	71,701.74	5,595.71	3,391.53	2,350.22
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	99,763.50	53,350.44	40,076.21	3,127.61	1,895.63	1,313.61
Denmark	211,693.27	113,207.03	85,039.77	6,636.63	4,022.42	2,787.42
Estonia	23,962.15	12,814.22	9,625.89	751.22	455.31	315.52
Finland	154,917.30	82,844.99	62,232.17	4,856.69	2,943.61	2,039.83
France	1,261,237.68	674,471.03	506,654.55	39,540.07	23,965.02	16,607.02
Germany	1,722,745.23	921,271.04	692,047.76	54,008.43	32,734.21	22,683.80
Greece	105,441.09	56,386.65	42,356.97	3,305.60	2,003.51	1,388.37
Hungary	125,718.23	67,230.23	50,502.54	3,941.29	2,388.80	1,655.36
Ireland	146,806.44	78,507.56	58,973.94	4,602.41	2,789.50	1,933.04
Italy	1,080,365.66	577,746.24	433,996.06	33,869.69	20,528.23	14,225.43
Latvia	29,696.02	15,880.51	11,929.25	930.98	564.26	391.01
Lithuania	45,294.24	24,221.96	18,195.25	1,419.98	860.64	596.40
Luxembourg	21,036.66	11,249.75	8,450.68	659.50	399.72	276.99
Malta	-	-	-	-	-	-
Netherlands	420,142.20	224,679.09	168,776.24	13,171.55	7,983.20	5,532.11
Poland	276,580.10	147,906.51	111,105.60	8,670.84	5,255.35	3,641.80
Portugal	240,892.34	128,821.80	96,769.39	7,552.03	4,577.24	3,171.89
Romania	111,118.69	59,422.85	44,637.73	3,483.59	2,111.39	1,463.13
Slovakia	31,632.33	16,915.99	12,707.09	991.68	601.05	416.51
Slovenia	-	-	-	-	-	-
Spain	619,669.19	331,379.98	248,928.67	19,426.76	11,774.45	8,159.33
Sweden	235,214.74	125,785.59	94,488.63	7,374.03	4,469.36	3,097.13
United Kingdom	1,532,140.18	819,341.33	615,479.39	48,032.92	29,112.49	20,174.05
Total EU27	**8,913,827.74**	**4,766,840.25**	**3,580,793.28**	**279,450.38**	**169,373.35**	**117,370.49**

2021	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	247,752.07	132,739.23	99,379.00	7,714.99	4,695.43	3,223.42
Belgium	184,817.65	99,020.58	74,134.57	5,755.22	3,502.69	2,404.60
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	103,300.02	55,345.51	41,435.99	3,216.76	1,957.75	1,344.00
Denmark	219,197.59	117,440.47	87,925.15	6,825.81	4,154.26	2,851.91
Estonia	24,811.58	13,293.41	9,952.49	772.63	470.23	322.82
Finland	160,408.97	85,943.03	64,343.69	4,995.13	3,040.09	2,087.03
France	1,305,947.35	699,693.25	523,845.22	40,667.16	24,750.48	16,991.25
Germany	1,783,814.90	955,722.48	715,528.78	55,547.93	33,807.08	23,208.63
Greece	109,178.88	58,495.26	43,794.13	3,399.83	2,069.17	1,420.49
Hungary	130,174.82	69,744.34	52,216.08	4,053.64	2,467.09	1,693.66
Ireland	152,010.59	81,443.39	60,974.91	4,733.60	2,880.92	1,977.76
Italy	1,118,663.58	599,351.39	448,721.44	34,835.15	21,201.05	14,554.56
Latvia	30,748.71	16,474.38	12,334.01	957.51	582.75	400.06
Lithuania	46,899.88	25,127.76	18,812.61	1,460.46	888.85	610.20
Luxembourg	21,782.38	11,670.45	8,737.41	678.30	412.82	283.40
Malta	-	-	-	-	-	-
Netherlands	435,035.84	233,081.09	174,502.78	13,547.00	8,244.85	5,660.11
Poland	286,384.60	153,437.55	114,875.38	8,918.01	5,427.60	3,726.06
Portugal	249,431.75	133,639.16	100,052.75	7,767.30	4,727.26	3,245.27
Romania	115,057.74	61,645.00	46,152.28	3,582.89	2,180.59	1,496.98
Slovakia	32,753.66	17,548.58	13,138.24	1,019.95	620.75	426.15
Slovenia	-	-	-	-	-	-
Spain	641,635.87	343,772.12	257,374.76	19,980.52	12,160.36	8,348.11
Sweden	243,552.88	130,489.42	97,694.61	7,584.23	4,615.84	3,168.79
United Kingdom	1,586,453.09	849,981.06	636,362.46	49,402.09	30,066.66	20,640.82
Total EU27	**9,229,814.40**	**4,945,098.89**	**3,702,288.75**	**287,416.10**	**174,924.60**	**120,086.07**

2022	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	256,490.30	137,524.16	102,892.68	7,964.18	4,820.92	3,288.36
Belgium	191,336.17	102,590.02	76,755.70	5,941.11	3,596.30	2,453.05
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	106,943.41	57,340.58	42,901.01	3,320.66	2,010.08	1,371.08
Denmark	226,928.70	121,673.91	91,033.86	7,046.28	4,265.29	2,909.36
Estonia	25,686.69	13,772.61	10,304.38	797.59	482.80	329.32
Finland	166,066.60	89,041.06	66,618.65	5,156.47	3,121.34	2,129.07
France	1,352,008.18	724,915.47	542,366.49	41,980.69	25,411.98	17,333.56
Germany	1,846,730.14	990,173.92	740,827.28	57,342.11	34,710.63	23,676.19
Greece	113,029.62	60,603.87	45,342.54	3,509.64	2,124.47	1,449.11
Hungary	134,766.09	72,258.45	54,062.25	4,184.57	2,533.03	1,727.78
Ireland	157,372.01	84,379.23	63,130.76	4,886.50	2,957.92	2,017.60
Italy	1,158,118.90	620,956.53	464,586.60	35,960.31	21,767.69	14,847.78
Latvia	31,833.22	17,068.24	12,770.09	988.44	598.33	408.12
Lithuania	48,554.04	26,033.55	19,477.76	1,507.63	912.61	622.49
Luxembourg	22,550.65	12,091.14	9,046.33	700.21	423.86	289.11
Malta	-	-	-	-	-	-
Netherlands	450,379.57	241,483.09	180,672.57	13,984.56	8,465.21	5,774.14
Poland	296,485.39	158,968.60	118,936.96	9,206.06	5,572.66	3,801.12
Portugal	258,229.21	138,456.52	103,590.25	8,018.18	4,853.61	3,310.65
Romania	119,115.83	63,867.15	47,784.06	3,698.62	2,238.87	1,527.14
Slovakia	33,908.89	18,181.16	13,602.76	1,052.89	637.34	434.73
Slovenia	-	-	-	-	-	-
Spain	664,266.40	356,164.25	266,474.60	20,625.88	12,485.37	8,516.30
Sweden	252,143.00	135,193.24	101,148.73	7,829.20	4,739.21	3,232.63
United Kingdom	1,642,407.36	880,620.78	658,861.92	50,997.77	30,870.24	21,056.65
Total EU27	**9,555,350.40**	**5,123,357.53**	**3,833,188.22**	**296,699.54**	**179,599.75**	**122,505.35**

2023	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	265,591.85	142,309.08	106,740.41	8,233.85	4,963.17	3,345.35
Belgium	198,125.73	106,159.47	79,626.02	6,142.27	3,702.42	2,495.56
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	110,738.30	59,335.65	44,505.32	3,433.10	2,069.39	1,394.84
Denmark	234,981.27	125,907.35	94,438.12	7,284.86	4,391.15	2,959.78
Estonia	26,598.18	14,251.80	10,689.71	824.59	497.05	335.03
Finland	171,959.47	92,139.10	69,109.89	5,331.07	3,213.44	2,165.97
France	1,399,984.17	750,137.68	562,648.58	43,402.14	26,161.82	17,633.95
Germany	1,912,261.33	1,024,625.36	768,530.93	59,283.69	35,734.85	24,086.50
Greece	117,040.48	62,712.48	47,038.15	3,628.47	2,187.16	1,474.22
Hungary	139,548.26	74,772.57	56,083.94	4,326.26	2,607.77	1,757.72
Ireland	162,956.36	87,315.06	65,491.57	5,051.95	3,045.20	2,052.57
Italy	1,199,214.73	642,561.67	481,960.07	37,177.91	22,409.99	15,105.09
Latvia	32,962.82	17,662.10	13,247.64	1,021.91	615.98	415.19
Lithuania	50,276.98	26,939.35	20,206.14	1,558.68	939.54	633.28
Luxembourg	23,350.86	12,511.83	9,384.63	723.92	436.36	294.12
Malta	-	-	-	-	-	-
Netherlands	466,361.28	249,885.09	187,428.92	14,458.07	8,715.00	5,874.20
Poland	307,006.17	164,499.65	123,384.67	9,517.77	5,737.09	3,866.99
Portugal	267,392.47	143,273.89	107,464.07	8,289.67	4,996.82	3,368.03
Romania	123,342.66	66,089.30	49,570.97	3,823.85	2,304.93	1,553.60
Slovakia	35,112.14	18,813.74	14,111.44	1,088.54	656.15	442.27
Slovenia	-	-	-	-	-	-
Spain	687,837.88	368,556.39	276,439.56	21,324.26	12,853.78	8,663.88
Sweden	261,090.29	139,897.06	104,931.25	8,094.29	4,879.05	3,288.65
United Kingdom	1,700,688.16	911,260.51	683,500.43	52,724.52	31,781.14	21,421.56
Total EU27	**9,894,421.86**	**5,301,616.18**	**3,976,532.43**	**306,745.64**	**184,899.27**	**124,628.34**

2024	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	274,780.70	147,094.00	110,588.14	8,519.63	5,123.71	3,455.23
Belgium	204,980.41	109,728.92	82,496.34	6,355.46	3,822.17	2,577.52
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	114,569.58	61,330.72	46,109.63	3,552.25	2,136.33	1,440.65
Denmark	243,111.06	130,140.79	97,842.38	7,537.70	4,533.18	3,057.00
Estonia	27,518.42	14,731.00	11,075.05	853.21	513.12	346.03
Finland	177,908.86	95,237.13	71,601.13	5,516.10	3,317.38	2,237.11
France	1,448,420.29	775,359.90	582,930.68	44,908.54	27,008.02	18,213.14
Germany	1,978,421.02	1,059,076.81	796,234.57	61,341.32	36,890.69	24,877.63
Greece	121,089.80	64,821.09	48,733.75	3,754.41	2,257.90	1,522.64
Hungary	144,376.30	77,286.68	58,105.63	4,476.41	2,692.12	1,815.46
Ireland	168,594.26	90,250.90	67,852.38	5,227.30	3,143.70	2,119.99
Italy	1,240,704.71	664,166.81	499,333.55	38,468.28	23,134.84	15,601.23
Latvia	34,103.26	18,255.96	13,725.18	1,057.38	635.91	428.83
Lithuania	52,016.45	27,845.14	20,934.52	1,612.78	969.93	654.08
Luxembourg	24,158.74	12,932.52	9,722.92	749.05	450.48	303.78
Malta	-	-	-	-	-	-
Netherlands	482,496.28	258,287.09	194,185.27	14,959.89	8,996.88	6,067.14
Poland	317,627.86	170,030.69	127,832.39	9,848.11	5,922.66	3,994.01
Portugal	276,643.62	148,091.25	111,337.89	8,577.39	5,158.44	3,478.65
Romania	127,610.02	68,311.45	51,357.88	3,956.57	2,379.48	1,604.63
Slovakia	36,326.94	19,446.33	14,620.13	1,126.32	677.37	456.79
Slovenia	-	-	-	-	-	-
Spain	711,635.43	380,948.53	286,404.53	22,064.39	13,269.53	8,948.45
Sweden	270,123.40	144,600.88	108,713.76	8,375.23	5,036.86	3,396.66
United Kingdom	1,759,527.93	941,900.23	708,138.94	54,554.49	32,809.10	22,125.16
Total EU27	**10,236,745.32**	**5,479,874.82**	**4,119,876.63**	**317,392.22**	**190,879.81**	**128,721.83**

2025	Total	Below 1KVA	1.1KVA to 5KVA	5.1KVA to 20KVA	20.1KVA to 200KVA	Above 200KVA
Austria	283,988.31	151,878.92	114,435.86	8,826.74	5,294.82	3,551.96
Belgium	211,849.09	113,298.37	85,366.66	6,584.55	3,949.82	2,649.69
Bulgaria	-	-	-	-	-	-
Cyprus	-	-	-	-	-	-
Czech Republic	118,408.69	63,325.79	47,713.94	3,680.30	2,207.67	1,480.99
Denmark	251,257.46	134,374.23	101,246.65	7,809.42	4,684.57	3,142.59
Estonia	28,440.53	15,210.19	11,460.39	883.97	530.26	355.72
Finland	183,870.40	98,335.17	74,092.37	5,714.94	3,428.17	2,299.75
France	1,496,955.34	800,582.12	603,212.78	46,527.39	27,909.99	18,723.07
Germany	2,044,715.85	1,093,528.25	823,938.22	63,552.52	38,122.71	25,574.14
Greece	125,147.39	66,929.70	50,429.36	3,889.75	2,333.31	1,565.27
Hungary	149,214.20	79,800.79	60,127.32	4,637.78	2,782.02	1,866.29
Ireland	174,243.68	93,186.73	70,213.19	5,415.73	3,248.69	2,179.34
Italy	1,282,279.43	685,771.95	516,707.02	39,854.97	23,907.46	16,038.02
Latvia	35,246.02	18,849.82	14,202.73	1,095.49	657.14	440.84
Lithuania	53,759.46	28,750.93	21,662.90	1,670.92	1,002.32	672.39
Luxembourg	24,968.28	13,353.21	10,061.21	776.05	465.52	312.29
Malta	-	-	-	-	-	-
Netherlands	498,664.22	266,689.09	200,941.62	15,499.16	9,297.35	6,237.01
Poland	328,271.24	175,561.74	132,280.10	10,203.11	6,120.45	4,105.83
Portugal	285,913.66	152,908.61	115,211.70	8,886.58	5,330.72	3,576.05
Romania	131,886.10	70,533.60	53,144.79	4,099.20	2,458.95	1,649.56
Slovakia	37,544.22	20,078.91	15,128.81	1,166.92	699.99	469.58
Slovenia	-	-	-	-	-	-
Spain	735,481.60	393,340.67	296,369.49	22,859.76	13,712.69	9,198.99
Sweden	279,174.95	149,304.70	112,496.27	8,677.13	5,205.08	3,491.76
United Kingdom	1,818,487.87	972,539.96	732,777.45	56,521.05	33,904.80	22,744.61
Total EU27	**10,579,767.98**	**5,658,133.46**	**4,263,220.84**	**328,833.43**	**197,254.52**	**132,325.73**

Appendix 4 – Sales and stock sensitivity analysis

This appendix presents the results for stock and sales using a 2020 global sales revenue figure from a market research report[288] and the same assumptions outlined in Table 7 to calculate a 2020 sales revenue figure for Europe. These results in significantly higher revenue figures, and therefore unit sales when compared to the analysis presented in Section 2.4.2 and 2.4.3 of the main report. Using this alternative approach, the revenue figures for the period 1995-2025 are summarised in Table 122.

Table 122: Alternative Revenue Figures 1995-2025

Year	Revenue (Million €)
1995	721
1996	757
1997	795
1998	834
1999	876
2000	920
2001	822
2002	856
2003	890
2004	924
2005	958
2006	1053
2007	1148
2008	1243
2009	994
2010	1119
2011	1116
2012	1108
2013	1125
2014	1149
2015	1164
2016	1391
2017	1618
2018	1845
2019	2072
2020	2300
2021	2527
2022	2754
2023	2981
2024	3208
2025	3435

[288] Global UPS market revenues for 2020 estimated at $14.8 billion (http://www.electrical-source.com/whitepapers/StateofUPSIndustry_whitepaper.pdf) European revenue calculated by applying the percentage above and exchange rate of 1USD = 0.7579 Euros.

Based on these revenue figures and the same price and lifetime assumptions outlined in Table 7, the sales (1995-2025) and stock (2011-2025) have been calculated. These are presented in Figure 93 and Figure 95.

Figure 93 and Figure 94 show the sales figures calulated by the modelling using the two different approaches for estimating future sales. Figure 93 shows the sales figures calculated using the projected revenue figure of €2,299 million for EU27 for 2020. As a comparison, Figure 94 shows the same data as used in Figure 5 i.e. based on the growth rate assumption from Table 7, with the scales adjusted to allow a direct comparison with Figure 93.

Figure 95 and Figure 96 show the stock figures calculated by the modelling using the sales figures calulated from the two different approaches.

Using the forecast revenue figure of €2,299 million for EU27 in 2020, unit sales are calculated to reach approximately 2.96 million in 2020. This is significantly higher than the estimate provided using the growth rate for the analysis shown in Table 10 and Figure 5, which show unit sales of approximately 1.82 million in 2020. As stock is calculated directly from sales, this affects the estimate of stock for future years. It is thought that the revenue forecast, which results in significantly higher unit sales, was made before the full extent of the economic downturn was known, therefore potentially over estimating sales and stock for UPS.

Given the limited data available and uncertainty regarding the sales revenue figures identified beyond 2015, it is proposed for the purposes of this study to use the sales figures presented in Table 10 and Figure 5 and the and the stock figures presented in Table 13 and Figure 6.

These stock and sales figures, estimated through our modelling, show a growth in the market for UPS, which is consistent with what would be expected given the market trends and drivers identified in Section 2.3.

