European Commission

Kick-off meeting of the technical working group for the EMAS sectoral reference document on best environmental management practice in the electrical and electronic equipment manufacturing sector

Minutes of the meeting

Brussels, 23-24 February 2015

Disclaimer:

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

Joint Research Centre

Contents

1. Opening of the Workshop

The JRC opened the session and welcomed the participants. After a brief explanation of the meeting procedure, an introduction to the workshop and overall exercise was given. The meeting agenda (attached in Annex 1) was presented and agreed by the participants. The TWG members introduced themselves and summarised their experience in environmental sustainability in the manufacture of electrical and electronic equipment (EEE) sector (the list of participants is attached in Annex 2). It was agreed to use first names to refer to the different TWG members[1]. The JRC explained that the work on EEE started in January 2014. The function of the TWG would be to steer the work further over the next year. Relevant comments from the TWG meeting will be incorporated and the draft background report will be revised accordingly. The next TWG meeting is scheduled at the end of 2015. The finalisation of the document is planned by the end of 2016.

2. Introduction to the EMAS Sectoral Reference Documents and purpose and goals of the meeting

The JRC introduced the framework of the EMAS Regulation[2]. The latest revision of EMAS was carried-out in 2009 [REGULATION (EC) No 1221/2009]. According to the regulation, the European Commission will develop, in consultation with stakeholders and member states, Sectoral Reference Documents (SRDs) comprising Best Environmental Management Practices (BEMPs), environmental performance indicators and benchmarks of excellence. The aim of the documents is to describe with concrete measures what organizations of a given sector can do to improve their environmental performance and minimise their negative environmental impact. After this introduction, the JRC presented the goal of the TWG kick off meeting, which is setting the scope of the document and discuss potential best environmental management practices.

A major question was asked to explain how the EMAS process is embedded in the overall policy landscape of the EU (e.g. RoHS, Ecodesign, REACH, WEEE, Type I Ecolabels, DG ENV's PEF/ OEF initiative etc.). **DG ENV** will produce a schematic diagram including the different policy tools addressing the EEE manufacturing sector.

3. Lessons learnt from the development of previous Sectoral Reference Documents

The JRC presented how the previous sectoral reference documents were developed as well as their structure. The approach and general structure will be the same for the EEE document. The presentation focused on the meaning of best environmental management practices, environmental performance indicators and benchmarks of excellence with useful examples from previous documents. The approach used to identify best environmental management practices by analysing the measures implemented by frontrunners was also presented. It was clarified that for each of the sectors investigated a Best-Practice report and a Sectoral Reference Document are produced. Focus was also given to the text of the EMAS regulation explaining the use of the Sectoral Reference Documents for organisations registered in EMAS.

[1] These minutes also refer to the different TWG members by their first name.

[2] A copy of the presentations used in this and in all the following sections is given in Annex 3.

It was also explained that the documents developed go beyond EMAS, offering support and being a source of information for all organisations that wish to improve their environmental performance, whether they have implemented EMAS or not. JRC stressed how essential it is to ensure that the TWG members contribute as much as possible to the development of the sectoral reference document to ensure its quality, relevance and usefulness for the companies of the sector.

4. Overview of the Electrical and Electronic Equipment Manufacturing sector and definition of the scope of the sectoral reference document

The term electrical and electronic equipment (EEE) covers a wide variety of products and devices, including: IT and telecommunications equipment; Large household appliances; Small household appliances; Consumer equipment and photovoltaic panels; 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; Automatic dispensers. The scope of the sectoral reference document to be developed will follow this and look at the sector from a life-cycle thinking approach ("from cradle to grave"). Three relevant perspectives to be included in the scope were so identified:

- Location-based perspective (within the "gate"): manufacturing
- Upstream perspective (towards “cradle”): supply chain management
- Downstream perspective (“from gate to grave”): recycling of waste from EEE

In terms of target groups, the BEMPs would be aimed either at EEE manufacturers or at companies dealing with the end-of-life treatment / recycling of waste electrical and electronic equipment (WEEE).

It was explained that use-phase is out of the scope of this project as other activities are already underway which address that area. However, the current work will look into the aspect of burden shifting if this happens in the use-phase as a result of the selection of the BEMPs. It was asked how relevant this study would be for certain sub-sectors of EEE. For instance, in terms of the geographical relevance, EU manufacturing has only 9% share in the global production of semi-conductors. The project team explained that there is still substantial manufacturing in Europe within the overall EEE sector and that the idea was also to have an indirect influence on production outside Europe. There was a short discussion on applying a vertical approach in the identification of a BEMP, meaning to consider all the actors of the value chain inclusively. The project team explained that it is important to consider the whole value chain but also to address specific actors in the specific BEMPs so that these can be picked up more easily.