Table 123: Alternative Unit Sales for 1995-2025

Year	Total	Sales Below 1.5 kVA	Sales 1.5 to 5 kVA	Sales 5.1 to 10 kVA	Sales 10.1 kVA to 200 kVA	Sales Above 200 kVA
1995	928,774	641,231	257,818	16,462	8,508	4,755
1996	975,213	673,292	270,709	17,286	8,934	4,992
1997	1,023,974	706,957	284,245	18,150	9,380	5,242
1998	1,075,172	742,304	298,457	19,057	9,849	5,504
1999	1,128,931	779,420	313,380	20,010	10,342	5,779
2000	1,185,377	818,391	329,049	21,011	10,859	6,068
2001	1,059,231	731,298	294,032	18,775	9,703	5,422
2002	1,103,068	761,564	306,201	19,552	10,105	5,647
2003	1,146,905	791,830	318,369	20,329	10,506	5,871
2004	1,190,743	822,095	330,538	21,106	10,908	6,096
2005	1,234,580	852,361	342,707	21,883	11,310	6,320
2006	1,357,007	936,885	376,691	24,053	12,431	6,947
2007	1,479,434	1,021,409	410,676	26,223	13,553	7,574
2008	1,601,861	1,105,933	444,660	28,393	14,674	8,200

2009	1,281,489	884,747	355,728	22,714	11,739	6,560
2010	1,441,675	995,340	400,194	25,554	13,207	7,380
2011	1,438,067	992,849	399,193	25,490	13,174	7,362
2012	1,428,273	986,087	396,474	25,316	13,084	7,312
2013	1,449,794	1,000,945	402,448	25,698	13,281	7,422
2014	1,480,465	1,022,121	410,962	26,241	13,562	7,579
2015	1,500,182	1,035,734	416,435	26,591	13,743	7,680
2016	1,792,835	1,237,782	497,673	31,778	16,424	9,178
2017	2,085,487	1,439,831	578,910	36,965	19,105	10,676
2018	2,378,139	1,641,880	660,147	42,152	21,785	12,174
2019	2,670,791	1,843,928	741,385	47,340	24,466	13,672
2020	2,963,443	2,045,977	822,622	52,527	27,147	15,171
2021	3,256,096	2,248,025	903,859	57,714	29,828	16,669
2022	3,548,748	2,450,074	985,096	62,901	32,509	18,167
2023	3,841,400	2,652,123	1,066,334	68,089	35,190	19,665
2024	4,134,052	2,854,171	1,147,571	73,276	37,871	21,163
2025	4,426,704	3,056,220	1,228,808	78,463	40,552	22,661

Table 124: Alternative Stock (Number of Units) for 2011-2025

Year	Total	Stock Below 1.5 kVA	Stock 1.5 to 5 kVA	Stock 5.1 to 10 kVA	Stock 10.1 kVA to 200 kVA	Stock Above 200 kVA
2011	7,512,695	3,978,869	3,060,389	235,296	142,169	95,973
2012	7,468,844	3,859,022	3,126,324	241,060	144,394	98,042
2013	7,655,648	3,975,221	3,186,066	246,429	147,972	99,960
2014	7,727,092	4,002,002	3,220,336	251,564	151,429	101,760
2015	7,785,292	4,044,887	3,226,096	256,272	154,666	103,371
2016	8,106,995	4,296,582	3,279,108	263,997	160,181	107,127
2017	8,792,629	4,735,468	3,502,290	274,739	167,976	112,156
2018	9,701,757	5,355,227	3,762,243	288,499	177,330	118,459
2019	10,895,259	6,163,421	4,104,434	313,124	188,244	126,036
2020	12,177,898	6,971,615	4,530,582	340,097	200,717	134,886
2021	13,547,539	7,779,810	5,031,993	372,322	218,806	144,608
2022	14,997,349	8,588,004	5,606,127	409,907	238,108	155,201
2023	16,531,313	9,396,199	6,256,026	452,298	260,125	166,666

2024	18,075,831	10,204,393	6,905,924	499,333	284,912	181,269
2025	19,628,347	11,012,587	7,555,822	551,206	312,182	196,550

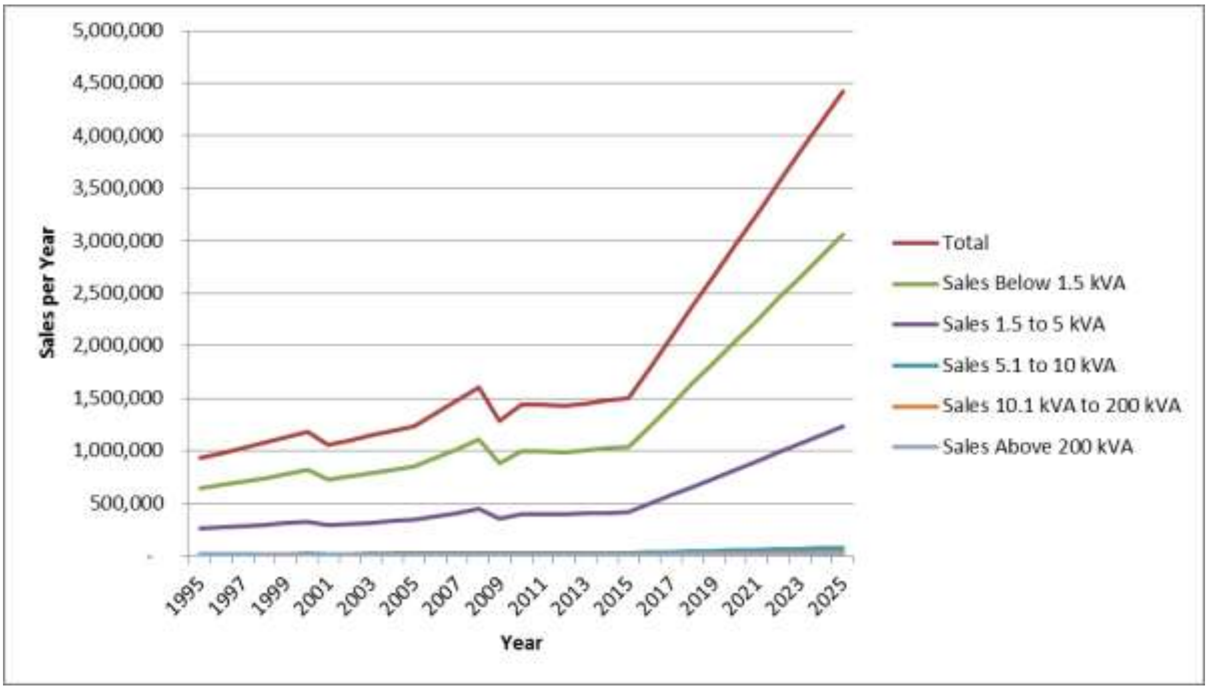


Figure 93: Unit Sales calculated using sales revenue projection of €2,299 million for EU27 in 2020 (Sensitivity analysis)

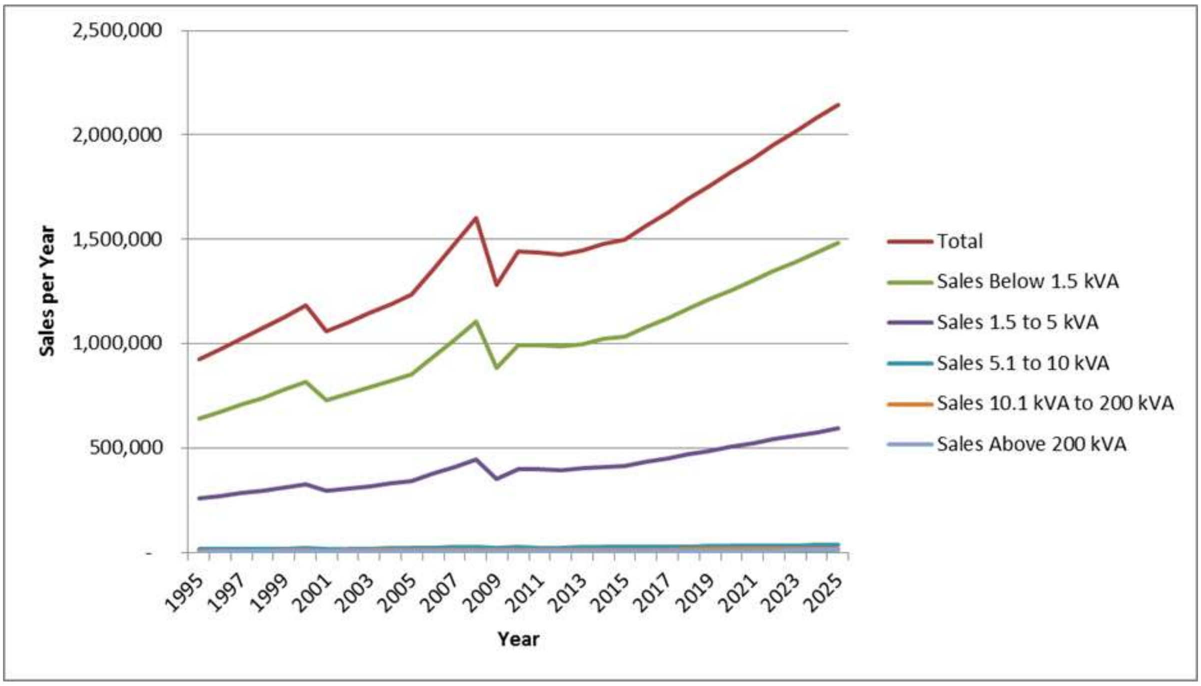


Figure 94: Unit sales calculated using the growth rate assumption for 2016-2025 based on previous growth from 2005-2015 (Based on same data as Figure 5)

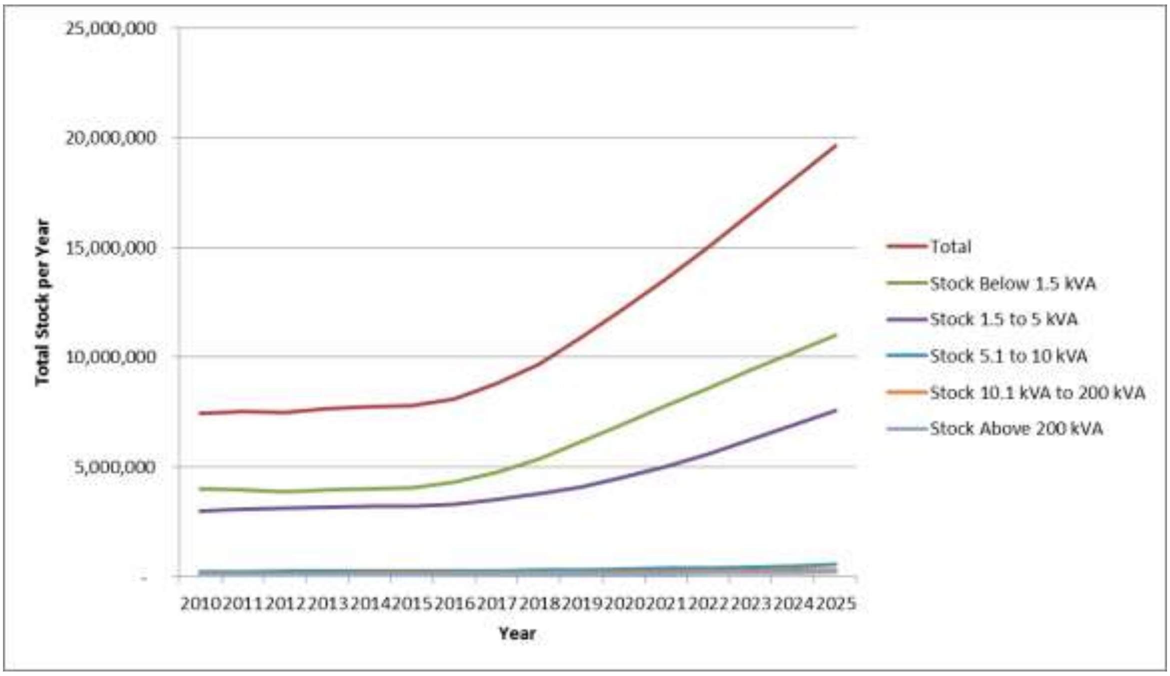


Figure 95: Stock (number of units) calculated using unit sales based on the sales revenue projection of €2,299 million for EU27 in 2020 (Sensitivity analysis)

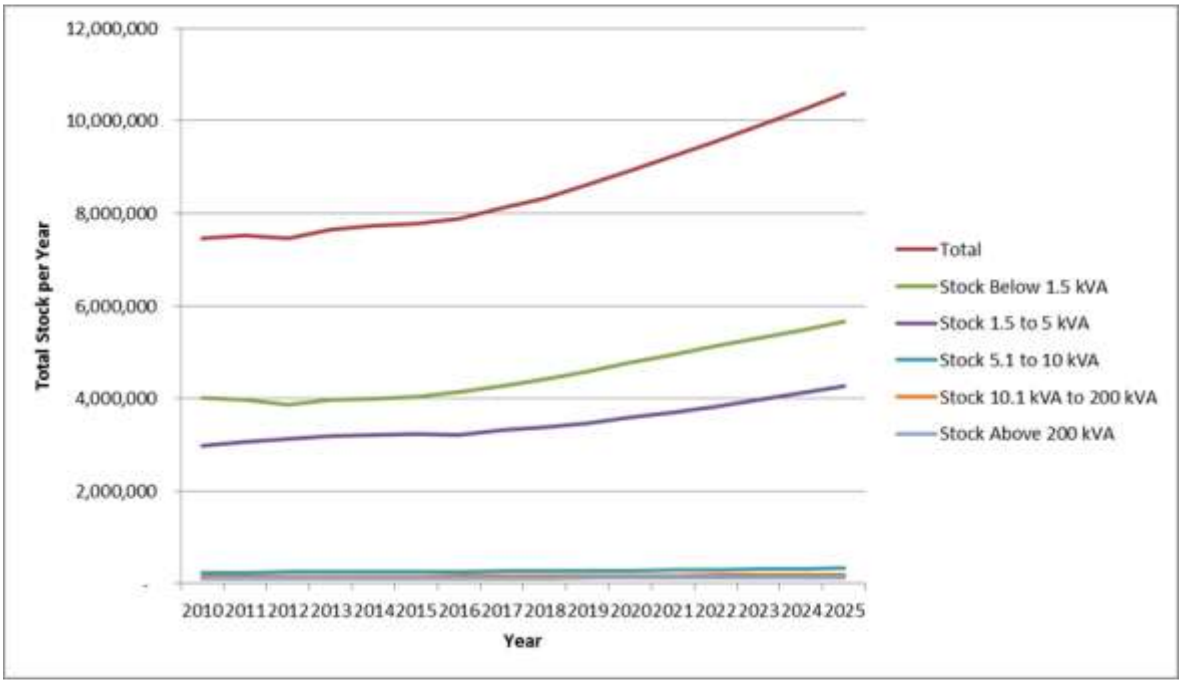


Figure 96: Stock (number of units) calculated using unit sales based on growth rate assumption for 2016-2025 based on previous growth from 2005-2015 (Based on same data as Figure 6)

Appendix 5 – Impact assessment for extra battery materials

Impact Assessment for Extra Materials (impacts per kg of material)

		Units	Antimony	Primary Lead	Secondary Lead	Sulphuric acid	Tap water
Other Resources & Waste	Primary Energy	MJ	7.59	8.26	1.85	0.87	
	Electrical Energy	MJ	26.27	1.38	1.87	0.09	0.00
	Feedstock	MJ					
	Water (process)	litres	468.99	27.44	5.36	49.75	1.13
	Water (cooling)	litres	289.82	15.42	29.47	2.15	0.01
	Haz Waste	g	409.83	409.83	67.73	1.04	0.00
	Non-Haz Waste	g	484,039.28	5,719.33	1.91	0.04	
Air Emissions	GWP	kg CO_2 eq.	18.11	2.70	1.45	0.15	0.00
	AP	g SO_2 eq.	0.37	0.06	0.02	0.02	0.00
	VOC	mg	18,587.82	1,561.15	245.15	52.97	0.07
	POP	ng i-Teq	0.00	0.00	0.00	0.00	0.00
	Heavy Metals	mg Ni eq.	0.00	0.00	0.00	0.00	0.00
	PAH	mg Ni eq.	0.00	0.00	0.00	0.00	0.00
	PM	g	0.23	0.00	0.00	0.00	0.00
Water Emissions	Heavy Metals	mg Hg/20	0.04	0.00	0.00	0.00	0.00
	EP	mg PO_4	0.75	0.01	0.00	0.00	0.00

Note: For those with a blank entry the value was zero, those with 0.00, this is the value when rounded to two decimal places.

Appendix 6 – Use phase energy calculations

Summary of parameter abbreviations

Parameter	Abbreviation	Units
Nominal active power	P	kW
Tested load levels	l	%
Conversion efficiency at each load level	Ef_l	%
Proportion of time spent at each load level	t_l	%
Power with each load level	Pl	kW
Yearly energy input with each load level	Eil	kWh
Yearly energy input	Ei	kWh
Yearly energy consumption with each load level	Ecl	kWh
Yearly energy consumption	Ec	kWh
Transformer Losses	Trans.L	%

Base Case 1

P	0.54			
l	25%	50%	75%	100%
Efl	86.0%	87.0%	88.0%	89.0%
tl	20%	20%	30%	30%
Pl	0.13	0.27	0.40	0.54
Eil	236.06	472.13	1 062.28	1 416.38
Ei	3 186.85			
Ecl	33.05	61.38	127.47	155.80
Ec	377.70			

Base Case 2

P	2.87			
l	25%	50%	75%	100%
Efl	85.0%	89.0%	89.9%	90.0%
tl	0%	30%	40%	30%
Pl	0.72	1.43	2.15	2.87
Eil	0.00	3 768.36	7 536.73	7 536.73
Ei	18 841.82			
Ecl	0.00	414.52	761.21	753.67
Ec	1 929.40			

Base Case 3

P	6.25			
l	25%	50%	75%	100%
Efl	88.0%	92.0%	92.5%	92.5%
tl	0%	30%	40%	30%
Pl	1.56	3.13	4.69	6.25
Eil	0.00	8 212.50	16 425.00	16 425.00
Ei	41 062.50			
Ecl	0.00	657.00	1231.88	1231.88
Ec	3120.75			

Base Case 4

P	94.50			
l	25%	50%	75%	100%
Efl	89.0%	93.0%	93.5%	93.5%
Trans. L	4.0%	2.9%	2.9%	3.2%
Efl	85.0%	90.1%	90.6%	90.3%
tl	25%	50%	25%	0%
Pl	23.63	47.25	70.88	94.50
Eil	51 738.75	206 955.0	15 5216.3	0.00
Ei	41 3910.0			
Ecl	7 760.81	204 88.55	14 590.33	0.00
Ec	42 839.69			

Appendix 7 – EcoReport outputs

Base Case 1:

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**1,751**		**18**	728	1,092	-51	**0**
2	TecPlastics	g			**10**		**0**	4	6	0	**0**
3	Ferro	g			**1,239**		**12**	64	1,223	-36	**0**
4	Non-ferro	g			**829**		**8**	43	818	-24	**0**
5	Coating	g			**0**		**0**	0	0	0	**0**
6	Electronics	g			**493**		**5**	251	261	-14	**0**
7	Misc.	g			**679**		**7**	240	466	-20	**0**
8	Extra	g			**2,926**		**0**	122	2,919	-85	**-29**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**7,928**		**50**	1,452	6,785	-230	**-29**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	572	141	**714**	**187**	**13,603**	14	-276		**14,242**
12	of which, electricity (in primary MJ)	MJ	215	49	**263**	**0**	**13,599**	0	-108		**13,755**
13	Water (process)	ltr	163	7	**169**	**0**	**2**	0	-109		**63**
14	Water (cooling)	ltr	374	40	**414**	**0**	**608**	0	-83		**938**
15	Waste, non-haz./ landfill	g	22,287	301	**22,588**	**142**	**7,230**	23	-21,603		**8,380**
16	Waste, hazardous/ incinerated	g	641	2	**643**	**3**	**221**	0	-525		**341**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	32	9	**41**	**14**	**581**	0	-19		**616**
18	Acidification, emissions	g SO2 eq.	410	43	**452**	**45**	**2,572**	1	-302		**2,768**
19	Volatile Organic Compounds (VOC)	g	2,201	1	**2,202**	**1**	**326**	0	-2,174		**355**
20	Persistent Organic Pollutants (POP)	ng i-Teq	15	0	**16**	**1**	**32**	0	-14		**34**
21	Heavy Metals	mg Ni eq.	83	1	**84**	**7**	**138**	0	-66		**164**
22	PAHs	mg Ni eq.	27	2	**28**	**4**	**32**	0	-17		**47**
23	Particulate Matter (PM, dust)	g	32	10	**42**	**25**	**55**	1	-23		**99**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	65	0	**65**	**0**	**59**	0	-47		**77**
25	Eutrophication	g PO4	4	0	**4**	**0**	**3**	1	-2		**6**

Base Case 2:

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Material	Manuf.	Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	Recycl.	Stock	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**5,085**		**51**	1,638	2,457	1,040	**0**
2	TecPlastics	g			**128**		**1**	41	62	26	**0**
3	Ferro	g			**6,678**		**67**	269	5,110	1,366	**0**
4	Non-ferro	g			**1,676**		**17**	68	1,283	343	**0**
5	Coating	g			**21**		**0**	1	16	4	**0**
6	Electronics	g			**1,324**		**13**	523	544	271	**0**
7	Misc.	g			**1,811**		**18**	496	963	370	**0**
8	Extra	g			**31,107**		**0**	1,002	24,055	6,361	**-311**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**47,830**		**167**	4,038	34,490	9,781	**-311**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	2,135	483	**2,618**	**74**	**138,938**	41	-891		**140,780**
12	of which, electricity (in primary MJ)	MJ	1,021	192	**1,213**	**0**	**138,927**	0	-419		**139,721**
13	Water (process)	ltr	1,081	19	**1,100**	**0**	**11**	0	-668		**442**
14	Water (cooling)	ltr	1,025	135	**1,159**	**0**	**6,184**	0	-508		**6,836**
15	Waste, non-haz./ landfill	g	235,407	1,213	**236,620**	**61**	**73,943**	112	-178,992		**131,745**
16	Waste, hazardous/ incinerated	g	5,705	5	**5,711**	**1**	**2,249**	0	-3,938		**4,023**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	154	29	**183**	**6**	**5,931**	0	-86		**6,035**
18	Acidification, emissions	g SO2 eq.	1,029	140	**1,169**	**17**	**26,250**	3	-529		**26,909**
19	Volatile Organic Compounds (VOC)	g	23,393	3	**23,396**	**1**	**3,336**	0	-17,909		**8,824**
20	Persistent Organic Pollutants (POP)	ng i-Teq	168	7	**175**	**0**	**326**	0	-125		**376**
21	Heavy Metals	mg Ni eq.	226	16	**242**	**3**	**1,407**	1	-124		**1,530**
22	PAHs	mg Ni eq.	135	4	**139**	**4**	**325**	0	-75		**393**
23	Particulate Matter (PM, dust)	g	83	31	**114**	**75**	**556**	1	-48		**700**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	179	0	**180**	**0**	**600**	0	-103		**677**
25	Eutrophication	g PO4	6	1	**7**	**0**	**26**	1	-2		**32**

Base Case 3:

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Material	Manuf.	Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	Recycl.	Stock	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**11,201**		**112**	3,333	4,999	2,980	**0**
2	TecPlastics	g			**125**		**1**	37	56	33	**0**
3	Ferro	g			**16,187**		**162**	602	11,440	4,307	**0**
4	Non-ferro	g			**2,918**		**29**	109	2,062	776	**0**
5	Coating	g			**13**		**0**	0	9	3	**0**
6	Electronics	g			**3,238**		**32**	1,180	1,228	861	**0**
7	Misc.	g			**5,077**		**51**	1,284	2,493	1,351	**0**
8	Extra	g			**67,741**		**0**	2,016	48,379	18,024	**-677**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**106,500**		**388**	8,561	70,667	28,336	**-677**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	4,913	1,168	**6,081**	**93**	**280,917**	89	-1,899		**285,280**
12	of which, electricity (in primary MJ)	MJ	2,345	459	**2,804**	**0**	**280,891**	0	-888		**282,808**
13	Water (process)	ltr	2,335	45	**2,381**	**0**	**23**	0	-1,342		**1,063**
14	Water (cooling)	ltr	2,166	324	**2,491**	**0**	**12,505**	0	-1,029		**13,966**
15	Waste, non-haz./ landfill	g	519,543	2,961	**522,504**	**70**	**149,936**	282	-364,828		**307,963**
16	Waste, hazardous/ incinerated	g	12,304	13	**12,317**	**1**	**4,555**	0	-7,876		**8,998**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	353	71	**424**	**7**	**11,993**	0	-181		**12,243**
18	Acidification, emissions	g SO2 eq.	2,114	340	**2,454**	**20**	**53,074**	6	-939		**54,615**
19	Volatile Organic Compounds (VOC)	g	50,945	7	**50,952**	**1**	**6,782**	0	-36,019		**21,716**
20	Persistent Organic Pollutants (POP)	ng i-Teq	464	19	**483**	**0**	**660**	0	-319		**824**
21	Heavy Metals	mg Ni eq.	484	48	**532**	**4**	**2,845**	2	-234		**3,148**
22	PAHs	mg Ni eq.	376	10	**386**	**4**	**659**	0	-195		**855**
23	Particulate Matter (PM, dust)	g	166	76	**243**	**140**	**1,125**	3	-83		**1,428**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	455	1	**457**	**0**	**1,214**	1	-240		**1,431**
25	Eutrophication	g PO4	13	3	**15**	**0**	**53**	1	-4		**65**

Base Case 4:

Nr	Life cycle Impact per product:		Reference year	Author
0	Products		2011	vhk

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			131,310		1,313	41,645	62,468	28,510	0
2	TecPlastics	g			1,861		19	590	885	404	0
3	Ferro	g			207,873		2,079	8,241	156,578	45,133	0
4	Non-ferro	g			90,595		906	3,592	68,240	19,670	0
5	Coating	g			1,500		15	59	1,130	326	0
6	Electronics	g			20,530		205	7,976	8,302	4,458	0
7	Misc.	g			32,396		324	8,733	16,953	7,034	0
8	Extra	g			1,024,251		0	32,484	779,625	222,384	-10,243
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			1,510,317		4,861	103,321	1,094,181	327,918	-10,243
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	40,883	11,690	52,572	1,550	4,627,095	521	-19,549		4,662,190
12	of which, electricity (in primary MJ)	MJ	5,017	5,467	10,484	4	4,626,737	0	-2,312		4,634,913
13	Water (process)	ltr	25,021	326	25,347	0	250	0	-17,661		7,937
14	Water (cooling)	ltr	30,364	3,238	33,602	0	209,334	0	-18,358		222,578
15	Waste, non-haz./ landfill	g	7,678,716	33,689	7,712,405	723	2,461,073	3,499	-5,773,946		4,403,754
16	Waste, hazardous/ incinerated	g	154,040	83	154,124	14	74,539	0	-114,208		114,469
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	3,578	691	4,269	101	197,533	2	-2,288		199,617
18	Acidification, emissions	g SO2 eq.	23,022	3,190	26,211	308	874,160	25	-15,131		885,574
19	Volatile Organic Compounds (VOC)	g	770,136	44	770,180	31	111,031	3	-580,392		300,853
20	Persistent Organic Pollutants (POP)	ng i-Teq	5,625	234	5,859	4	10,852	2	-4,178		12,539
21	Heavy Metals	mg Ni eq.	5,186	563	5,749	37	46,833	7	-3,729		48,897
22	PAHs	mg Ni eq.	6,093	64	6,158	68	10,857	0	-3,256		13,826
23	Particulate Matter (PM, dust)	g	2,347	644	2,990	5,061	18,530	35	-1,407		25,209
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	6,446	18	6,464	1	19,980	5	-4,178		22,272
25	Eutrophication	g PO4	95	19	114	0	875	7	-41		956

Appendix 8 – EcoReport Sensitivity Analysis Results

Reduced Battery Lifetime:

Base Case 2

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	**unit**									
1	Bulk Plastics	g			**3,297**		**33**	1,062	1,593	674	**0**
2	TecPlastics	g			**128**		**1**	41	62	26	**0**
3	Ferro	g			**6,678**		**67**	269	5,110	1,366	**0**
4	Non-ferro	g			**1,676**		**17**	68	1,283	343	**0**
5	Coating	g			**21**		**0**	1	16	4	**0**
6	Electronics	g			**1,324**		**13**	523	544	271	**0**
7	Misc.	g			**1,454**		**15**	398	773	297	**0**
8	Extra	g			**15,553**		**0**	501	12,027	3,181	**-156**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**30,132**		**146**	2,863	21,408	6,162	**-156**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	1,949	410	**2,359**	**74**	**138,936**	38	-858		**140,549**
12	of which, electricity (in primary MJ)	MJ	980	148	**1,128**	**0**	**138,927**	0	-400		**139,655**
13	Water (process)	ltr	741	18	**759**	**0**	**7**	0	-416		**351**
14	Water (cooling)	ltr	642	114	756	0	6,180	0	-274		6,662
15	Waste, non-haz./ landfill	g	124,268	985	**125,253**	**61**	**72,831**	108	-93,943		**104,310**
16	Waste, hazardous/ incinerated	g	3,428	5	**3,433**	**1**	**2,226**	0	-2,201		**3,459**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	125	25	**151**	**6**	**5,931**	0	-67		**6,021**
18	Acidification, emissions	g SO2 eq.	1,017	123	**1,140**	**17**	**26,250**	3	-529		**26,880**
19	Volatile Organic Compounds (VOC)	g	11,699	3	**11,702**	**1**	**3,219**	0	-8,956		**5,966**
20	Persistent Organic Pollutants (POP)	ng i-Teq	168	7	**175**	**0**	**326**	0	-125		**376**
21	Heavy Metals	mg Ni eq.	226	16	**242**	**3**	**1,407**	1	-124		**1,530**
22	PAHs	mg Ni eq.	135	4	**139**	**4**	**325**	0	-75		**393**
23	Particulate Matter (PM, dust)	g	81	29	**110**	**75**	**556**	1	-48		**696**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	179	0	**180**	**0**	**600**	0	-103		**677**
25	Eutrophication	g PO4	6	1	**7**	**0**	**26**	1	-2		**31**

Base Case 3

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Stock	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**7,307**		**73**	2,174	3,262	1,944	**0**
2	TecPlastics	g			**125**		**1**	37	56	33	**0**
3	Ferro	g			**16,187**		**162**	602	11,440	4,307	**0**
4	Non-ferro	g			**2,918**		**29**	109	2,062	776	**0**
5	Coating	g			**13**		**0**	0	9	3	**0**
6	Electronics	g			**3,238**		**32**	1,180	1,228	861	**0**
7	Misc.	g			**4,299**		**43**	1,087	2,111	1,144	**0**
8	Extra	g			**33,871**		**0**	1,008	24,190	9,012	**-339**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**67,957**		**341**	6,198	44,357	18,081	**-339**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	4,508	1,009	**5,517**	**93**	**280,913**	83	-1,833		**284,772**
12	of which, electricity (in primary MJ)	MJ	2,257	364	**2,621**	**0**	**280,890**	0	-849		**282,662**
13	Water (process)	ltr	1,596	44	**1,640**	**0**	**16**	0	-834		**821**
14	Water (cooling)	ltr	1,332	279	**1,612**	**0**	**12,496**	0	-559		**13,549**
15	Waste, non-haz./ landfill	g	277,511	2,463	**279,973**	**70**	**147,515**	274	-193,773		**234,059**
16	Waste, hazardous/ incinerated	g	7,344	13	**7,358**	**1**	**4,505**	0	-4,382		**7,482**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	291	62	**354**	**7**	**11,992**	0	-144		**12,209**
18	Acidification, emissions	g SO2 eq.	2,089	302	**2,391**	**20**	**53,074**	6	-938		**54,552**
19	Volatile Organic Compounds (VOC)	g	25,479	7	**25,486**	**1**	**6,527**	0	-18,012		**14,002**
20	Persistent Organic Pollutants (POP)	ng i-Teq	464	19	**483**	**0**	**660**	0	-319		**824**
21	Heavy Metals	mg Ni eq.	484	48	**532**	**4**	**2,845**	2	-234		**3,148**
22	PAHs	mg Ni eq.	375	10	**385**	**4**	**659**	0	-195		**853**
23	Particulate Matter (PM, dust)	g	163	71	**234**	**140**	**1,125**	3	-83		**1,419**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	455	1	**456**	**0**	**1,214**	1	-240		**1,431**
25	Eutrophication	g PO4	12	3	**14**	**0**	**53**	1	-4		**64**

Base Case 4

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases --> / Resources Use and Emissions	unit	PRODUCTION Material	PRODUCTION Manuf.	PRODUCTION Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	END-OF-LIFE* Recycl.	END-OF-LIFE* Stock	TOTAL
	Materials	unit									
1	Bulk Plastics	g			**72,445**		**724**	22,976	34,464	15,729	**0**
2	TecPlastics	g			**1,861**		**19**	590	885	404	**0**
3	Ferro	g			**207,873**		**2,079**	8,241	156,578	45,133	**0**
4	Non-ferro	g			**90,595**		**906**	3,592	68,240	19,670	**0**
5	Coating	g			**1,500**		**15**	59	1,130	326	**0**
6	Electronics	g			**20,530**		**205**	7,976	8,302	4,458	**0**
7	Misc.	g			**20,623**		**206**	5,560	10,792	4,478	**0**
8	Extra	g			**512,126**		**0**	16,242	389,813	111,192	**-5,121**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**927,553**		**4,154**	65,236	670,203	201,389	**-5,121**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	34,758	9,285	**44,043**	**1,550**	**4,627,034**	422	-18,472		**4,654,578**
12	of which, electricity (in primary MJ)	MJ	3,687	4,019	**7,706**	**4**	**4,626,723**	0	-1,694		**4,632,739**
13	Water (process)	ltr	13,833	304	**14,138**	**0**	**138**	0	-9,483		**4,793**
14	Water (cooling)	ltr	17,752	2,556	20,308	0	205,808	0	-9,376		216,740
15	Waste, non-haz./landfill	g	4,019,193	26,154	**4,045,347**	**723**	**2,424,478**	3,374	-3,017,410		**3,456,512**
16	Waste, hazardous/incinerated	g	79,050	83	**79,134**	**14**	**73,789**	0	-57,907		**95,031**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	2,649	557	**3,206**	**101**	**197,524**	2	-1,685		**199,148**
18	Acidification, emissions	g SO2 eq.	22,641	2,614	**25,255**	**308**	**874,156**	24	-15,122		**884,622**
19	Volatile Organic Compounds (VOC)	g	385,089	43	**385,133**	**31**	**107,180**	2	-290,210		**202,135**
20	Persistent Organic Pollutants (POP)	ng i-Teq	5,625	234	**5,858**	**4**	**10,852**	2	-4,177		**12,539**
21	Heavy Metals	mg Ni eq.	5,184	563	**5,747**	**37**	**46,833**	7	-3,728		**48,896**
22	PAHs	mg Ni eq.	6,070	64	**6,134**	**68**	**10,856**	0	-3,257		**13,801**
23	Particulate Matter (PM, dust)	g	2,299	555	**2,855**	**5,061**	**18,530**	34	-1,408		**25,071**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	6,446	18	**6,463**	**1**	**19,980**	5	-4,178		**22,272**
25	Eutrophication	g PO4	86	18	**103**	**0**	**875**	6	-41		**943**

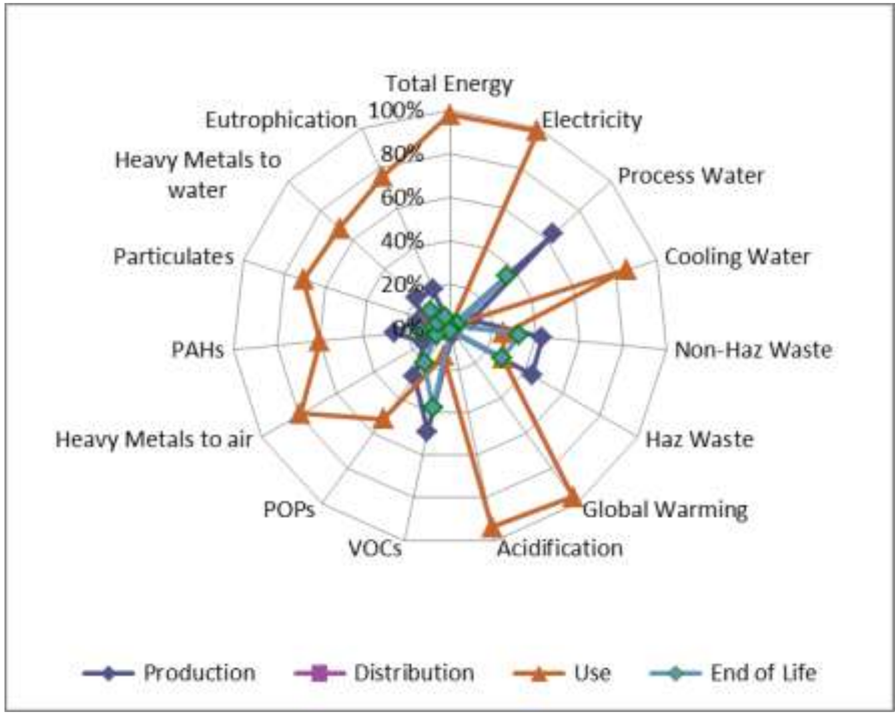
Impacts / benefits for each parameter across the different life cycle phases for bases cases 3, 3 and 4, taking into account no battery replacement

		Base Case 2 1.5 to 5 kVA				Base Case 3 5.1 to 10 kVA				Base Case 4 10.1 to 200 kVA			
		Production	Distribution	Use	End of Life	Production	Distribution	Use	End of Life	Production	Distribution	Use	End of Life
Other Resources & Waste	**Units**												
Total Energy (GER)	MJ	2%	0%	98%	1%	2%	0%	97%	1%	1%	0%	99%	0%
of which, electricity (in primary MJ)	MJ	1%	0%	99%	0%	1%	0%	99%	0%	0%	0%	100 %	0%
Water (process)	ltr	64%	0%	1%	35%	66%	0%	1%	34%	60%	0%	1%	40%
Water (cooling)	ltr	10%	0%	86%	4%	11%	0%	85%	4%	9%	0%	87%	4%
Waste, non-haz./ landfill	g	43%	0%	25%	32%	45%	0%	24%	31%	43%	0%	26%	32%
Waste, hazardous/ incinerated	g	44%	0%	28%	28%	45%	0%	28%	27%	38%	0%	35%	27%
Emissions (Air)													
Greenhouse Gases in GWP100	kg CO_2 eq.	2%	0%	96%	1%	3%	0%	96%	1%	2%	0%	98%	1%
Acidification, emissions	g SO_2 eq.	4%	0%	94%	2%	4%	0%	94%	2%	3%	0%	96%	2%
Volatile Organic Compounds (VOC)	g	49%	0%	13%	38%	51%	0%	13%	36%	49%	0%	14%	37%
Persistent Organic Pollutants (POP)	ng i-Teq	28%	0%	52%	20%	33%	0%	45%	22%	28%	0%	52%	20%
Heavy Metals	mg Ni eq.	14%	0%	79%	7%	15%	0%	79%	6%	10%	0%	83%	7%
PAHs	mg Ni eq.	26%	1%	60%	14%	31%	0%	53%	16%	30%	0%	53%	16%
Particulate Matter (PM, dust)	g	14%	10%	71%	6%	15%	9%	71%	5%	10%	18%	67%	5%
Emissions (Water)													
Heavy Metals	mg Hg/20	20%	0%	68%	12%	24%	0%	64%	13%	21%	0%	65%	14%
Eutrophication	g PO_4	19%	0%	76%	5%	20%	0%	75%	5%	10%	0%	86%	3%

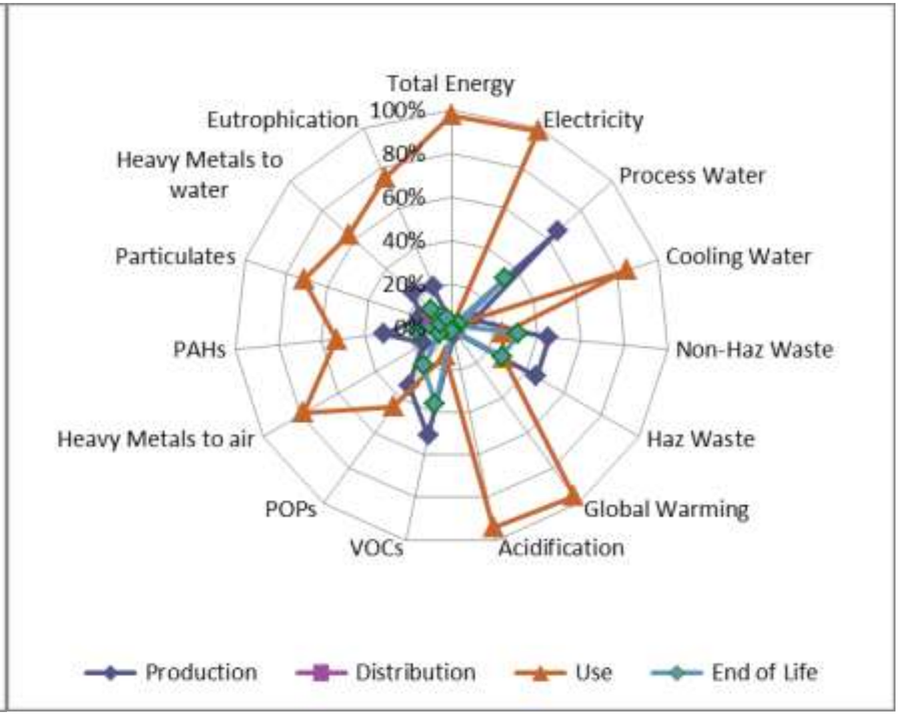
***Note:** The sign of contribution (impact or benefit) is ignored in the colours and percentages, which just reflect relative magnitude. For production, distribution, and use phases the contributions are impacts, for end of life phase the contributions are benefits.*

Impacts / benefits for each parameter across the different life cycle phases for bases cases 3, 3 and 4, taking into account no battery replacement

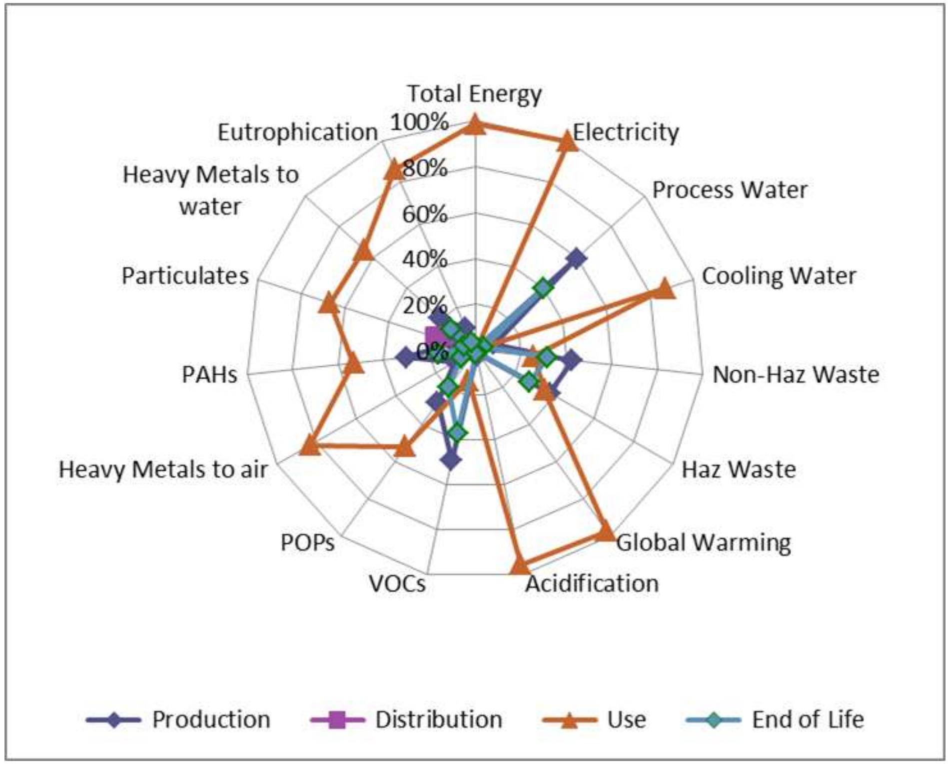
Base Case 2



Base Case 3



Base Case 4


Total Energy
Electricity
Process Water
Cooling Water
Non-Haz Waste
Haz Waste
Global Warming
Acidification
VOCs
POPs
Heavy Metals to air
PAHs
Particulates
Heavy Metals to water
Eutrophication
100%
80%
60%
40%
20%
0%
Production
Distribution
Use
End of Life