Another point raised by some participants was how to ensure that the work, in line with the principles of EMAS, focus on organisational environmental management practice, rather than taking a product approach, given that the border between the two may sometimes be rather blurred. Organisations produce products and influence the characteristics of products through their processes and use of technologies, and through their management practices. However, the work will keep a process/technology approach and, especially in the area of Supply Chain Management, a management approach, but not a product approach.

One stakeholder enquired whether BEMPs implemented by companies who are producing and operating outside Europe are to be considered. The project team explained that BEMPs coming from other countries are also welcome. However, they should be applicable in Europe.

The main environmental aspects and impacts presented were fine with the group. Only two minor comments were made during the discussion: 1) The listing of PVC under SVHC on the slide on environmental pressures is not correct, the JRC must ensure that the terminology on hazardous substances is in line with RoHS directive. 2) The environmental pressure of biodiversity must cover not only site impacts but also impacts from supply chain.

There was a short discussion on the ownership of resources and target group of various BEMPs. Change in the ownership of the resources from the manufacturer to traders to recyclers has to be considered. The project team explained that a BEMP on Product Service Systems addresses the ownership issue.

5. Manufacturing BEMPs

5.1. Efficient supply and substitution of compressed air

One participant mentioned that it is not correct to term the compressed air technology as the most expensive and least efficient process. When compared to electric-driven tools, both technologies have merits and demerits, and it was pointed out that pneumatic tools offer several advantages, such as ergonomics, size/weight ratio and end-of-life treatment (e.g. air tools are very easy to disassemble whereas electric tools are either mains or battery powered. Moreover batteries contain heavy metals and rare earths). Furthermore, durability of pneumatic tools was mentioned to be higher. Thus, it was recommended to look beyond the aspect of energy efficiency in this BEMP and also ensure a more balanced approach both in the text and in the title of the BEMP. The project team emphasized that compressed air contributes with up to 10% of total electricity consumption during EEE manufacturing (thus very relevant) and that there are cases where, for specific uses, the most efficient solution is switching to electric tools (according to the experience of companies of the sector). However, the assessment, if the compressed air technology is to be substituted, is only one of the approaches presented. Afterwards, 4 other approaches for sustainable use of compressed air are presented in the BEMP. It is important to understand that the use of compressed air is process dependent and has to be evaluated on a case by case basis. In particular, the decision criteria should include not only energy efficiency but also size, weight and end of life of the process and the tool (technique) used. Concerns mentioned above can be addressed under Cross-Media Effects. **Paul** will provide written comments/ feedback on the current text of the BEMP.

5.2. Energy-efficient cooling technology

There was good agreement for this BEMP among the TWG members. There was one question regarding the pay-back times which according to one participant, should be explicitly stated as being case-specific. The project team explained that the four described approaches, i.e. (1). Assessment and optimization of the required room temperatures; (2) Use of cooling cascades, (3) Use of free cooling, and (4) Use of absorption cooling technology, give an indication of how companies should consider investing in energy-efficient cooling technologies. These examples are already labelled as specific cases,

whereas all relevant assumptions are given in the document, which enable users to calculate individual pay-back times by adapting the assumptions to their specific cases.

5.3. Energy-efficient cleanroom technology

This BEMP was mentioned to be rather applicable to companies who are planning a new cleanroom or planning a major retrofit. It was asked if communication with state-of-the-art companies making cleanroom technologies (construction companies) took place. The project team clarified that the communication took place at the user level (i.e. users of the cleanroom technology). **Silke** will provide contact details of a clean room construction company. Furthermore, it was mentioned that the environmental performance indicator kWh/ cm^2 of processed silicon wafer might not cover all silicon manufacturing processes (this will be further stressed in the next draft of the document), but is still meaningful. The influence of external sources of heat, such as solar radiation, in minimizing the external heat load was also discussed. The project team mentioned that this is already covered in this BEMP.

5.4. Energy efficient soldering

It is necessary to specify what kind of electronic boards are addressed here. Another stakeholder raised the issue of covering the aspect of hazardous versus non-hazardous soldering processes. The project team clarified that lead-free soldering was taken as baseline and covering all forms of lead-free soldering would have been too detailed, but this would have been clarified in the next draft version of the BEMP. Regarding the EPI, it was mentioned that the metrics kWh/m^2 highly depends on the kind of printed circuit board manufactured. **Tom** will provide data on cost analysis, including payback times, of soldering systems.