Spare Part Replacement:

Base Case 3:

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Material	Manuf.	Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	Recycl.	Stock	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**11,519**		**115**	3,428	5,141	3,065	**0**
2	TecPlastics	g			**125**		**1**	37	56	33	**0**
3	Ferro	g			**16,213**		**162**	603	11,458	4,314	**0**
4	Non-ferro	g			**2,928**		**29**	109	2,069	779	**0**
5	Coating	g			**13**		**0**	0	9	3	**0**
6	Electronics	g			**3,561**		**36**	1,298	1,351	947	**0**
7	Misc.	g			**5,077**		**51**	1,284	2,493	1,351	**0**
8	Extra	g			**67,741**		**0**	2,016	48,379	18,024	**-677**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**107,177**		**394**	8,775	70,957	28,517	**-677**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	5,070	1,223	**6,292**	**93**	**280,918**	93	-1,946		**285,450**
12	of which, electricity (in primary MJ)	MJ	2,348	468	**2,816**	**0**	**280,891**	0	-888		**282,819**
13	Water (process)	ltr	2,351	49	**2,400**	**0**	**24**	0	-1,346		**1,077**
14	Water (cooling)	ltr	2,237	340	**2,577**	**0**	**12,505**	0	-1,033		**14,049**
15	Waste, non-haz./ landfill	g	519,833	3,038	**522,871**	**70**	**149,939**	284	-364,946		**308,218**
16	Waste, hazardous/ incinerated	g	12,314	14	**12,328**	**1**	**4,555**	0	-7,878		**9,006**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	361	75	**436**	**7**	**11,993**	0	-184		**12,252**
18	Acidification, emissions	g SO2 eq.	2,169	359	**2,528**	**20**	**53,074**	6	-958		**54,671**
19	Volatile Organic Compounds (VOC)	g	50,945	7	**50,952**	**1**	**6,782**	0	-36,019		**21,716**
20	Persistent Organic Pollutants (POP)	ng i-Teq	466	19	**485**	**0**	**660**	0	-320		**825**
21	Heavy Metals	mg Ni eq.	488	48	**536**	**4**	**2,845**	2	-236		**3,151**
22	PAHs	mg Ni eq.	443	11	**454**	**4**	**660**	0	-220		**898**
23	Particulate Matter (PM, dust)	g	179	82	**260**	**140**	**1,125**	3	-88		**1,442**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	480	1	**481**	**0**	**1,214**	1	-249		**1,447**
25	Eutrophication	g PO4	13	3	**16**	**0**	**53**	1	-4		**66**

Base Case 4:

Nr	Life cycle Impact per product:	Reference year	Author
0	Products	2011	vhk

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Material	Manuf.	Total	DISTRI-BUTION	USE	END-OF-LIFE* Disposal	Recycl.	Stock	TOTAL
	Materials	**unit**									
1	Bulk Plastics	g			**136,299**		**1,363**	43,228	64,841	29,593	**0**
2	TecPlastics	g			**1,861**		**19**	590	885	404	**0**
3	Ferro	g			**208,888**		**2,089**	8,281	157,342	45,353	**0**
4	Non-ferro	g			**91,466**		**915**	3,626	68,895	19,859	**0**
5	Coating	g			**1,500**		**15**	59	1,130	326	**0**
6	Electronics	g			**32,530**		**325**	12,638	13,154	7,063	**0**
7	Misc.	g			**32,396**		**324**	8,733	16,953	7,034	**0**
8	Extra	g			**1,024,251**		**0**	32,484	779,625	222,384	**-10,243**
9	Auxiliaries	g			**0**		**0**	0	0	0	**0**
10	Refrigerant	g			**0**		**0**	0	0	0	**0**
	Total weight	g			**1,529,191**		**5,049**	109,640	1,102,827	332,016	**-10,243**
									see note!		
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	46,132	13,446	**59,578**	**1,550**	**4,627,148**	650	-21,491		**4,667,435**
12	of which, electricity (in primary MJ)	MJ	5,055	5,635	**10,690**	**4**	**4,626,737**	0	-2,313		**4,635,119**
13	Water (process)	ltr	25,523	472	**25,995**	**0**	**255**	0	-17,854		**8,396**
14	Water (cooling)	ltr	31,847	3,733	**35,580**	**0**	**205,949**	0	-17,170		**224,358**
15	Waste, non-haz./ landfill	g	7,689,036	35,678	**7,724,714**	**723**	**2,461,176**	3,555	-5,778,782		**4,411,386**
16	Waste, hazardous/ incinerated	g	154,326	131	**154,457**	**14**	**74,542**	0	-114,299		**114,715**
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	3,866	811	**4,676**	**101**	**197,536**	3	-2,399		**199,917**
18	Acidification, emissions	g SO2 eq.	25,088	3,830	**28,918**	**308**	**874,181**	32	-16,012		**887,427**
19	Volatile Organic Compounds (VOC)	g	770,138	68	**770,205**	**31**	**111,031**	3	-580,392		**300,878**
20	Persistent Organic Pollutants (POP)	ng i-Teq	5,694	235	**5,929**	**4**	**10,853**	2	-4,220		**12,568**
21	Heavy Metals	mg Ni eq.	5,364	578	**5,942**	**37**	**46,835**	8	-3,830		**48,991**
22	PAHs	mg Ni eq.	8,563	101	**8,663**	**68**	**10,881**	0	-4,242		**15,370**
23	Particulate Matter (PM, dust)	g	2,795	832	**3,627**	**5,061**	**18,535**	49	-1,583		**25,689**
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	7,354	18	**7,372**	**1**	**19,989**	7	-4,540		**22,830**
25	Eutrophication	g PO4	99	28	**126**	**0**	**875**	7	-41		**968**

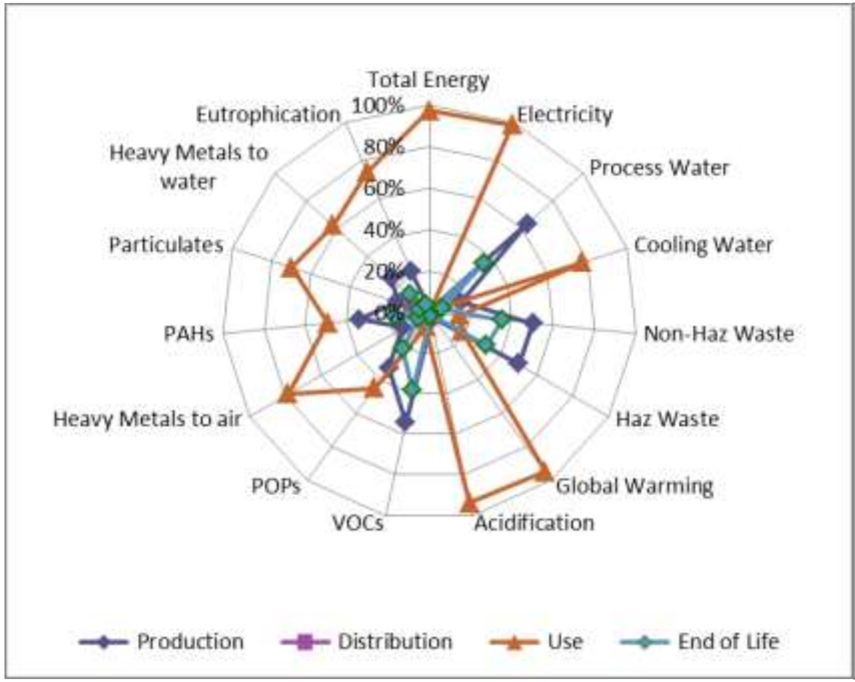
Impacts / benefits for each parameter across the different life cycle phases for bases cases 3 and 4, taking spare parts into account

		Base Case 3 5.1 to 10 kVA				Base Case 4 10.1 to 200 kVA			
		Production	Distribution	Use	End of Life	Production	Distribution	Use	End of Life
Other Resources & Waste	**Units**								
Total Energy (GER)	MJ	2%	0%	97%	1%	1%	0%	98%	0%
of which, electricity (in primary MJ)	MJ	1%	0%	99%	0%	0%	0%	100%	0%
Water (process)	ltr	64%	0%	1%	36%	59%	0%	1%	40%
Water (cooling)	ltr	16%	0%	78%	6%	14%	0%	80%	7%
Waste, non-haz./ landfill	g	50%	0%	14%	35%	48%	0%	15%	36%
Waste, hazardous/ incinerated	g	50%	0%	18%	32%	45%	0%	22%	33%
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	3%	0%	95%	1%	2%	0%	96%	1%
Acidification, emissions	g SO_2 eq.	4%	0%	94%	2%	3%	0%	95%	2%
Volatile Organic Compounds (VOC)	g	54%	0%	7%	38%	53%	0%	8%	40%
Persistent Organic Pollutants (POP)	ng i-Teq	33%	0%	45%	22%	28%	0%	52%	20%
Heavy Metals	mg Ni eq.	15%	0%	79%	6%	10%	0%	83%	7%
PAHs	mg Ni eq.	34%	0%	49%	16%	36%	0%	46%	18%
Particulate Matter (PM, dust)	g	16%	9%	70%	5%	13%	18%	64%	5%
Emissions (Water)									
Heavy Metals	mg Hg/20	25%	0%	62%	13%	23%	0%	63%	14%
Eutrophication	g PO_4	22%	0%	74%	4%	12%	0%	85%	3%

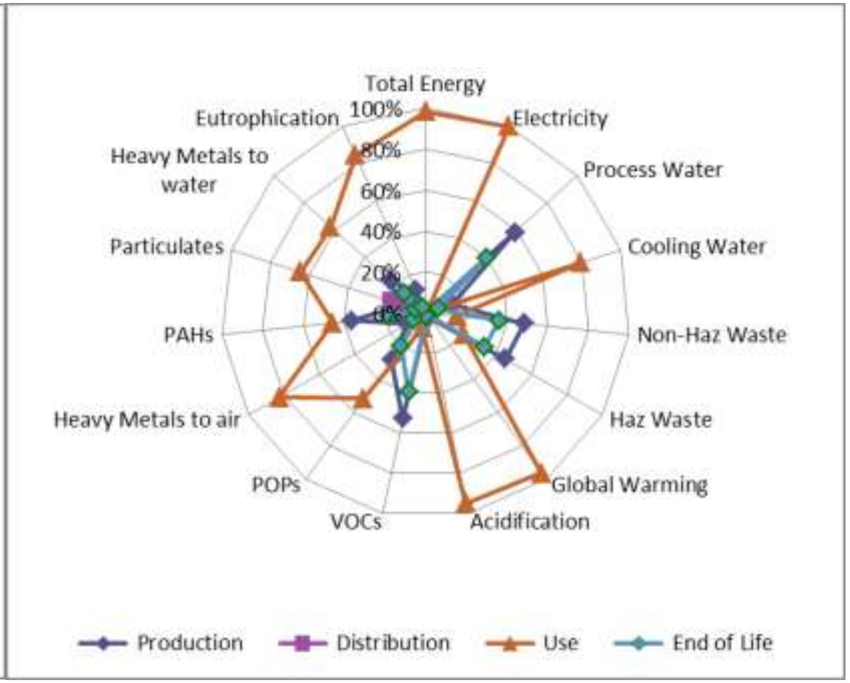
Note: *The sign of contribution (impact or benefit) is ignored in the colours and percentages, which just reflect relative magnitude. For production, distribution, and use phases the contributions are impacts, for end of life phase the contributions are benefits.*

Impacts / benefits for each parameter across the different life cycle phases for bases cases 3 and 4, taking spare parts into account

Base Case 3:



Base Case 4:



Appendix 9 - Total stock electricity consumption and savings for the minimum efficiency performance standard scenarios

Table 125: Total stock electricity consumption and savings for the MEPS scenario – Base Case 1

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	1.583	1.600	1.637	1.686	1.745	1.815	1.886	1.956	2.027	2.097	2.168	2.238
MEPS Scenario (TWh)	1.583	1.600	1.637	1.493	1.351	1.006	0.647	0.465	0.276	0.285	0.295	0.304
Savings (TWh)	0.000	0.000	0.000	0.193	0.394	0.809	1.239	1.491	1.751	1.812	1.873	1.934
Savings. (%)	0.0%	0.0%	0.0%	11.4%	22.6%	44.6%	65.7%	76.2%	86.4%	86.4%	86.4%	86.4%

Table 126: Total stock electricity consumption and savings for the MEPS scenario – Base Case 2

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	6.297	6.308	6.288	6.477	6.613	6.787	7.001	7.239	7.495	7.775	8.056	8.336
MEPS Scenario(TWh)	6.297	6.308	6.288	6.097	5.838	5.192	4.555	3.912	3.258	2.597	1.906	1.566
Savings (TWh)	0.000	0.000	0.000	0.380	0.775	1.595	2.446	3.327	4.237	5.178	6.150	6.770
Savings (%)	0.0%	0.0%	0.0%	5.9%	11.7%	23.5%	34.9%	46.0%	56.5%	66.6%	76.3%	81.2%

Table 127: Total stock electricity consumption and savings for the MEPS scenario – Base Case3

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	0.808	0.823	0.835	0.843	0.848	0.876	0.897	0.923	0.953	0.985	1.019	1.056
MEPS Scenario(TWh)	0.808	0.823	0.835	0.828	0.817	0.810	0.798	0.788	0.781	0.776	0.771	0.767
Savings (TWh)	0.000	0.000	0.000	0.015	0.031	0.066	0.099	0.135	0.172	0.209	0.248	0.289
Saving (%)	0.0%	0.0%	0.0%	1.8%	3.7%	7.5%	11.0%	14.6%	18.0%	21.2%	24.3%	27.4%

Table 128: Total stock electricity consumption and savings for the MEPS scenario – Base Case 4

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	6.537	6.677	6.825	6.981	7.114	7.224	7.312	7.551	7.753	7.982	8.240	8.515
MEPS Scenario(TWh)	6.537	6.677	6.825	6.875	6.898	6.783	6.638	6.636	6.588	6.558	6.550	6.551
Savings (TWh)	0.000	0.000	0.000	0.106	0.216	0.441	0.674	0.915	1.165	1.424	1.690	1.964
Savings (%)	0.0%	0.0%	0.0%	1.5%	3.0%	6.1%	9.2%	12.1%	15.0%	17.8%	20.5%	23.1%

Table 129: Total stock electricity consumption and savings for the MEPS scenario – Total

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	15.22	15.41	15.58	15.99	16.32	16.70	17.10	17.67	18.23	18.84	19.48	20.15
MEPS Scenario(TWh)	15.22	15.41	15.58	15.29	14.90	13.79	12.64	11.80	10.90	10.22	9.52	9.19
Savings (TWh)	0.00	0.00	0.00	0.69	1.42	2.91	4.46	5.87	7.33	8.62	9.96	10.96
Savings (%)	0.0%	0.0%	0.0%	4.3%	8.7%	17.4%	26.1%	33.2%	40.2%	45.8%	51.1%	54.4%

Table 130: Total stock electricity consumption and savings for the Multi-mode scenario – Base Case 3

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	0.808	0.823	0.835	0.843	0.848	0.876	0.897	0.923	0.953	0.985	1.019	1.056
Real2 Multi-mode Scenario (TWh)	0.808	0.823	0.835	0.828	0.817	0.797	0.771	0.747	0.726	0.705	0.685	0.665
Saving(TWh)	0.000	0.000	0.000	0.016	0.032	0.078	0.126	0.176	0.227	0.280	0.335	0.391
Savings (%)	0.0%	0.0%	0.0%	1.9%	3.8%	8.9%	14.0%	19.0%	23.8%	28.4%	32.8%	37.0%

Table 131: Total stock electricity consumption and savings for the Multi-mode scenario – Base Case 4

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	6.537	6.677	6.825	6.981	7.114	7.224	7.312	7.551	7.753	7.982	8.240	8.515
Multi-mode Scenario (TWh)	6.537	6.677	6.825	6.875	6.898	6.734	6.538	6.483	6.381	6.296	6.229	6.170
Savings (TWh)	0.000	0.000	0.000	0.106	0.216	0.490	0.774	1.068	1.372	1.686	2.011	2.345
Savings (%)	0.0%	0.0%	0.0%	1.5%	3.0%	6.8%	10.6%	14.1%	17.7%	21.1%	24.4%	27.5%

Table 132: Total stock electricity consumption and savings for the Multi-mode scenario – Total for Base Cases 1-4

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU (TWh)	15.22	15.41	15.58	15.99	16.32	16.70	17.10	17.67	18.23	18.84	19.48	20.15
Multi-mode Scenario (TWh)	15.22	15.41	15.58	15.29	14.90	13.73	12.51	11.61	10.64	9.88	9.12	8.71
Savings(TWh)	0.00	0.00	0.00	0.69	1.42	2.97	4.59	6.06	7.59	8.96	10.37	11.44
Savings (%)	0.0%	0.0%	0.0%	4.3%	8.7%	17.8%	26.8%	34.3%	41.6%	47.5%	53.2%	56.8%

Table 133: Total stock electricity consumption and savings for the MEPS+Transformerless and Multi-mode+Transformerless scenarios – Base Case 4

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU+Transformerless (TWh)	4.633	4.732	4.837	4.948	5.042	5.120	5.182	5.352	5.495	5.657	5.840	6.035
MEPS+Transformerless (TWh)	4.633	4.732	4.837	4.842	4.826	4.679	4.508	4.436	4.330	4.234	4.150	4.071
MEPS+Transformerless Savings (TWh)	0.000	0.000	0.000	0.106	0.216	0.441	0.674	0.916	1.165	1.423	1.690	1.964
MEPS+Transformerless	0.0%	0.0%	0.0%	2.1%	4.3%	8.6%	13.0%	17.1%	21.2%	25.2%	28.9%	32.5%

Savings (%)												
Multi-mode+Transformerless (TWh)	4.633	4.732	4.837	4.842	4.826	4.630	4.408	4.284	4.123	3.971	3.830	3.690
Multi-mode+Transformerless Savings (TWh)	0.000	0.000	0.000	0.106	0.216	0.490	0.774	1.068	1.372	1.686	2.011	2.345
Multi-mode+Transformerless Savings (%)	0.0%	0.0%	0.0%	2.1%	4.3%	9.6%	14.9%	20.0%	25.0%	29.8%	34.4%	38.9%

Table 134: Total stock electricity consumption and savings for the MEPS+Transformerless and Multi-mode+Transformerless scenarios – Base Cases 1-4 Total

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
BAU+Transformerless (TWh)	13.32	13.46	13.60	13.95	14.25	14.60	14.97	15.47	15.97	16.51	17.08	17.67
MEPS+Transformerless (TWh)	13.32	13.46	13.60	13.26	12.83	11.69	10.51	9.60	8.64	7.89	7.12	6.71
MEPS+Transformerless Sav.1ings (TWh)	0.00	0.00	0.00	0.69	1.42	2.91	4.46	5.87	7.33	8.62	9.96	10.96
MEPS+Transformerless Sav.1ings (%)	0.0%	0.0%	0.0%	5.0%	9.9%	19.9%	29.8%	37.9%	45.9%	52.2%	58.3%	62.0%
Multi-mode+Transformerless (TWh)	13.32	13.46	13.60	13.26	12.83	11.63	10.38	9.41	8.38	7.56	6.72	6.23
Multi-mode+Transformerless Savings (TWh)	0.00	0.00	0.00	0.69	1.42	2.97	4.59	6.06	7.59	8.96	10.37	11.44
Multi-mode+Transformerless Savings (%)	0.0%	0.0%	0.0%	5.0%	9.9%	20.4%	30.6%	39.2%	47.5%	54.2%	60.7%	64.8%

Appendix 10 - UPS manufacturing stakeholders' energy labelling level proposals and suggested improvements to the ambitions of those proposals

Manufacturing stakeholders' energy labelling proposals are based on an objective of a market shift in UPS efficiency from 10% of the market achieving Energy Star requirements or better in 2014 to 55% of the market achieving Energy Star requirements or better by 2019. Instead of the suggested common label scaling (Task 8 2.2.2) for all UPS performance classifications (VFD, VI and VFI) a separate label scale for each performance classification is suggested. Only an A to G label scaling is proposed with all G level products removed from the market by 2019. Table 135, Table 136 and Table 137 summarise stakeholders' proposals and a more ambitious scaling compatible with current EU energy label design.

Table 135: Stakeholders' Distribution of A to G efficiency label scaling for each output power group (Stk's) and proposed improvements (PI) Performance Classification VFD

Label Level	**UPS Power Group Label Floor Threshold Figures For Label Graphic (%)**					
	P ≤ 1500 W		**1500 W < P ≤ 10 kW**		**P >10kW**	
	Stk's	**PI**	**Stk's**	**PI**	**Stk's**	**PI**
G	87.7	87.7	93.7	92.7	94.7	94.7
F	89.5	89.5	95.1	94.0	95.2	95.7
E	91.3	91.3	96.5	95.2	95.7	96.7
D	93.1	93.1	97.9	96.5	96.2	97.8
C	94.9	94.9	99.3	97.7	96.7	98.8
B	96.7	96.8	100.7	99.0	97.2	99.9
A	98.5	98.6	102.1	100.2	97.7	100.9
A+		100.4		101.5		101.9
A++		102.2		102.7		103.0
A+++		104.0		104.0		104.0

Note: Scaling values only (e.g. full allowances added to a measured 100% weighted efficiency UPS scales at 104.75%).

Table 136: Stakeholders' Distribution of A to G efficiency label scaling for each output power group (Stk's) and proposed improvements (PI) Performance Classification VI

Label Level	**UPS Power Group Label Floor Threshold Figures For Label Graphic (%)**					
	P ≤ 1500 W		**1500 W < P ≤ 10 kW**		**P >10kW**	
	Stk's	**PI**	**Stk's**	**PI**	**Stk's**	**PI**
G	87.5	87.5	92.2	89.7	91.1	91.1
F	89.3	89.3	93.6	91.0	91.9	92.2
E	91.1	91.1	95.0	92.3	92.7	93.3
D	92.9	92.9	96.4	93.6	93.5	94.4
C	94.7	94.8	97.8	94.9	94.3	95.4
B	96.5	96.6	99.2	96.2	95.1	96.5
A	98.3	98.4	100.6	97.4	95.9	97.6
A+		100.2		98.7		98.7

A++		102.0		100.0		99.7
A+++		103.8		101.3		100.8

Note: Scaling values only (e.g. full allowances added to a measured 100% weighted efficiency UPS scales at 104.75%).

Table 137: Stakeholders' Distribution of A to G efficiency label scaling for each output power group (Stk's) and proposed improvements (PI) Performance Classification VFI

Label Level	UPS Power Group Label Floor Threshold Figures For Label Graphic (%)					
	P ≤ 1500 W		1500 W < P ≤ 10 kW		P >10kW	
	Stk's	**PI**	**Stk's**	**PI**	**Stk's**	**PI**
G	77.4	77.4	86.4	83.3	87.9	87.9
F	79.5	79.5	87.6	84.7	89.1	89.0
E	81.6	81.5	88.8	86.1	90.3	90.1
D	83.7	83.6	90.0	87.5	91.5	91.2
C	85.8	85.6	91.2	88.9	92.7	92.3
B	87.9	87.7	92.4	90.3	93.9	93.5
A	90.0	89.7	93.6	91.7	95.1	94.6
A+		91.8		93.1		95.7
A++		93.8		94.5		96.8
A+++		95.9		95.9		97.9

Note: Scaling values only (e.g. full allowances added to a measured 100% weighted efficiency UPS scales at 104.75%).

Appendix 11 - Summary of Stakeholder Feedback on Task Reports

This appendix summarises stakeholder feedback on the task reports and how their comments have been considered. We would also like to acknowledge the significant input provided by stakeholders, which helped inform the study, for example through the questionnaire responses, and direct discussions and engagement.

Stakeholder name	Date feedback received	Task No.	Comment Ref No.	Comments	Response / Action
ZVEI	10/09/12	1	1	Directive 2009/125/EC establishes a framework for setting ecodesign requirements (such as energy efficiency) for all energy related products (ErP). It amended Directive 2005/32/EC which was restricted to energy using products (EuP) and will affect the environmental and/or energy efficiency specifications for future products that are sold and traded in Europe. Ecodesign Preparatory Study for DG Energy - ENER/C3/413-2010 “LOT 27 - Uninterruptible Power Supplies – UPS” is the first step in considering and identifying the ecodesign requirements that could be set for the UPS equipment considered in the scope of the study. From the point of view of manageability and focus, the definition in the initial questionnaire currently covers domestic and commercial equipment, though the domestic market represents only a small market share. The project team proposed the following definition of UPS to be used: “*A UPS is a combination of electronic power converters, switches and energy storage devices (such as batteries) constituting a power system for maintaining the continuity of power to a load in the case of input power failure.1”* In some applications, the UPS product is brought on the market as a “plug and play” device. But there are other applications, where the UPS is specifically designed for a specific installation e. g. in central telecommunication switching operations, in the chemical industry, in power plants or in control rooms of energy distribution networks. The same applies to power supplies for currents without transients or frequency failures for big servers, measurement systems,	Stakeholder comments and feedback regarding the scope and definition of the product group have been taken into account throughout the project to ensure a robust scope and definition has been provided. The final version, which incorporates feedback in relation to specific UPS applications and exclusions, is included at the beginning of Task 8.

				medical equipment or other critical equipment. Article 15 of Directive 2009/125/EC names criteria which shall be met, if a product shall be covered by an implementing measure. One of these criteria is that the product shall represent a significant volume of sales and trade, indicatively more than 200 000 units a year within the Community according to the most recently available figures.	
		1	2	**Custom-made uninterruptible power supplies should be exempted** The uninterruptible power supplies which are specifically designed for a specific application must meet specific safety needs defined by the installation they have to protect against failure of the input power. They are tailor made, intended to be fixed permanently for its entire ”lifetime” and used as part of an infrastructure in an industrial or commercial environment or in public buildings or e. g. a ship, used and maintained by professionals. They do not meet the criterion of Art. 15 of the ecodesign directive. They should therefore be exempted from the scope of LOT 27. It is proposed to amend the scope as follows: *This implementing measure does not apply to large-scale uninterruptible power supplies being a complex combination of electronic power converters, switches and energy storage devices(such as batteries), which are assembled and installed by professionals, intended to be used permanently in a pre-defined and dedicated location, and de-installed by professionals.*	Stakeholder comments and feedback regarding the scope and definition of the product group have been taken into account throughout the project to ensure a robust scope and definition has been provided. The final version, which incorporates feedback in relation to specific UPS applications and exclusions, is included at the beginning of Task 8. In developing the definition we have made, in line with stakeholder comments, provision for bespoke systems. Such systems are excluded from the scope of Lot 27.
EUROBAT	28/09/12	1	3	With regards to the questions in slide 28, namely to secure the consensus on the product group definition and the other products to consider excluding from this product group, we would like to highlight that **custom-made uninterruptible power supplies should be exempted from the scope.** There are uninterruptible power supplies which are specifically designed for specific application, which must meet specific	Stakeholder comments and feedback regarding the scope and definition of the product group have been taken into account throughout the project to ensure a robust scope and definition has been provided. The final version, which incorporates feedback in relation to specific UPS applications and exclusions, is included at the beginning of

				safety needs defined by the installation they have to protect against failure of the input power. They are tailor-made, intended to be fixed permanently for its entire "lifetime" and used as part of an infrastructure in an industrial or commercial environment or in public buildings or e. g. a ship, used and maintained by professionals. They do not meet the criterion of Art. 15 of the eco-design directive 2009/125/EC. They should therefore be exempted from the scope of LOT 27. We would propose to amend the exemption list (slide 24) as follow: *This implementing measure does not apply to large-scale uninterruptible power supplies being a complex combination of electronic power converters, switches and energy storage devices (such as batteries), which are assembled and installed by professionals, intended to be used permanently in a pre-defined and dedicated location, and de-installed by professionals.* We understood from the meeting that this was also the vision of the other industry partners who were present and that it will be aligned to that.	Task 8. In developing the definition we have made, in line with stakeholder comments, provision for bespoke systems. Such systems are excluded from the scope of Lot 27.
CEMEP	11/03/13	N/A	4	Proposed Base Cases: In order to be in line with IEC 62040 UPS standards the split of the UPS sizes shall be: • Below 1 kVA • 1.1 to 5 kVA • 5.1 to 25 kVA • 25 to 250 kVA • Above 200 kVA This would not change the proposed BoM breakdown. We agreed with your decision not to select products above 250kVA.	The proposed base cases were discussed extensively during the stakeholder meetings. The final base cases were agreed with stakeholders and devised as follows: • Below 1.5 kVA • 1.5 to 5.0 kVA • 5.1 to 10 kVA 10.1 to 200 kVA

				We also consider that a 200kVA unit is a good sample for the situation in the 25 to 250 kVA market and therefore that there is no need to address information for products in the neighborhood of the 40 kVA sizes.	
		N/A	5	Batteries: We acknowledge the breakdown of a typical lead acid battery composition although UPS manufacturers do not have any particular means to control and change this. Lead acid batteries are used in many other applications other than UPSs. UPS systems are only a minor part of the lead acid batteries market. Thus the UPS industry has no real power to make this breakdown change in the future. We would just like to remember that lead acid batteries disposal are part of the best controlled action in the complete life cycle of a product since UPS manufacturers have also to comply with the European battery directive.	Comments noted thank you. A description of a typical lead acid battery was taken from the literature for the purposes of this study.
CEMEP	17/05/13	3	6	As discussed you will find hereafter our different comments that we had not yet provided on the document “Task 3-Customer behavior” - Breakdown of losses fix or in proportional or square losses: We have been having, over the last decades, the objective of reducing the losses and mainly the "square" losses to tend to a pure proportional relation between load rating and losses which draw to have a "flat energy efficiency curve". The new high frequency and tranformerless products have roughly the same efficiency from 20 % to 100% load. The consequence is that efficiency sensitivity to load rating and linear/non-linear load is negligible. A secondary consequence is the reduction of sensitivity to power factor of the load.	The following text has been added to Task 3 to reflect this very positive development by industry. *‘Over the last decades the manufactures have focused on reducing the losses and mainly the "square" losses to tend to a pure proportional relation between load rating and losses which draw to have a "flat energy efficiency curve". The new high frequency and tranformerless products have roughly the same efficiency from 20% to 100% load. The consequence is that efficiency sensitivity to load rating and linear/non-linear load is negligible. A secondary consequence is the reduction of sensitivity to power factor of the load.’*
		3	7	- Standards have defined several categories of UPSs	Task 3 includes reference to the following to

				such as VI, VFD and VFI it is because they provide various kind of power qualities. Although we support the concept of future Energy Efficiency label for UPS a clear differentiation shall be made between these 3 categories.	cover this comment: "The label should also display information about general design and performance (filtering power grid disturbances and power quality)". *'The Industry supports the concept of a future Energy Efficiency label for UPS; however, it should include a clear differentiation between VI, VFD and VFI, as these different topologies provide various kinds of power qualities.'* Our Task 8 labelling proposal distinguishes different UPS categories, by proposing an allowance for certain categories enabling a common labelling scale to be adopted. An alternative approach using separate labelling scales for different UPS categories is also included in an Appendix.
		3	8	- The concept of the 2 modes as described i.e Normal or By-Pass is not used any more in our industry	Clarification added in a footnote a as follows: *'The concept of the 2 modes as described i.e Normal or By-Pass is not used any more in the industry of UPS.'*
ECOS	21/05/13	N/A	9	Following the stakeholder meeting of last Wednesday I have discussed the issue of battery life time in the Blue Angel for UPS with a colleague. There are no detailed studies or material on which the respective criteria (see Blue Angel criteria section 3.3.2 and 3.3.3) are based, the information regarding this was obtained from discussions with manufacturers. However, as it is usual in the process of setting new Blue Angel criteria, a short background study was prepared. The relevant sections in the study are 2.6, 3.2 (Header: "Anforderungen an die Batterien") as well as the brief LCA (no	We have undertaken sensitivity analysis in relation to battery lifetime by reducing the battery replacement from one to zero over product lifetime for base cases 2, 3 and 4. Further discussions regarding battery lifetimes and appropriate approaches were discussed at the third stakeholder meeting. As a result of those discussions, Task 7 outlines the proposed design options with regards battery lifetimes for the different base cases in response to stakeholder feedback.

				real LCA according to standards, only giving an overview) in section 3.1, which analyses the effect of different battery life times.	See responses to Task 7 comments regarding battery design options below, for more information.
German Federal Environment Agency, Section III 1.3 Ecodesign, Environmental Labelling, Environmentally Friendly Procurement	24/05/13	1	10	**<u>Task 1 Final Draft</u>** **P. 7 Definition/scope**: Only some products which perform functions similar to UPS are mentioned explicitly as excluded from the scope (engines and generator systems). It might be necessary to mention explicitly additional exemptions, e.g. for products with integrated batteries for mobile use (such as laptops; cf. the Energy Star specifications). **Subtask 1.3**: a reference to the **Blue Angel** is still missing. The German Ecolabel "Blauer Engel" recently published the criteria for the product group "uninterruptible power supply systems" (UZ 182), which is not mentioned in the study. This should also be taken into account in the section on definitions, where it currently says "The US Energy Star is the only existing product label identified for UPS" (p. 5). **Section 4.1.8** (p. 13) on the **Energy Labelling** Directive it says "Although UPS are not currently included under this Directive, energy labelling of UPS has been the subject of previous re-search." What does this mean, "UPS are not currently included under this Directive"? The Directive's scope clearly includes UPS, and it usually follows the work plan established under Ecodesign, i.e. products subject to Ecodesign preparatory studies are also potential candidates for the Energy Label. This should be corrected. In addition, the study should in later tasks assess whether the option of an Energy Label makes sense for UPS. **Section 4.1.9** (p. 13): In the section on the **Ecolabel**, the following sentence is misleading: "Besides the Ecodesign Directive under which this preparatory study has been launched, there is no legislation currently in place specific to the environmental or energy performance of uninterruptable energy supplies in Europe." It disregards both the Energy Star	The following text has been added to clarify this point: '*Portable devices designed to operate using battery power such as laptop computers are excluded from the product group.'* A section has been added to the report to include details of other member State schemes; this includes the Blue Angel and the UK ECA scheme. Report updated to refer to the Blue Angel. The report text has been updated as follows to clarify this point: *'There is not currently an EU energy label for UPS, although the energy labelling of UPS has been the subject of previous research. Further details are provided in the Task 3 report. '* This text has been deleted and the following added to the report to clarify this point: *'There is currently no EU Ecolabel criteria for UPS.'*

				and the Blue Angel criteria. Instead, the section should state that there are currently no EU Ecolabel criteria in place for UPS. **Section 4.1.10** on the Ecodesign Directive seems odd as the aim of the prep study is to analyse UPS under this directive. It would make more sense to discuss under this header whether there are overlaps with other Ecodesign lots, which is not done so far in Task 1 (EPS, products with integrated batteries etc.).	Reference to Energy Star and Blue Angel are made in subsequent sections of the report and are therefore not included in this section. The following text was added to clarify this point: *'It is under this Directive that this Preparatory Study for UPS has been commissioned. Other preparatory studies potentially relevant to UPS have been reviewed to check for overlaps in requirements that may have already been set in relation to UPS. None specifically cover UPS or requirements in relation to UPS, for example Lot 7 preparatory study and subsequent regulation (Commission Regulation 278/2009) specifically excludes UPS. It will however, be important to take into consideration the outcomes from the ENTR Lot 2 Distribution and Power Transformers preparatory study and subsequent regulation proposals from the perspective of transformer efficiency in larger UPS. In addition, the preparatory study on Enterprise Servers, Data Storage and ancillary equipment, is expected to commence in 2013 and may have implications for UPS and should therefore be considered as appropriate when developing the final policy for UPS.'*
				Task 1 (generally): Concerning **environmental aspects beyond energy efficiency**, no statement is made regarding which environmental aspects should be considered additionally for UPS. Energy efficiency is clearly an important environmental aspect of UPS with a still very large improvement potential. However, besides this, the use of batteries and contained hazardous substances is a relevant	The following text was added to Task 1: *It is anticipated that the environmental aspect that will be of main concern is in use energy consumption, which will be affected by both the efficiency of the product and the installation configuration. These issues will be considered and discussed in further detail in*

				issue which should be mentioned. As lead-acid batteries are commonly used in UPS systems, reducing the overall use of lead by prolonging the lifetime of the batteries is a potential improvement option. This was implemented in the criteria of the "Blue Angel" in two ways: by prescribing the prospected lifetime of the batteries and by limiting the range of spectral internal resistance in order to avoid the early end-of-life of single batteries which often results in the disposal of the entire battery set.	*subsequent tasks. In addition to energy consumption, other environmental impacts related to the use of materials may also be important. For example, the battery can be a significant part of the product by weight, which by extending battery lifetime and reducing the need to replace batteries could reduce environmental impacts for those aspects associated with particular materials. Again, this will be considered further in subsequent tasks.*
		3	11	**<u>Task 3 Final Draft V01</u>** **Subtask 3.1: operating modes** and conditions: The chapter currently discusses typical load factors and the related efficiency, but it omits a characterization of the applicable operating modes such as in other product groups (e.g. "standby" or "on-mode"; these are of course not directly applicable for UPS but probably similar modes could be derived). These modes as well as the related time a device stays in each mode typically could however be helpful to derive efficiency improvements in a transparent way. The different load factors mentioned in the study could be linked to different operating modes to state dependencies and interlinkages.	In UPS the different operating modes are the different load levels and the different conditions are the different load types. Such issues are explained briefly in Task 3, and covered in more detail as part of Task 4.
Viegand Maagoe, Denmark	17/06/13	1	12	**Comments on the scope** The general impression is that the study is well on its way and only minor comments will be given on the scope and content of preparatory study task 1, 2 and 3. A general recommendation is to a possible extent to use the experiences from the EU Code of Conduct of UPS systems and from the ENERGY STAR require-ments for UPS systems.	Thank you. Experiences from the EU Code of Conduct and the US Energy Star for UPS systems have been reviewed and taken into account in the work. Various aspects of these two schemes have been used to inform our work, for example definitions, efficiency levels and time spent at different load levels.
		2	13	**Study Structure** It should be noted that Task 2.2 and 2.3 (Market and stock data, Market trends) are reversed in the study, if not	Presenting sub-task 2.3 before 2.2 is intentional. Modelling has been required for sub-task 2.2 and subtask 2.3 provides the

				intentional, it may be more comprehensive to follow the structure of MEErP Methodology Report. Task 2 and 3 (Markets and Users) should each have clear recommendations at the end on a) refined product scope from the economical or commercial perspective, b) barriers and opportunities for Ecodesign from the economical or commercial perspective.	context of the market and the assumptions we have used for this. The analysis under Task 2 and 3 did not change the scope from an economical or commercial perspective. Barriers and opportunities relevant to UPS infrastructure are included in Task 3.
		1	14	**Task 1.2 Test Standards** It might be worthwhile to list separately the European test standards and the international test standards. Have test standards from countries such as China and South Korea being explored? A comparative analysis of the test standards could provide a useful insight into the numerous standards. A list on new test standards that are being developed, possible problems on accuracy of the test standards or to what extent they reflect real-life operation should be considered.	There are numerous international test standards for UPS. These are therefore referenced where appropriate. Appendix 1 provides further details.
		2	15	**Product Lifetime** Table 10 in Task 2 shows the product lifetimes of UPS in different sizes. It should be noted that 5.1kVA to 5kVA UPS have 8 years of lifetime, but 5.1kVA to 20kVA UPS have however lower lifetime, 7 years. This does not follow the inclining trend of lifetime with UPS sizes. It should be considered to provide explanation for this abnormality. The product lifetime in Table 10 is lower than our expectation and inconsistent with section 3.1 in Task 3. It should be considered to elaborate on the differences of the lifetimes.	The lifetimes used in the initial Task 2 analysis were based on stakeholder feedback from the first questionnaire. Following further discussion and input from stakeholders the final lifetimes were agreed at the second stakeholder meeting as follows: • Below 1.5 kVA – 4 years • 1.5 to 5 kVA – 8 years • 5.1 to 10 kVA – 10 years • 10.1 to 200 kVA – 12 years • Above 200 kVA – 15 years These have been used in the final Task 2 market analysis and also the Task 5 life cycle assessment.
		3	16	**Task 3.1 System aspects use phase**	These issues are addressed and discussed in