5.5. Minimising the use of perfluorocompounds

The main comment to this BEMP was if other PFCs (e.g. PFOS) and impacts related to the replacement of fluorinated gases with other fluorinated gases were considered. **Manfred** will send some comments on other PFCs. Generally, there was agreement for this BEMP among the TWG members. **Silke** mentioned that this BEMP was checked and verified with the help of the European Semiconductor Industry Association (ESIA).

5.6. Substitution and optimized use of VOC-based solvents

It was mentioned that clean room conditions exist in semiconductor manufacturing, and thus exposure of workers to solvents is limited. Therefore, it is necessary to formulate the improvement options more precisely. It was also mentioned that on-site solvent recovery is not a feasible option for semiconductor companies. **Silke** proposed to find out about more examples on improvement potentials with the help of the industry and offered help with the refinement of this BEMP. Furthermore, **Miquel** mentioned that VOC-solvents are also used in washing machines and efficient washing machines release less VOC-emissions. He will provide information on the use of solvents in coating and washing machines (and their efficiency) and aspects related to limiting of VOCs emissions.

5.7. Water savings and recovery in cascade rinsing systems

This BEMP was agreed among the stakeholders. There was only one question if energy use is increased by the implementation of this BEMP. The project team clarified that this is the case when using UV lamps for controlling germ contamination. However the BEMP presents also a solution without electricity use.

5.8. On-site recycling of metals in process chemicals

It was mentioned that a start-up company in France has developed an innovative technology to trap precious metals. **Stephane** will provide contact details of the company. The BEMP was in general agreed and it may be extended also to the recovery of precious metals.

5.9. Protecting and enhancing biodiversity

It was mentioned to include land-use and soil sealing among the environmental pressures addressed. A German project on greening the premises was briefly presented by a participant, which developed a biodiversity indicator as well as a list of biodiversity friendly measures. The project also addressed monitoring issues and included a monitoring system with selected indicator species in the local / regional context. A further aspect of the project is related to the compensation of the biodiversity footprint, which could take place by a wide variety of measures, such as biodiversity conservation, restoring mining sites for example in Indonesia, planting trees etc. About 50 companies in Germany are already implementing the recommendations. There was a short discussion if this project also covers an EEE companies. **Marion** will check if this is the case. Another participant mentioned that there are some interesting EEE-specific issues concerning the support functions of ecosystems, e.g. noise and dust barrier (removal of nitrous oxide), which should also be taken into account. Moreover, local municipalities often have a biodiversity conservation plan and this could help as a reference for cross-checking the companies' plan. **Evert** mentioned about a possible indicator on biodiversity issues in the supply chain, e.g. in mining, and will provide more information on this aspect.

5.10. Use of renewable energy

There was a short discussion on the credible accreditation which will be required when communicating on green electricity. A question was raised on allocation and accounting of voluntary investments of companies in renewable energy, e.g. wind mills. The project team explained that it can be considered / accounted if it is related directly to company's operations, is produced on-site or nearby and it is not accounted for in the generating mix of the national grid. During the discussion it was emphasized that it has to be ensured that the biomass used is sourced sustainably. Another question was raised regarding the use of CHP not being a BEMP. The project team explained that CHP per se can be considered a good practice but not a best practice. CHP can be considered BEMP if conventional fuels are replaced by biomass-based fuels and if these fulfil the biodiversity and sustainability requirements.

5.11. Summary and final overview of the manufacturing BEMPs

Among the stakeholders a general agreement with the approach and all the proposed BEMPs could be observed. However, **all participants** are invited to provide feedback on the level of ambition and relevance of the agreed BEMPs in order to insure that the most relevant practices in terms of applicability and environmental relief are covered.

In order to clarify the target and scope of the developed BEMPs, the title of the section will be changed into 'manufacturing operations'.

As an additional BEMP the waste management on manufacturing premises was proposed.

6. Supply Chain Manufacturing BEMPs

6.1. Assessment tools for cost-effective and environmentally sound substitution of hazardous substances

A major part of the discussion concentrated on the discussion on appropriate environmental performance indicators for monitoring the implementation of the BEMP and / or its environmental benefits. Concern was expressed over the high ambition level related to the requirement that major OEM suppliers (in terms of % of supply chain expenditure) provide a Full Material Declaration. It was mentioned that effort for complying with this requirement might be too high and not possible to achieve for the majority of companies. Difficulties because of Intellectual Property Rights need to be considered as well in this case. The project team explained that a Full Material Declaration is performed by few companies, as for instance Seagate for its bromine- and chlorine-free hard disk drives. It was agreed to keep the requirement for Full Material Declaration within the environmental performance indicators. However, other options, such as Supplier Declaration of Conformity for company-specific list of restrictions, complemented by a certification (preferably third-party) based on laboratory testing should also be considered best practice. Furthermore, some participants asked to update the information related to the costs of using the assessment tools by taking the costs of testing procedures, if required, into consideration. Finally, it was also mentioned to cover the substance requirements of WEEE in addition to those of RoHS and REACH.