				Possible factors to be considered in Task 3.1: frequency and characteristic of use, temperature, power management, and Best Practice in sustainable product use etc. In addition, more subchapters could be considered to allow easier discovery of each factor.	Task 3.
		N/A	17	**Recommendations for further studies** The current study already addresses the important issues of energy efficiency of UPS that most data centers usually operate at 10 to 30% of their full load which significantly reduces efficiency. Improvement of energy efficiency has also been discussed in terms of new topologies. It could be useful to elaborate on the technology and feasibility of eco-mode and ways to promote the use of this more efficient mode. We would also recommend to explore the option of DC systems and their saving potentials and if feasible, ways to promote them. Finally, we would also recommend exploring various battery technologies and particularly if other types of batteries than normally used today, could be both feasible and reducing the environmental impact.	These points are acknowledged and are addressed in Task 6.
		N/A	18	**Recommendations for Ecodesign requirements** As the product lifetime is relatively long, a strict ecodesign requirement for energy consumption is recommended as there is large energy saving potential. Due to the fact that the efficiency of UPS is relative to the operating load, a strict information requirement for providing data sheet of power and performance for each UPS system – similar to requirements in the ENERGY STAR specification for UPS systems version 1.0 – is also recommended. This could help the technicians to choose the UPS with the highest performance at the operating load that is best suitable for them.	This is dealt with in Tasks 7 and 8.
Viegand Maagoe, Denmark	28/10/13	4 and 5	19	Consistency and clarification: It should be noted that the headings for each product type should be consistent throughout the report. It is recommended that “double conversion” is added for all “VFI” types of UPS on	The information presented in this table was provided by a stakeholder in response to the second questionnaire. The information has

				page12 in Table 6 in Task 4. In the same table, the conversion efficiency for Standby VFD 0-1.5KvA is stated "always 96 %"; a quick note on why it is always 96 % could be helpful for the understanding of this table. The calculation steps for section 3.3 in Task 5 are very easy to follow, but it should indicate in step 2 that "8760" is the number of operating hours (annual hours) to avoid any doubt. In order to keep the structure consistent with MEErP methodology, it is recommended to add Task 4.1 Technical product description which states clearly the performance, price, resources/emissions impact of existing products, products with standard improvement options, BAT and BNAT.	been included in the form it was received to provide an indication of the typical use phase characteristics. The use phase characteristics were developed further through assumptions based on the Energy Star and Code of Conduct rather than the limited use phase characteristics received via the questionnaire. A footnote has been added to clarify the figure of '8760' used in step 2. An overview of current UPS topologies is provided in Task 4, with information on performance, price, impacts of existing products, improvement options and BAT/BNAT covered in Task 5, 6 and 7.
		4	20	Efficiency for UPS: In Task 4, the conversion efficiencies for UPS of different sizes are based on the requirement of EU Code of Conduct 2011 or 2009. It should be noted that EU CoC is not mandatory; the level of compliance with CoC should be investigated before assuming that the majority of UPS are complied with either CoC 2011 version or the 2009 version.	We acknowledge that the code of conduct is not mandatory. Stakeholder feedback indicated that the use of these efficiencies was appropriate for establishing the base cases.
		N/A	21	Eco Mode UPS: Is it also accepted for very critical applications? We have the impression that companies and data centers running critical applications are hesitant to use eco mode because of it takes extra time to get power from the UPS compared to online modes. This should be dealt with.	This issue is addressed in Task 6, 7 and 8 through the discussion of redundancy.
Viegand Maagoe, Denmark	13/11/13	6	22	Flat efficiency curve: In chapter 2.1 of subtask 6.1, BAT is reviewed in terms of improving weighted efficiency and flat efficiency curve. Although there is a good definition of weighted efficiency presented in the report, the definition of a flat efficiency curve is very ambiguous. It is therefore recommended to clarify clearly what the term means; especially in this study flat	Task 6 has been updated to clarify the definition of flat efficiency: *An efficiency curve can be considered as presenting a flat efficiency if the efficiency achieved with different load levels presents a small variation.*

				efficiency curve is considered for 25 % to 100 % load. In Task 3 of the preparatory study, it was presented that most UPSs operate in the range of 10 % to 30 % load, it would be therefore recommended to present the flat efficiency curve from 10 % to 100 % load level if possible, in order to assess if efficiency is truly improved at low load levels. Additionally, there is not much mentioning of which technology should be used to achieve a flat curve. Thus, this section seems more as describing a desired target than a real BAT. Another conclusion is that an information requirement on an efficiency vs load curve or table is important in order that the customer can select the UPS which is optimised for the use. Furthermore, it could be considered if it would be possible to promote modular UPS systems, which then can be extended in line with an increased need for UPS service.	Efficiencies are considered for 25%-100% load based on the data available, and in line with the load levels tested under the appropriate test standards. The achievement of a flat efficiency curve is possible using technologies such as: digital signal processing (DSP) for a better digital control of power components, the availability of new power components in the field of semi-conductors and magnetics, as well as multi-level power topology design. These are discussed in Task 6. The proposals in Task 8 address information requirements related to optimised performance. An allowance is also provided as part of the labelling proposal to address issues of redundancy through functionality that facilitates automatic UPS replacement deactivation and load sharing.
		6	23	DC distribution: We agree that it is relevant to assess further the use of DC distribution systems at lower voltage levels due to fewer losses. However, at the same time the implications of larger currents and the selection of non-standardised server, storage and network equipment i.e. supplied with DC. There would be need for a common action broadly by the industry of various products and components e.g. through an industry standard or memorandum of understanding.	The comment is noted; however this study is focused specifically on UPS and not equipment such as servers, storage and network equipment. This may also be relevant to the Enterprise Servers preparatory study. In addition there is also an existing code of conduct for data centres, developed by the JRC, in conjunction with industry: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency
ECOS	08/02/14	7	24	We regret that the option of long life batteries is not taken into	The rationale for not including longer life

				account for BC 1 (the BC with the highest sales numbers) despite this having been requested during the third stakeholder meeting. Even though industry stakeholders say that BC 1 products are replaced anyway with the IT equipment every three years, such replacement cycles can vary, as three years is only the (claimed) average. According to the on-going preparatory study on servers, even the economic lifetime of servers is between three and five years (cf. ENTR Lot 9 study, 1st support document, p. 75). Moreover, it points in the wrong direction of the status quo, not encouraging potential users to think about acquiring a longer life product together with their longer life UPS. Also, it is not appropriate to exclude an improvement option for certain base cases already at the stage of the preparatory study, which aims at mapping out and giving an overview of the various improvement potentials. We therefore call for the inclusion of long life batteries for BC1 in this Task.	batteries in relation to BC1 have been expanded in Task 7. An alternative design option for BC1 products in relation to the battery has been included to take into account circumstance where it would be appropriate to extend the product lifetime and not replace it at the same time the IT equipment is upgraded. This focuses on designing products to enable battery replacement, battery monitoring and operating conditions.
		7	25	Even though greater life cycle cost savings and environmental impact reductions can be achieved through the energy related design options, we believe that the reduction in life cycle costs as a result of moving to longer life batteries coupled with lower hazardous waste and VOC emissions, are significant reasons for this improvement option to be tackled in Task 8. **We therefore call upon the study team to explore in the Task 8, policy options of incorporating longer life batteries in a potential future regulation**. Further details are given below (Task 8 section).	See response above regarding long life batteries in relation to BC1. In addition Task 7 outlines the reasons for not progressing with specific requirements for long life batteries for BC2, 3 and 4. This however has been updated to include proposals relating to information requirements in relation to batteries, and is covered further in the Task 8 report.
		7	26	Regarding other improvement options that had been discussed during the stakeholder meeting, but that are not considered in the final report, we recommend that these are expanded on beyond the footnote on p. 11, which will be easily overlooked ("For other design options discussed with stakeholders, for example the automatic battery self-test or internal resistance of battery cells, there are no detailed data available to calculate the improvement potential properly. Nevertheless stakeholder confirmed the improvement	A section has been added to Task 7 to include a brief overview of the discussions held with regards internal resistance of batteries and automatic battery self-test.

				potential in general."). **More data data may become available in the future, so we suggest to include some more short background on these options on p. 3**, which can be further investigated in the future (e.g. in a review study).	
		8	27	**Concerning, longer life batteries, policy options should be investigated under this task**, as aforementioned. These could take the form of an information requirement (section 2.2.3 of the report), whereby information is conveyed to end users concerning benefits from the use of longer life batteries via technical documentation, booklet of instructions and free access websites of manufacturers.	Task 8 has been expanded to include proposals for the inclusion of information relating the benefits of longer life batteries and factors that affect lifetime, for example operating conditions. It also proposes a requirement for clear instruction on how to replace the battery for smaller UPS products.
		8	28	With regard to other design options discussed at the stakeholders meeting "for example the automatic battery self-test or internal resistance of battery cells" and on the basis that improvement potential was confirmed, the groundwork should be laid out in a future regulation that would lead to generation of data and potential consideration at a later stage. **Reference to these improvement options should therefore be made in an information requirement or in a potential review clause**, so they are tackled at the review of a potential future regulation.	A section has been added to Task 7 to include a brief overview of the discussions held with regards internal resistance of batteries and automatic battery self-test. In addition, Task 8 includes reference to the testing of internal resistance of batteries as a possible resource impact bonus for labelling. Limitation in terms of definitions and test standards relating to some functionality, including battery testing is included in Task 8.
		8	29	We support the declaration of annual energy consumption on the Energy Label, as it is important to convey this information to the final user.	Noted, however the annual consumption will vary depending on load and usage patterns and in the case of multimode UPS the condition of the mains supply. In an optimum main supply situation a multimode UPS would be in full bypass and use a small fraction of its full operational energy. Therefore it is proposed that the energy labelling focuses on an efficiency perspective.
		8	30	We disagree with the following statement on p. 13 on GPP: "The Green Public Procurement covers just public works contracts, public supply contracts and public service contracts	At this stage it is recommended the Commission focuses it efforts and resources on developing a well thought through

				and therefore is a policy without major impact outside the public sector." Firstly, the public sector and its purchasing impact on the market regarding more energy efficient products is not to be underestimated ; secondly, GPP does not only strictly concern the public sector, but sometimes large companies align their purchase practices with GPP criteria. **The option of setting GPP criteria should therefore not be ruled out**, especially in a preparatory study that aims at mapping out possible policy options.	mandatory policy based on MEPS and Energy Labelling which addresses the market as a whole, rather than diluting its resources developing multiple options. Once MEPS and Energy Label requirements have been adopted, suitable groundwork will have been completed for informing GPP.
		8	31	Also on p. 13: "European Ecolabel – UPS are already covered by the EPA Energy Star Product Labelling. The specifications of such label are recognised by the different manufacturers and therefore it is not recommended to implement another label with different specifications. However, the adoption in Europe of the existing Energy Star label, has already happened for office equipment, and so is a possible solution for UPS." While indeed the adoption of the Energy Star in this field is a positive development in the EU, **an Ecolabel could cover additional environmental aspects (e.g. related to resource efficiency, end of life, hazardous chemicals) and should therefore not be ruled out**.	UPS are already covered by the EPA Energy Star Product Labelling. The specifications of this label are recognised by the different manufacturers and therefore it is not recommended to implement another label with different specifications and or other requirements. Of note is that the adoption in Europe of the existing Energy Star label is well underway. The scope of the European Ecolabel means it could include additional environmental aspects, for example relating to resource efficiency and end of life. However the proposed Energy Labelling and Ecodesign information requirements address important aspects beyond energy efficiency, including battery monitoring and maintenance and addressing aspects relating to redundancy. As with GPP, it is recommended at this stage that the Commission focuses it efforts and resources on developing mandatory policies addressing the market as a whole and after these are implemented, considers the need and scope of other policy initiatives.
		8	32	It seems unclear where the improvement option of extended battery life was considered in the scenarios. Obviously not in the Ecodesign measure, which seems to cover only MEPS – even though table 12 seems to suggest this. This	Table 12 has been deleted to avoid confusion. Options relating to batteries focus on information requirements. Task 8 has been expanded to include proposals for the

				improvement option should be clarified.	inclusion of information relating the benefits of longer life batteries and factors that affect lifetime, for example operating conditions. It also proposes a requirement for clear instruction on how to replace the battery for smaller UPS products.
Danish Energy Agency	10/02/14	7	33	Following our comments for earlier tasks that flat efficiency curve is more of a target rather than a BAT, it is unclear how flat efficiency could be achieved in task 7 - improvement options.	This has been addressed in Task 6 and a short explanation added to Task 7 outlining the types of improved components that can be used to achieve flat efficiency.
		7	34	There is contradicting information given in the preparatory study on the load levels. On page 3, it states that it is unusual for UPS to operate below 20-25 % load level, slightly contrary to which, in Task 3 figure 2 shows that most data centres operate in 10 % to 30 % range. There should be a clarification whether figure 2 only applies to data centres, or investigate if information is incorrect or outdated; it is recommended to keep the messages consistent in the reports. It should also be taken into account that the load will be substantially reduced after server virtualization and consolidation. Often the load is reduced to below 20-25 % due to re-moval of servers. Virtualization and consolidation is an ongoing activity in the data centre and server room area.	The paragraph in Task 7 has been updated as follows to clarify the position with regards load levels: *‘Stakeholder feedback indicates that it is not the norm for a UPS to operate below 20-25% and a UPS operating below this load level would be considered poor system design. UPS systems may operate below this level for limited periods, for example soon after system installation, where an over allowance has been included to allow for IT equipment load expansion. This is reflected in the information presented in Task 3, which indicates many datacentres operate at 15-30% load. Further stakeholder feedback indicates that UPS will generally not reach loads above 50-60%, however this is not always the case and some UPS applications may have higher loads depending on specific circumstances. Therefore this design option focuses on the load levels of 25, 50, 75 and 100%, which are consistent with the load levels at which products are tested under IEC 62040.’*
		7	35	Regarding improved component section on page 5 and the	The improved efficiency scenarios will be

				statement “Stakeholder feedback indicates that implementation of improved components is de facto as they become viable.”: Our experiences from electronic product development are that there are many parameters that a manufacturer needs to take into account when deciding on the use of improved components, which does not always result in a cost optimized product for the customer in the LLCC perspective. Therefore, we believe that there are still possible savings that can be achieved with feasible improved components. In the same section, it is stated that 2.5 % total consumption reduction for separation or isolation transformers is a limited potential. It is difficult to judge if it is a small or large potential; therefore please also state the estimated potential in TWh in order to better decide on actions needed in relation to the size of the saving potential.	achieved through improved components and control. This has been addressed in Task 6 and a short explanation added to Task 7 outlining the types of improved components that can be used to achieve flat efficiency. It is recommended in the Task 8 report that the transformer losses where they are used in UPS are declared in the product Fiche and that the UPS is physically configured so that independent conformance tests can verify these losses. The losses may then be added to the measured efficiency of the UPS for labelling purposes. It is also recommend that if the UPS is not configured so that transformer losses can be readily verified independently then for labelling purposes a BAT transformer loss of an average of 2.5% is used for the labelling efficiency level. Our understanding, based on industry feedback is that transformers are a small part of the total market and strictly tied to safety considerations. We therefore believe our approach in dealing with transformers is sufficient and proportional to the potential impact they have with regards UPS.
		7	36	Page 6, above the formula, it should be corrected that Energy Star is not a standard, but a voluntary labelling scheme. The formula is not meant for assessing the impact of multi-mode, but for finding average efficiency for qualification purposes.	Report updated to reflect that the Energy Star is a voluntary labelling scheme. The main objective of the equation is to calculate an average efficiency with different modes. It is correct that its main purpose is to

					calculate efficiencies for Energy Star qualification purposes; however it is also suitable for our purposes to enable the assessment of multi-mode scenarios. Industry feedback at the 3rd stakeholder meeting supported the use of this equation for this purpose.
		7	37	On page 7, it is stated that longer battery lifetime is not considered for BC1 due to no battery replacement, but a longer battery lifetime could mean a longer BC1 UPS lifetime. It should be considered that the customer behaviours can be influenced by product quality, if the BC1 UPS lasts longer, it will not be necessary to replace them when the IT system is being changed. Therefore, we neither understand the comment on page 22 that "The use of batteries with an extended lifetime is not effective in BC1..."	The rationale for not including longer life batteries in relation to BC1 have been expanded in Task 7. In addition an alternative design option for BC1 products in relation to the battery has been included to take into account circumstance where it would be appropriate to extend the product lifetime and not replace it at the same time the IT equipment is upgraded. This focuses on designing products to enable battery replacement, battery monitoring and operating conditions.
		7	38	In the summary of design options, page 10, we recommend to provide solid arguments for not including "improved components" as a design option.	The summary table has been updated to reflect that improved components are used to achieve flat efficiency. Excluding transformer based UPS from the market is not appropriate for the reasons outlined in Task 7.
		7	39	Page 21 task 7.3 costs, we would like to know if experts and/or stakeholders outside the UPS manufacturers have been consulted on the cost implications behind the design options.	The cost information relating to batteries included in this section is mainly from product catalogues. The reports are in the public domain for stakeholders to review, comment upon and provide additional data. We have not received any additional data with regards to battery costs. With regards other design options, cost information presented for these have been informed by feedback from stakeholders.

		7	40	On page 23, it states most UPS are never loaded at 50-60 %, in combination with previously provided information above, it is deduced that the most common range for UPS is between 20 % to 60 %. It should be considered, if the deduction is correct, whether the focus should be on getting the efficiency between 20 % and 60 % as high as possible instead of flat efficiency between 25 % - 100 %. However, it should be emphasised here again that we believe below 20 % load level could still be relevant.	Task 7 has been updated to clarify the position with regards load levels, and also the cost of increasing efficiency at different load levels. Stakeholder feedback indicates that if a UPS operates with less than 20% load it should be considered a poor system design and not a normal operation of the UPS. This would therefore be a system design issue, rather than a product efficiency issue. Stakeholder feedback suggests that the costs of extending flat efficiency below 20% would be significant and not necessary as this is not the normal operation of UPS. Higher load levels may be applicable in some cases. The study team has identified that a modular approach to UPS installation allows much better matching of a UPS to the load requirement to optimise efficiency throughout the lifetime of an IT complex. This is discussed further in Task 8.
		7	41	On page 23, it is stated that eco-mode requires more digital control capability, which could be prohibitive in cost. We recommend that the statement is supported with facts as far as possible in order to be able to know how the project team came to the conclusion.	This was feedback provided by a stakeholder. No additional information has been provided or identified. The report has been updated to clarify the source of this statement.
		7	42	On page 29, it is stated that "End users do not necessarily consider they are using long life batteries and take a precautionary approach, replacing them before it is necessary". We believe that larger, professional end users with a structured maintenance approach would know the life time of the batteries. An option would be to include an information requirement, e.g. with a label on the UPS.	An information requirement has been proposed to cover the benefits of longer life batteries.
		7	43	On the same page, it is stated that "The lifetime of batteries is affected by a range external factors...". We would like to know if this comment is specifically for the long life batteries or for	This relates to all batteries. The operating condition will affect battery lifetime, as discussed in previous reports. It is therefore

				all batteries. We would also like to know if there would be experiences available that could indicate real life time.	proposed that an information requirement on the optimal conditions to maximise battery lifetime are included.
		7	44	Furthermore, regarding the comment that “Cash flow means that facilities managers will purchase cheaper batteries at the installation stage, rather than the longer life option.” it would not be the case if there is a regulative measure against it.	There are a number of variables, such as operating conditions, charging regimes etc. that will affect battery lifetime. This makes it difficult to define the performance of a long life battery. It is not therefore possible to stipulate specific battery lifetimes. An alternative approach using information requirements relating to batteries has been included in the report. This includes the benefits of long life batteries, battery monitoring and optimal operating conditions.
		7	45	The last sentence on page 29 is not very clear and we suggest editing it.	Edited to provide clarity.
		8	46	On page 5, the stakeholders indicated the best performing products from Energy Star 2013 could become the norm within 4 to 7 years. There should be a clarification that it could not be achieved by the market drive itself without the help of regulation, otherwise it renders the regulation more or less redundant. With that said, Energy Star 2013 database’s BAT are products designed probably several years ago. With the expected development, more options would be feasible. If the best performing products from Energy Star 2013 would become norm within 4 to 7 years, they should represent Tier 1 requirements, if not BaU level. Therefore it is recommended to use Energy Star BAT as Tier 1.	The 2019 requirements relate to BAT efficiencies identified from the Energy Star database. They are not based on averages, as originally thought by the stakeholder commenting. The project team believes the proposed timescales are appropriate to enable the market achieve this. Applying BAT before 2019 would be unrealistic talking into consideration the time required to develop a Regulation and the design cycle of products. This is however only a proposal and further refinement of the timescales for introducing different Tiers can be made during the development of the regulation. Further discussion on this point with the stakeholder clarified the position.
		8	47	In Tier 2, information requirements for redundancy and long life batteries should be included, e.g. there should be information on the manufacturer's website on use of reduced	See response to comment 46 above regarding efficiency levels.

				redundancy and long life batteries. Furthermore, there must be more efficient options for Tier 2 than best Energy Star 2013 products (or older).	We tackle redundancy in a way that could not be achieved through regulation by recommending Automatic Management Systems (AMS) and encouraging it through labelling rewards. We established at an early stage in our report that redundancy is a user choice that could not be qualified through regulation that might compromise IT security. CEMEP and most manufacturers provide detailed information to users (White Papers etc. on their websites) on levels of redundancy associated with required installation security. Information requirements relating to batteries have now been proposed.
		8	48	On page 10, UPS battery monitoring is mentioned. It seems like an advantageous technical option and we recommend considering to include this option as an option for extending lifetime of the battery.	Battery monitoring is included as part of the labelling allowances proposal.
		8	49	On page 12, we recommend to include an information requirement on redundancy and life time of batteries.	Information requirements relating to batteries have now been proposed.
		8	50	On page 13, it should be noted that EU Energy Star for UPS version 1.0 is planned to be adopted very soon.	Feedback from the EC desk officer for the EU Energy Star indicates that the current US Energy Star was adopted for Europe on 20th March 2014 and will be published in the Official Journal shortly afterwards.
		8	51	On page 21, impacts from labelling, it is mentioned that “example saving scenarios have been included”. We recommend including a reference to the place in the report with the examples.	Report updated, and examples cross referenced where applicable.
		8	52	On page 25, the industrial electricity prices are used in the analysis. However, it should be considered that a lot of the places where UPS are used may not qualify for industrial	The issue was addressed in Task 5, with sensitivity analysis undertaken for BC1 using the domestic/household electricity rate.

				electricity prices, household electricity prices or reduced household electricity prices may be used.	In addition Task 8 includes sensitivity analysis regarding to the fluctuations between member states.
		8	53	On page 30, regarding the timing of the MEPS Tiers, we recommend to state the basis for proposing this timing.	These dates were chosen on the basis that 2017 would be the earliest date at which Regulation would be likely and that BAT products are already available on the market in 2013, which will have been designed two to three years previously, allowing sufficient time for these to become the standard in 2019. The report has been updated to outline this.
		8	54	Minor detail to be corrected in the table on page 30: the last row is missing % sign, it should be kept consistent. The table shows only up to 2025, it is recommended to include up to 2030, according to MEErP.	Report updated.
		8	55	On page 31, referring to MEErP methodology for summary of policy recommendations, it could be useful to include a summary table presenting assumptions as well as possible negative impacts behind BAU, regulation scenarios, and savings in TWh for each scenario in 2020, 2025 and 2030 etc. The conclusion should be revised after taking our comments into account.	A summary table has been added to the conclusions to outline potential savings from the different scenarios, when compared against the business as usual scenario.
UBA	07/02/14	8	56	We welcome the thorough analysis of the study and the proposals for improving the energy efficiency of UPS, which point out the significance of the improvement potential for this product group. The timing should not be delayed further as introducing tier 1 in 2017 seems feasible. We also welcome that the option of extending the battery life time was suggested in Task 7 - it is, however, not clear where this is reflected in Task 8 as a policy option. This option should be included in the scenarios to avoid that it will be "forgotten" later in a potential regulatory process. (By the way, the abbreviation MEPS is used for both "minimum environmental	The rationale for not including longer life batteries in relation to BC1 have been expanded in Task 7. An alternative design option for BC1 products in relation to the battery has been included to take into account circumstance where it would be appropriate to extend the product lifetime and not replace it at the same time the IT equipment is upgraded. This focuses on designing products to enable battery replacement, battery monitoring and

				performance standards" AND for "Minimum Efficiency Performance Standards" in the study, where the former could in principle include battery life time, while the latter couldn't.)	operating conditions. In addition Task 7 outlines the reasons for not progressing with specific requirements for long life batteries for BC2, 3 and 4. This however has been updated to include proposals relating to information requirements in relation to batteries. The Task 8 report has been expanded to include proposals for the inclusion of information relating the benefits of longer life batteries and factors that affect lifetime, for example operating conditions. It also proposes a requirement for clear instruction on how to replace the battery for smaller UPS products.
Staffan Reveman	20/01/14	8	57	With Facility DC-UPS for 380VDC is it possible to involve renewable energy in a very simple and reliable way. PV modules on the roof can be connected direct to the DC bus via a simple DC regulator device. In central Europe we can calculate with 950 hours of full power from PV modules per year. The cost for PV modules are decreasing so that an oversizing of the system in combination with a larger battery bank can squeeze out even more then 950 h/year. A data center for standard commercial use has due to the energy proportional server processors a higher power consumption during the day which is interesting in combination with PV-Modules. Attention: a PV inverter is not needed with this setup! A datacenter like this is already running in Sweden in a government facility since 2 years and they are very happy.	This is outside the scope of UPS defined in Task 1 for this study. However a paragraph has been added to the section on DC Distribution in Task 6 for completeness.
EUROBAT	27/01/14	7	58	We have received many comments from our members / battery manufacturers on the proposed assumptions about the cost increases and the weight increases between the two battery lifetime scenarios proposed in your study. None of our battery experts support the values of the weight	Increasing the amount of lead in a lead acid battery is a well-known option to extend the battery life and has been adopted by several manufacturers. Such a solution increases the weight of the battery and has an associated influence on the BoM. The project team is

				increases that are indicated in the slide n° 21 of the presentation from the 3rd stakeholders meeting. Even though the weight of a battery was a quality character in the past because they simply added lead (or specific alloys), today it is much more complex on how they can increase the lifetime of a battery. The development of lead batteries over the many years for increasing the design-life has led to divergent technical solutions at all levels (chemistries, metallurgy, thermal design, manufacturing methods…). Those technical solutions can possibly impact the weight of the battery but does not necessary led to an increase. In some cases there is simply no increase of the weight to produce batteries with a longer design-life. We fully understand the purpose of the exercise in the study and the need to focus on the weight of the battery to define the impact on the BoM, but the assumption that the weight would increase because the battery is designed for a 'longer life' is certainly not correct and is not supported by our experts; there is simply no direct correlation between the design-life and the weight of a battery. As for the cost increase due to using a battery with a longer design-life (slide n°25), we cannot go too deep in the cost aspect but we would like to highlight that it make more sense to speak about the "total cost of ownership over the lifetime". In this context we can confirm that the total cost will be less if you go for more robust solutions (e.g. using batteries with a longer design-life). The design-life is the estimated life determined under laboratory conditions. A EUROBAT brochure classifies the design-life of batteries in 4 main categories. This brochure can be downloaded from the EUROBAT website http://www.eurobat.org/brochures-reports. This document is currently under review and an updated is scheduled to be published in the spring of 2014.	aware that there are other technological options to increase the battery life. Since these different technologies are not standardised and may vary from manufacturer to manufacturer, the focus has been on the common technology. As the impact of the implementation of long life batteries is marginal compared to other design options (1%), independent from the technology applied, it was decided to model the worst case scenario in terms of weight. This is based on data currently available to the public from products available on the market (the percentage of weight increase was assessed using the datasheets of batteries with the same characteristics, from the same manufacturer, but with different lifetime) and not to model other potential technological and design options with smaller or no influence on the battery weight. Footnotes have been added to the relevant sections of our report to clarify the approach we have taken. Using batteries with a longer design-life, described as option E, will increase the initial purchase cost, but lead to a reduced total cost of ownership over the lifetime of the UPS since only one longer life battery is needed instead of two standard life batteries. This assumption is only valid, if the use time of the UPS is according to the average life time expectation of a UPS as mentioned in Task 5. If the life of the respective UPS is shortened due to decisions by the user to shift to new equipment before the end of the scheduled life time, the assumptions made above are not valid. There are no data available about

					the number of UPS systems taken out of operation before their technical end of life. Task 7 provides further details of the life cycle costs of UPS when considering long life batteries.
		8	59	With reference to the advice on the Minimum Environmental Performance Standards (MEPS – paragraph 2.3.1) and the analysis on the environmental savings in relation to the eco-design requirements (paragraph 3.1), EUROBAT would like to highlight that the applicable IEC standards on battery safety tests and the IEC standards on battery performance and reliability tests are undeniable related to the eco-design objectives. For that reason we believe that these standards should be the basis and should be part of the eco-design requirements to ensure that we meet the safety aspect and that the claimed performances/design-life of the batteries on the market fulfill the severe test requirements. May we ask you to include this requirement in the study?	In Task 8 it is proposed that details should be provided to confirm that the UPS battery has been tested and meets the relevant IEC standards with regards safety and performance. Example standards relating to battery performance, reliability tests and safety tests have also been added to Task 8.
CEMEP	31/01/14	8	60	The Energy Star program is considered as an Elite program for which only 20% of the UPS market shall comply with. The Energy Star level shall never be market access requirements. Best performing products from the 2013 Energy Star database are high end products developed in accordance with more demanding specifications than the average market needs and with a corresponding cost for the customer between 1.5 and 2 times more than the average cost of products with equivalent power rating and technology. De facto this cannot be the level for your “Tier 2”scenario.	Our proposal is that Tier 2 (based on 2013 best performing products) is operational from 2019. The assumption is that between now and 2019 the market moves towards higher efficiency. Over the same time frame the Energy Star standard would similarly move to a higher standard. The purpose of including MEPS is to ensure that products with low efficiency levels are not brought indefinitely onto the market. It is common practice that energy star data and specifications are used as reference for Ecodesign regulations or (binding) Voluntary Agreements, of course with different, more generous, time frames. Further discussion with the stakeholder indicates that in 2015 Energy Star have

					indicated they will start to look at revising their criteria. Energy performance in some UPS will plateau and an adjustment to included non-energy attributes is likely. In addition, DOE US has announced plans to create a mandatory requirement for UPS – when this has been done previously for other products Energy Star requirements have been taken as the minimum performance standards – this would eliminate the need to have Energy Star requirements and the EPA may "grandfather" (suspend) Eneregy Star for UPS.. Cemep's US representative indicated this is likely to be the case. It was also pointed out by the stakeholders US representative that the DOE regulation for UPS would only apply to retailed products intended for domestic and office use. It is understood from stakeholder feedback that the costs of improving products to meet existing BAT efficiency levels is minimal, and can be achieved mainly through improved energy management controls. To achieve improvements above existing BAT would incur significant additional costs as different components would need to be used including larger semi-conductors. This has therefore not been considered as part of the design or policy options. Current variations in product price is understood to be a commercial marketing issue enabling the distinction between for example, entry level and premium models, rather than a reflection of the long term manufacturing costs, which will reduce as products become established and production

					levels increase.
		8	61	The E.C program should operate a voluntary program for a few years, gather data and then decide which products to exclude from the market if any. It shall be a way for customers to make a selection on the best efficient products and for the governments to decide on possible local incentives or penalties. If a minimum market exclusion level was to be given it should be in the low end of the labelling program products with low efficiency not to be marketed.	A voluntary programme as outlined in your response could potentially give rise to different Member State approaches, causing coherence problems later. Previous stakeholder feedback also indicated that a voluntary approach was unsuitable for the smallest sizes of UPS, due to the large number of manufacturers and products on the market. A mix of voluntary and mandatory approaches would not be appropriate, as it would cause confusion for customers and additional administrative burdens. For these reasons we do not propose to recommend a voluntary approach to the EC. The information previous work, including the Code of Conduct and the Energy Star database provide sufficient data to characterize the efficiency levels. Our proposal is to exclude the lowest efficiency products and ramp up the standards in order to move the market forward. This is a common approach used for other products groups covered by the Ecodesign Directive, such as fridges and lamps, with the majority of the market for these products now at the top end of the performance spectrum.
		8	62	Shall such an unrealistic program apply for “Tier”, the time lines as stated in the report are too short. The time line shall be based on the size of the product with larger products having more time (e.g 5-7 years for small products and 10-12 for large products).	The Task 8 report presents a proposal for consideration, with sensitivity analysis undertaken on the potential implementation time line. With regards longer lifetimes for larger sized UPS products one option to consider would be to apply requirements for certain product types only from tier 2 on (and/or implement a tier 3 at a later date). A similar approach has been used in Regulation

					801/2013 for networked standby, where certain equipment was exempted from the first tier requirements to take into account longer redesign cycles. The implementation time line would be a point for refinement during the Consultation Forum meeting stage.
		8	63	In the 2011 edition of the UPS Code of Conduct the manufacturers have committed to "achieve the minimum energy efficiency targets set out in Annex B for new UPS models placed on the market after 1.1.2011" (4.2)and not for older models. Many UPS products are not complying yet with the UPS Code of Conduct levels. Some of the current marketed products have been launched few years ago before the CoC was implemented. Some recently introduced new products will be in the market for few years. This could be for a period of 10 to 12 years for large sizes. This means that 2013 efficiency levels from the UPS CoC could not be applicable for the Tier as called "Business as usual". We are convinced that the IEC 62040-3 standard minimum levels are reasonable and fair minimum objectives.	It was previously agreed as part of Task 5 that CoC levels would be taken as business as usual for the purposes of this study. It is appreciated that there will be older products on the market; however these should be exceptions, and not the majority of representative products. If there are still a large number of products not yet complying with the UPS Code of Conduct levels then this would support the case for a mandatory approach.
		8	64	You are assuming that the US Energy Star performance will apply at European voltages. This is not the case. Some products are more efficient at European voltages and others are not. That is mainly due to different voltages in North America (208v-480v).	We are aware of this, but do not have data available to characterize such differences. While some products can have a higher efficiency and others a lower efficiency, we would consider that in average the efficiencies would be similar for the European market with higher efficiency compensating the lower efficiency. We therefore consider it appropriate to use this information to inform the Preparatory Study. Other stakeholders have confirmed that this approach is reasonable.
		8	65	The BAT products in the Energy Star data base may not be categorized correctly (e.g. VFD or VI products listed as VFI). The Energy Star BAT products shall be validated against the manufacturer web site to ensure that the topology matches	Our BAT efficiency levels are determined from the products with the highest efficiency for the different topologies listed in the Energy Star database. We have checked the

				the declared performance.	data sheets for these products, which confirm they represent to correct topologies. Any wider validation of the data in the Energy Star database would be the responsibility for Energy Star market surveillance. Other stakeholders are not aware of any particular issues regarding this.
		8	66	We recommend not to permit allowances for additional components such as transformers or others. Allowances are not enough precisely specified, with theoretical saving values on the loss reduction or life improvement (or even not technically proven e.g Battery Monitor). They should lower the requirement rather than add the measured performance of the product by creating loopholes. Having levels of 104% are counter intuitive at best and may lead to a result opposite to the objectives of a labelling program on energy efficiency or even worst open the door to possible cheaters.	Many labelling regimes have a labelling metric which makes allowances for efficiency features (e.g. Automatic Brightness Control for TVs). The metric that includes allowances in UPS is simply used for the labelling step not the measured efficiency. The various allowances proposed have been included to take into account particular issues e.g. transformers, different topologies to ensure a single labelling scale can be applicable to all products, and also promote the incorporation of features to address issues such as battery monitoring and redundancy, by rewarding such innovations within the energy label ratings. The purpose of our work is to provide the Commission with recommendations. It is for the Commission in conjunction with the Consultation Forum (Stakeholders and Member State representatives) plus, for Ecodesign, the Regulatory Committee (Member States) to decide what approach will be taken forward.
		8	67	Efficiency targets should take in account the VFD, VI, VFI technology, as this is directly related to the level of service that UPS can provide in terms of power quality, this being the essence of the UPS mission. Energy Star program, Code of Conduct and IEC 62040-3 have all indeed taken this in	Table 1 in the Task report summaries the base cases we have identified in previous tasks and the most common topology (VFD, VI, VFI) for the different sizes. The efficiency values we have used in relation to each base

				account. Table 1 in Task 8 report, proposing to split UPS by kVA sizes, is not adapted for this purpose.	case from the Code of Conduct and/or the Energy Star database take into account the different sizes and topologies to ensure we are using the most appropriate values. Our work has identified that size (kVA) and topology can influence efficiency, therefore the scaling of the labelling takes into account different sizes of UPS (Table 11) and an allowance is made for topologies where appropriate to ensure a single label scale can be used for all products. The stakeholder has provided further information for an alternative proposal for a separate labelling scale to take into account VFD, VFI and VI technology. This is included as an Appendix to the Task 8 report.
		8	68	High efficiency modes do not only consist of VFD technologies. This is an open field for innovation to provide UPS with both high efficiency levels and high power quality service. Energy Star approach to include this in weighted average efficiency calculation, such as described in 2.2.2, is the proper way to take this in account. This differs from the closed approach chosen in table 5.	We are using the weighted average efficiency calculation from Energy Star.
			69	EU policies shall not re-create information or methodology about efficiency measurement, such as in 2.2.3, but refer to the international standard IEC 62040-3 adopted by the World Trade Organization. Standards are the result of many years of works and discussions between various stakeholders in the world in order to reach a consensus.	We are not proposing to change the basic efficiency testing methodology. We are suggesting a labelling metric that incorporates allowances.
		8	70	Apart from transformer allowance, several proposed allowances are irrelevant to the actual market situation: HotSwap is a marketing term, not a technical concept as it is essentially modularity plus concurrent maintenance, and it does not take into account more advanced concepts such as automated module de-activation. Resilience at high efficiency	This allowance provides both resource efficiency through providing resilience with low UPS redundancy and energy efficiency through the better matching if UPS rating to

				is an open field for system improvement innovation; freezing one solution only is too restrictive. VFI should not get an allowance on VI or VFD, but have rather other target values. As explained above, different technologies provide different services and should have different targets You have chosen only battery resistance as non-efficiency environmental item to consider. The IEC 62040-4 standard describes a larger family of items and we recommend to value them with a different mean than distorting efficiency calculation through allowances. The narrow focus on lead-acid sealed batteries potentially negates all advances that could be made in energy storage and is therefore not suitable for a regulation that will outlast the useful life of that technology (even if we don't know yet what will replace it).	load requirements, a modular approach. Our understanding is that many manufacturers have the equivalent of hot swap systems. We propose to retain this allowance as part of our proposals; however we have updated the terminology to refer to Automatic Management System (AMS) instead of the marketing term. We have included a clear explanation in the report outlining what is meant by AMS within the context of this project. Within the context of UPS it refers to a combination of installation and modular UPS functionality which allows the automatic detection and replacement of a faulty UPS and its automatic disconnection for safe maintenance concurrent with full continuity of installation system usage. The allowance for VFI has been included to enable the scaling used for the labelling classes to ensure a single labelling scale can be applicable to all products. The alternative approach would be to have different scales and identify on the label the topology. An example of this alternative approach was provided by the stakeholder and is included in Appendix 10. We are not proposing to change the basic efficiency testing methodology. We are suggesting a labelling metric that incorporates allowances. The allowance for AMS also covers non-efficiency environmental aspects i.e. reduced resource use.