6.2. Elimination of certain phthalates

It was suggested to clarify that the BEMP specifically addresses four phthalates, namely DEHP, DBP, BBP and DIBP. As these phthalates (or some of these four) might be banned from the use in electrical and electronic equipment by integration into the RoHS Directive, this BEMP might become obsolete. As the RoHS related decision on these phthalates is expected for summer 2015, a final decision on this BEMP is postponed. In the meantime, **Dirk** will provide written comments on the text of the BEMP and additional scientific literature. **Marta** will provide information on efforts by the household appliance industry to phase-out the four phthalates.

6.3. Elimination of brominated flame retardants (BFR) and polyvinyl chloride (PVC)

Some participants questioned the relevance of this BEMP. On the one side, participants referred to studies suggesting limited dioxin and furan generation from (end-of-life) management of brominated flame retardants and polyvinyl chloride used in electrical and electronic products. On the other side, others referred to studies suggesting the availability of substitutes with significantly lower environmental impacts. The fact that WEEE collection rates are far from reaching 100% in EU member states and that a certain share of the not separately collected volumes undergo sub-standard treatment was also mentioned. It was thus decided that this BEMP would be reconsidered in light of all the elements mentioned at the meeting and that participants would have provided. If needed, the JRC proposed the possibility to further discuss and decide about this BEMP in a smaller working group. All parties interested in contributing to this working group are asked to inform JRC about their willingness to participate. Furthermore, **all participants** are asked to provide written comments on technical aspects of this BEMP by Easter 2015.

6.4. Disclose and set targets for supply chain GHG emissions

There was consensus about this BEMP, especially because of the importance of going beyond reporting of GHG emissions and transparency aspects. However, participants stressed that varying methodologies and implementations make it difficult to compare results. Thus, it is recommended not to use disclosed GHG emissions for comparisons of companies and products; instead, the major benefit is considered to be the use as an internal tool in order to monitor and reduce GHG emissions at the company level, which is in line with the proposed BEMP. Furthermore, it was clarified that the aim of this BEMP is not to duplicate initiatives such as the Carbon Disclosure Project, but to set additional incentives for companies to join such initiatives. Therefore, specific data availability issues for the EEE sector (e.g. emission factors for fluorinated GHGs) need to be addressed. In addition to this, information on both benefits and costs needs to be elaborated. **All participants** are invited to provide data on relevant business cases by Easter 2015.

6.5. Conducting Life-Cycle Assessment

In-line with the comments on the last BEMP, it was also stressed here that this BEMP should not only be about measuring, but a basis for tangible improvements. Also similar problems about methodologies, implementation and data exist. Some participants stressed that the implementation of this BEMP should also take wider impacts such as the impacts of sold products and their end-of-life into account. Furthermore, it should be considered to also include examples of the actions that businesses drew from conducting LCA. These should also be included in the indicators. This might encompass information on structural reduction of impacts, as well as design of green products. It is mentioned that first-time LCA implementation causes significant upfront costs (e.g. in the field of data collection) and that LCA implementation and monitoring can – on the other side – yield economic benefits. Both aspects should be stronger reflected by the BEMP. **All participants** are invited to provide data on related business cases by Easter 2015.

6.6. Increasing the content of recycled plastics in EEE – Case study of closed-loop recycling process for polyethylene terephthalate (PET) and polypropylene (PP) plastics in inkjet printing cartridges

It was recommended to revise this BEMP in light of the EU waste hierarchy that gives clear priority to waste prevention and re-use. In particular, regarding inkjet printing cartridges this BEMP should be embedded as a part of an integrated approach including especially refilling and remanufacturing of used cartridges. The revision should also take into account a potential widening of scope to a broader product range and the reported difficulties that secondary plastics might not be suitable to be applied in new EEE product as its chemical composition and additives might interfere with new material related requirements (e.g. phasing out of certain chemicals). **Norbert** is asked to provide data on the types of plastics that can be recycled in close-loop systems.