				Battery resistance test is one way to manage battery lifetime and failure; it accounts for no more than half of battery life story, and its execution reliability could heavily varies; no standardized method is there to insure its implementation is worth getting an allowance. It should not provide allowance.	Throughout this study lead acid batteries have been highlighted by stakeholders as the predominant energy storage mechanism for UPS. The Task 6 report highlights alternative energy storage that may be used in the future. We do not believe future innovation would be restricted by any potential Regulation, as it is usual for a review timeframe to be included as part of any Regulation, for example 4 years after entry into force to take into account future technological developments. We propose to amend the text in our Task 8 report to refer to batteries, rather than lead acid batteries. See response above regarding proposals and the opportunity for further discussion at the Consultation Forum. Any allowances need clear definitions/ standards to avoid ambiguity and variations in specifications between manufacturers. These can be defined as part of the regulation development and later included in a supporting harmonised standard. As there is not a current definition or standard for battery monitoring we would propose that the focus is on establishing MEPS and the labelling with the other allowances and that the battery monitoring allowance is considered as part of an update to a first regulation.
Emerson	25/03/14	8	71	The Task 8 – Scenario, Policy, Impact and Sensitivity Analysis has been subjected to Emerson Network Power Analysis. Our Company supports the activity of the consultants of EC, DG Energy. We notice with satisfaction the UPS will be	

				considered in the 2009/125/EC Directive scope and it is proposed for an Energy labelling, this will be an added value to our products, and will be an incentive to design best performing products. The simplification of the power classes from 9 as per 62040-3 to 4 (BC: Base Case), as proposed by the Tasks, make the result of this study more comprehensive. What it has been noticed is that the methodology considered in this document to calculate efficiencies is the one adopted by the Energy Star Program which is not in consistency with EN62040-3. We support the use of the average efficiency and therefore of part of the methodology present in Task 8, but we have some remarks about the way Energy Star formulas and coefficients have been considered in the calculation. Indeed, the methodology does not consider and correctly addresses the latest technology already in use in three-phase UPS. This technology has been developed to clearly improve UPS efficiency and therefore increase significantly energy savings for customers. In the next two chapters we aim to propose some adjustments to the methodology proposed in Task 8 in order to better reflect the offering present significantly in the UPS market in the last 3 years with highest efficiency without compromising on reliability.	Products with the functionality to operate in three different modes were highlighted to stakeholders during the third stakeholder meeting. However the use of Energy Star equations for the calculation of efficiencies was preferred by the wider stakeholder group as it forms part of an existing standard and methodology that manufacturers already use.
		8	72	The following table defines the average time spent at the proportion of reference load; it has been extracted by Energy Star Program (Version 1.0 Program Requirements for Uninterruptible Power Supplies (Rev. Jul-2012) — August 1, 2012), and proposed as it is in the Task 8 of the preparatory study.	It was agreed at the second stakeholder workshop during Task 5 that the percentage time spent at different load levels would follow that established by Energy Star to ensure consistency between the Preparatory Study and existing policy measures. Industry stakeholders were in support of this approach. Given that the US Energy Star is to be

Task 8 Base Case	Output power P [P] Units: Watts	Input Dependency Characteristics	Proportion of Time spent at specified Proportion of Reference Test Load [t]			
			25%	50%	75%	100%
BC 1	P ≤ 1500 W	VFD	0,2	0,2	0,3	0,3
BC 1	P ≤ 1500 W	VI or VFI	0	0,3	0,4	0,3
BC 2 & 3	1500 W< P ≤10000 W	VFD, VI or VFI	0	0,3	0,4	0,3
BC 4	P > 10000W	VFD, VI or VFI	0,25	0,5	0,25	0

Load profiles for BC1, BC2, BC3 come from assumptions of typical consumer/commercial use cases, as data were not available to EPA. We think European manufacturers may have the same troubles to find data from field since the most of these units don’t have monitoring systems able to extract this information. Most of the products falling on these base cases are business to customer marketing and don’t require specialized servicing.

The situation is completely different for BC4 (usually business to business), where there is a more significant amount of statistical data available from different manufacturers and for sure from our side, where we are constantly remote monitoring roughly 11.000 UPS.

New technologies, such as the circular redundancy, which many UPS manufacturers are promoting in the high power end of this segment are pushing the UPS usage more on the right of the efficiency/load curve. Therefore, the 100% load point is still relevant and should be taken into consideration at least with a 0.1 weight as proposed in table below.

With the result to match with our statics the BC3 or four shall consider at least a 0.1 coefficients and change as follow:

adopted as part of the EU Energy Star programme our approach also aligns with these requirements. This consistent approach reduces the effort required by manufactures when making efficiency declarations for different policy measures.

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<tr><th rowspan="2">Base Case (BC)</th><th rowspan="2">Output power P [P] Units: Watts</th><th colspan="4">Proportion of Time spent at specified Proportion of Reference Test Load [t]</th></tr>
<tr><th>25%</th><th>50%</th><th>75%</th><th>100%</th></tr>
<tr><td>BC1</td><td>P ≤ 1500 W</td><td>0,2</td><td>0,2</td><td>0,3</td><td>0,3</td></tr>
<tr><td>BC2 & BC3</td><td>1500 W < P ≤ 10000 W</td><td>0</td><td>0,3</td><td>0,4</td><td>0,3</td></tr>
<tr><td>BC4 (proposed change)</td><td>P > 10000W</td><td>0,24</td><td>0,4</td><td>0,25</td><td>0,11</td></tr>
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<td>73</td>
<td>The same exercise has been carried out on multimode units, which is very typical in BC4. Also in this case EPA made assumption to formulate equation 2:

Equation 2:
$$Eff_{AVG} = 0.75 \times Eff_1 + 0.25 \times Eff_2$$
The equation weights at 75% the lowest input dependency mode (i.e. VFI or VI) and at 25% the time passed on the highest input dependent mode (i.e VFD), without taking in consideration the difference between European and US units. <u>Some current CE products (this is particularly valid if we consider products on Base Case 4) have the possibility to work on the three different operative modes (VFI, VI and VFD) and not only 2 of them as up until recent.</u> This is indeed a step forward of using only 2 functioning modes as it allows to increase the efficiency while keeping the same expected reliability of a VFI, VFD UPS. The formula above (Equation 2) penalizes this important feature, which increase the reliability of the Datacenter Architecture and protect the critical load from spikes and noise coming from the mains, while improving the overall efficiency.

We statistically analyzed units on Base Case 4 and the most correct results come only if an additional equation is taken in</td>
<td>Regarding a triple multi-mode calculation, it is interesting to note that we have proposed a double multi-mode equation, which is consistent with Energy Star and an approach that the wider stakeholder group were in agreement with. Likewise the time spent by UPS in different modes is also consistent with the methodology proposed by Energy Star, and is an approach that the wider stakeholder group were also content with.

It was agreed at the second stakeholder workshop during Tasks 5 and 7 that the percentage time spent at different load levels would follow that established by Energy Star to ensure consistency between the Preparatory Study and existing policy measures. Industry stakeholders were in support of this approach.

Given that the US Energy Star is to be adopted as part of the EU Energy Star programme our approach also aligns with these requirements. This consistent approach reduces the effort required by manufactures when making efficiency declarations for different policy measures.</td>
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				consideration (Equation 3 below). Therefore, instead of using only one equation, we propose to use 2 equations as below. 1. When a UPS has available only 2 working modes (Typically VFI/VFD or VI/VFD) the following shall apply: $\mathrm{Effavg} = 0{,}75 * \mathrm{Eff(VFI\ or\ VI)} + 0{,}25 * \mathrm{Eff(VFD)}$ Equation 2 2. When a UPS has available all 3 working modes (VFI, VI and VFD) the following shall apply: $\mathrm{Effavg} = 0{,}3 * \mathrm{Eff(VFI)} + 0{,}55 * \mathrm{Eff(VI)} + 0{,}15 * \mathrm{Eff(VFD)}$ Equation 3 The weights in Equation 3 come from an analysis of 60 UPS with three working modes available that are constantly remotely monitored by Emerson and which are currently working in field.	
		8	74	Some of the allowances proposed do not give a real added value, therefore our suggestion is: **No allowances shall be permitted for:** - Transformers and other components added to the configuration also if used for safety reason. Allowances for additional or embedded transformers or harmonic current filters connected at the inlet or outlet in the normal power path cannot be generically quantified. - Hot swappable UPS. Not correlated to energy efficiency - Battery monitoring system is not correlated to energy efficiency and is not the only technology to save battery life.	Further discussion was held with the stakeholder to clarify the allowances for Transformers. This is primarily aimed at products where the transformer is integral to the product and the efficiency of the UPS cannot be defined in isolation. Using an allowance based on BAT for the types of transformers usually included means that the UPS efficiency still needs to be high in order to meet the proposed requirements. The stakeholder appreciated this rationale and the issue the allowance is aimed at. They will

				Similarly to what has been proposed by CEMEP, below what we believe are more correct allowances to be considered for this exercise: **Allowances should be gained for:** - Units with VFI mode (as it is now) – therefore UPS which gain on energy savings but not using the double conversion technology to protect quality will not gain from this allowance - Units with circular redundancy or similar algorithm which maximize efficiency at low power for modular architectures. This needs to be added as an allowance since it is a clear energy saving benefit which will not be seen from the equations in point 3 - Units with algorithms to increase input dependent modes reliability (e.g. Fast Transfer) that should be considered when the investment on these technology justify the improvements (e.g. BC4). This will increase protection to the load while using the high energy efficiency mechanisms. Therefore the products which have these algorithms implemented should be given an extra allowance.	consider it further with a view to providing an alternative solution if appropriate. Further explanation was provided to the stakeholder with regards hot swap i.e. Within the context of UPS it refers to a combination of installation and modular UPS functionality which allows the automatic detection and replacement of a faulty UPS and its automatic disconnection for safe maintenance concurrent with full continuity of installation system usage. Following this clarification they confirmed this is similar to the functionality provided by products with circular redundancy. The term Automatic Monitoring System (AMS) is now used in the report to describe this functionality. The aim is not to restrict UPS to specific battery monitoring technologies, rather include the functionality of battery testing to provide end users with information on the status of the batteries, and maximise the battery lifetime by ensuring they are only changed when necessary. As outlined in our Task 8 report, further input will be required from industry to provide a workable definition with regards battery monitoring as part of a revised standard to support a potential regulation. We would propose that the focus is on establishing MEPS and the labelling with the other allowances and that the battery monitoring allowance is considered as part of an update to a first regulation. In terms of allowances for different topologies, the proposed approach in Task 8

					is for a common label scaling, therefore allowances for VFI have been proposed to enable this. The alternative approach would be to have a separate scale for the main topologies i.e. VFD, VI, and VFI. This alternative proposal, which other stakeholders have provided information on is included in Appendix 10. The stakeholder was asked to consider further their proposal to include metrics relating to fast transfer. It was not clear how this would be defined in terms of availability.
Emerson (additional information provided following their response above)	21/05/14	8	75	Emerson supports the European Commission's initiative to consider UPS under the Ecodesign and Energy labeling Directives. As a leading manufacturer of UPS, Emerson contributed as stakeholder to the preparatory study and welcomes an approach based on minimum efficiency performance requirements and energy labeling, as recommended in the Task 8 report. Nonetheless, Emerson is concerned that the proposed energy efficiency calculations do not reflect the technology of "3-mode UPS", although this technology is more efficient, equally reliable, and has already a significant penetration on the European market. Furthermore, Emerson believes that the rules for efficiency allowances should better reflect the technologies of circular redundancy and fast transfer. Allowances for transformers should also be further clarified and limited to certain types of transformers only. This paper outlines Emerson's proposals to address these concerns. Our aim is to ensure that the future regulations will effectively drive the market towards highly efficient and reliable UPS.	See response to specific issues below.
		8	76	***UPS functioning three modes within a single UPS topology***	Products with the functionality to operate in three different modes were highlighted to stakeholders during the third stakeholder

				At present, the most widespread UPS technology within industry for large installations is double conversion. In double conversion mode the UPS provides reliable insulation against power quality problems. It allows control of output voltage and frequency regardless of the voltage and frequency of input conditions. Although double conversion technology has proven to be reliable in protecting installations against disturbances, it has one notable drawback: energy efficiency. Double conversion UPS constantly work in maximum protection mode, causing the use of a large amount of surplus energy. UPS manufacturers have therefore developed 3-mode UPS. 3-mode UPS are able to differentiate between different types of electrical disturbances and to respond using the most efficient and effective functioning mode for each particular disturbance. Functioning modes are defined in IEC62040-3 as follows:: **Maximum Energy Saving mode (IEC 62040-3 VFD):** This mode detects when the need for conditioning is non-existent and allows energy flow to pass through the bypass line. In this case, efficiency may reach 99%. **Maximum Power Control mode (IEC 62040-3 VFI):** This is the double conversion mode which provides the highest level of power conditioning. It protects the load from all types of electrical network disturbances using a greater amount of energy. Efficiency at full load with the latest transformer free technology is over 96% (BAT). **High Efficiency & Power Conditioning mode (IEC 62040-3 VI):** This mode compensates only the main disturbances such as the load THDi, the load PF and main sags and swells. The energy used is derived from the use of the inverter as an active filter giving all the necessary reactive power. In typical conditions, this mode will have an efficiency of between 96	meeting. However the use of Energy Star equations for the calculation of efficiencies was preferred by the wider stakeholder group as it forms part of an existing standard and methodology that manufacturers already use. Task 8 has been updated to acknowledge that 3-mode products are available to ensure the issue is captured as part of the study and appropriate discussions between industry stakeholders with different views can be held as appropriate within the Consultation Forum process.

				and 98%, depending on the load type (e.g. non linear, linear etc.) and the input mains conditions. 3-mode technology allows to achieve significantly higher energy efficiency by quickly and seamlessly activating one of the three different functioning modes of the UPS (based on the above described standards).	
		8	77	***Efficiency calculation for 3-mode UPS (average efficiency of the three functioning modes)*** Regarding efficiency targets, Emerson supports the approach to set mandatory energy efficiency requirements based on weighted efficiency average. Nonetheless, we are concerned that the proposed methodology to calculate efficiency levels for multimode UPS does not correctly address the technology of 3-mode UPS above described. The proposed equation in Task 8 (Equation 2) estimates the lowest input dependency mode (i.e. VFI or VI) at 75% and the time passed on the highest input dependent mode (i.e VFD) at 25%. It does not take into account UPS which can work on the three different operative modes (VFI, VI and VFD). Based on data gathered by Emerson from the remote monitoring of 60 3-mode UPS in operation, Emerson proposes a new equation (Equation 3 below) for UPS with 3-modes, in addition to Equation 2, for UPS with 2 modes. 3. When a UPS has only 2 working modes available (Typically VFI/VFD or VI/VFD) the following equation should be used: Equation 2: $\mathrm{Effavg} = 0{,}75 * \mathrm{Eff(VFI\ or\ VI)} + 0{,}25 * \mathrm{Eff(VFD)}$ 4. When a UPS has all 3 working modes available (VFI, VI and VFD), the following equation should be used:	Please see response above. Task 8 has been updated with the following footnote to cover this aspect: *This equation from Energy Star covers 2-modes to calculate multimode efficiency. The use of this equation was agreed with stakeholders during discussions at the third stakeholder meeting. Stakeholders advised that in their view, it was not necessary to make special provision for 3-mode functionality, as the majority of manufacturers only use 2-mode functionality, which also aligns with the approach and equations already established in Energy Star, reducing the testing burden on manufacturers. It was also indicated that they had no data available to inform the study and a revision of the equation to cover 3-mode functionality. Subsequent feedback from another manufacturer proposes a revised equation to take into account three mode functionality – details are included in Appendix 11. The manufacturer has used their own monitoring data to establish the proposed time spent at each of the 3-modes within their equation, which cannot be verified. It is recommended that this issue is discussed with the wider manufacturing stakeholder group during the Consultation Forum process to establish*

				Equation 3: $$\text{Effavg} = 0{,}3 * \text{Eff(VFI)} + 0{,}55 * \text{Eff(VI)} + 0{,}15 * \text{Eff(VFD)}$$	*whether verifiable data is available in order to develop a proposal, the extent of 3-mode functionality and reach a consensus on whether it is appropriate to include a 3-mode efficiency equation.*
		8	78	***Allowances*** **Circular redundancy** Emerson believes that efficiency allowances should be granted for UPS equipped with circular redundancy. When using a redundant system it is common that the UPS operates at light loads which in turn lowers its efficiency. Circular redundancy capacity allows the system to automatically switch off excess UPS power capacity not used in meeting immediate load requirements. This allows UPS to operate with extremely high efficiency even at very light loads, while at the same time increasing the level of the system reliability by activating only the required number of power modules. The use of automatic circular redundancy means that the overall system is able to run at optimum efficiency at all times while maintaining a high level of load protection. The system of circular redundancy ensures that the “rested” (excess) UPS modules are rotated so as to allow them to be operated for an equal amount of time. **Fast-transfer from input dependent modes** The possibility to switch between different operative modes may cause the interruption of the energy fed to the load, or in a particularly severe case (low impendence failure), even the loss of the load. Customers in the datacenter business are increasingly requesting energy saving solutions which can achieve similar reliability performance. The fast transfer technology has been	Further explanation was provided to the stakeholder with regards the term hot wasp, used in the draft Task 8 report. Within the context of UPS it refers to a combination of installation and modular UPS functionality which allows the automatic detection and replacement of a faulty UPS and its automatic disconnection for safe maintenance concurrent with full continuity of installation system usage. Following this clarification the stakeholder confirmed this is similar to the functionality provided by products with circular redundancy and fast transfer. Different manufacturers use different terms for this type of functionality. Task 8 has therefore been updated to remove the term hot swap and instead make reference to ‘automatic management system’ to avoid confusion.

				developed to meet this need. The fast transfer feature allows to minimize the transfer time from a high efficient mode (VI/VFD) to a less efficient mode (VFI) to a few milliseconds in case of failure during an input dependent operative mode (VI or VFD), and this at any load (leading, lagging, or resistive). Fast transfer technology allows to achieve a reliability close to double conversion during input depended mode operation. Emerson believes therefore that efficiency allowances should be granted for fast transfer. **Transformers** The Task 8 definition of transformer used for safety reason could be misunderstood by manufacturers. We therefore suggest that the definition should be rephrased in the following way: *Safety reason: insulation transformers/transformers shall permit to fully insulate both the ac input sources from the a.c output (input output independently grounded). This feature may be internally provided or externally.*	Direct discussions with the manufacturer indicate that UPS's with integrated transformers are used less frequently, and this is an increasing trend. If UPS's with integrated transformers are likely to be phased out before an Ecodesign Regulation can be implemented, then a transformer allowance would not necessarily be required, however there is insufficient evidence at the present to confirm whether this would be appropriate. Other stakeholders may also have different views regarding this. To ensure clarity with regards the scope of use for the proposed transformer allowance, the following footnote has been included in Task 8: *Safety purposes specifically relates to the use of insulation transformers/transformers (internally or externally to the UPS) that fully insulate both the ac input sources from the ac output (input output independently grounded)*

		8	79	The Ecodesign Directive should be a stimulus to reduce the environmental impact of UPS units, but at the same time push the manufacturer to keep the quality level of the power supplied to the critical load at the highest standards. Therefore we believe that products which should be given the premium are the ones which can provide a high level of efficiency while keeping the expected quality of the energy supplied to the load and taken from the mains. To that end, specific efficiency targets, based on a new “Equation 3”, should be set for 3-mode UPS. We furthermore believe that allowances should be granted to the best available technologies such as circular redundancy and fast transfer, as well as to technologies that reflect the peculiarities of the UPS environment, such as transformers used for safety reason.	Noted, see responses above.
		8	80	It should be clarified in the Task 8 report that UPS above 200 kVA are also to be covered by the ecodesign and labelling requirements.	The following footnote has been added to Task 8 to clarify this matter: *‘The base cases were established up to 200kVA following discussion with stakeholders as part of Tasks 4 and 5. Above 200kVA systems tend to be bespoke and therefore representative bill of materials were not available for these products. The market data in Task 2 was also structured in accordance with these base cases, which have therefore been used to structure our MEPs scenario. One stakeholder questioned whether MEPs could be set for products above 200kVA. There would not necessarily be a reason why this could not include products above 200kVA, which are not bespoke. This should be discussed with the wider industry, whose feedback helped inform the study’s base cases, as part of the Consultation Forum. Indeed our labelling proposal aligns with Energy Star boundaries, and would therefore include products above*

					200kVA.'
ZVEI	04/04/14	8	81	Comments to Task 8 Chapter 2.1: Qualifying Notes: Definition "Bespoke Systems" / Please add: In scope of this study: UPS- systems with AC input and AC output voltage. DC- Power Systems were not included in the study and are not included the respective policy proposals. For non-standard UPS used in customer specific applications causing efficiency reduction or in mission critical applications with high risks for human life/health, including but not limited to chemical industries, oil and gas industries, marine or submersed applications, power plants, including nuclear power plants, aviation control and railway systems the following conditions should apply: For these and similar applications that request additional energy consuming components as specific cooling, IP5 compliant casing or low battery voltages for safety applications, etc. the energy consumption of such components should be not included in the measurements of the UPS system. In case of specific requests by such applications that prevents from using standard components, the manufacturer must provide the documents that explain the need for implementing such non-standard components. Such bespoke systems should be excluded from the regulation.	Following further discussions with stakeholders regarding bespoke system, Task 8 has been updated as follows to reflect the feedback received: *For non-standard UPS used in mission critical applications with high risks for human life/health, including but not limited to, chemical industries, oil and gas industries, marine or submersed applications, power plants, including nuclear power plants, aviation control and railway systems, the following conditions should apply: For these and similar applications that require additional energy consuming components such as, but not restricted to the following , specific cooling, ingress- prevention- compliant casing, low battery voltages for safety applications, etc. the energy consumption of such components should not be included in the measurements of the UPS system. Where the requirements of such applications prevent the use of standard components and/or standard designs, the manufacturer must provide documentation that explains the need for using such non-standard components/designs. Such bespoke systems should be excluded from the ecodesign regulation and energy efficiency labelling.* *As noted in Task 1, the study has primarily focused on AC input and AC output UPS, which dominate the market. These types of UPS are therefore the focus of the proposals outlined in Task 8. Stakeholder feedback has indicated that DC Power Systems are a niche market and these are discussed in Task 6.*

					In addition a footnote has been added with a proposed definition of bespoke systems: *A bespoke UPS product is defined as "a UPS products made to a customer's design and/ or specification and not made available to any third party as part of the UPS manufacturer's product range"*

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