6.7. Summary and final overview of the supply chain management BEMPs

Among the stakeholders a general agreement with the approach and a number of the proposed BEMPs could be observed. For those BEMPs to be reconsidered and/or further developed, and, more broadly, for all the proposed BEMPs, **all participants** are invited to provide feedback and inputs.

7. BEMPs for recycling of waste from electrical and electronic equipment

7.1. End-of-life removability of rechargeable batteries

The participants supported the approach of this BEMP in general.. In order to achieve end-of-life removability, the fact that the battery is often glued to the circuit board was mentioned as a major obstacle. The aspect of removability without tools also received support. However, it was also mentioned that tools are needed for batteries used in household appliances because they are often connected to a charging electronic unit. Some participants recommended to widen the scope and/or to formulate a new BEMP on design for reuse / refurbishment (see section 7.6). Concerning the applicability of the existing BEMP, also smaller smart products with embedded batteries (e.g. smart watches) should be considered and addressed as these are particularly challenging. Moreover, it was mentioned to further elaborate on safety issues during recycling operations that can be mitigated with easily removable batteries. Hence, on top of environmental / resource efficiency benefits, also safety benefit at the shredder level should be mentioned. With regards to the section on economics, it was proposed to consider a more in-depth cost calculation.

7.2. Integrated Product Service Offerings (IPSO)

There was a good agreement on the concept of the BEMP. It was mentioned that Integrated Product Service Offerings have also been covered in the FP7 project 'ZeroWin' (www.zerowin.eu) and the project's conclusions could be integrated in this BEMP. **Ian** will provide information from the ZeroWin project, especially concerning business cases and barriers to IPSO. In addition to this, it needs to be considered to further elaborate this BEMP in terms of B2C approaches. Within this context, it is worthwhile looking at the voluntary agreement that exists under the eco-design framework for set-top boxes (provisions about taking back). Regarding applicability, feasible product groups should be targeted and clearly defined in the corresponding section: it needs to be mentioned that IPSO does not work for smaller appliances with low bill of materials or large (heavy) appliances if the economical/technical value is too low and / or transportation costs are prohibitively high. **Marcel** will provide further information on the applicability of this BEMP.

7.3. High quality refurbishment of used products

Many participants considered this BEMP to be a good approach, however, it needs to be clarified that this BEMP is not about waste, but on products. Moreover, also the possibility of harnessing parts of used products for services is an interesting option. **Martin** is asked to provide comments and to suggest improvements in this respect. With regards to the environmental benefits section, this BEMP can also benefit from the results of the 'ZeroWin' project (see previous BEMP). Thus, **Ian** will provide information on three LCA case studies with data on environmental benefits that were carried out in this project. Concerning driving forces, Green Public Procurement (GPP) should be considered as a relevant driver for warrant refurbishment, since public administrations can be seen as relevant market actors for buying used equipment. Finally, it was also mentioned that refurbishment can be sometimes problematic due to brand issues (if refurbishment is carried out by independent third parties and not done properly) and thus the possibility for manufacturers to define a set of quality requirements (e.g. use of original spare parts) could be mentioned in order to deal with these potential barriers.

7.4. Non-destructive extraction of circuit boards

It was mentioned by some participants that the intentions of this BEMP are good, but in practice it would lead in the wrong direction. Due to economic constraints, once a 'cherry picking' of the most valuable circuit boards is carried out, a cost-effective treatment of a mixture of the remaining circuit boards might no longer be possible. Instead, the use of certified recyclers and a third party auditing of recyclers were proposed by a stakeholder as core elements of a new BEMP that could replace the existing one. Against this background, the existing BEMP needs to be reconsidered. If it is kept, the title needs to be changed, and it would be necessary to clarify that the goal is not to obtain undamaged circuit boards for re-use, but circuit boards that have been treated with limited physical stress in order to facilitate their recycling (removal of boards without compromising of the target substances). **Interested participants** are invited to provide input on the content of this BEMP.

7.5. Innovative sorting solutions for black plastics from waste electrical and electronic equipment

Based on positive feedback of the TWG members it was concluded to keep this BEMP. However, since its applicability is currently very limited (because of the type of plastics addressed and because only one company is using this technology) it is worthwhile to consider broadening the scope (e.g. including sorting of other types of plastics). Hence, **Stephane** will provide information on the FP7 project 'WEEElibs' (http://weeelibs.eu), which also covers black plastics separation. In addition to this, **Norbert** will send further material about improving the sorting of plastics from waste electrical and electronic equipment.

7.6. Summary and final overview of the BEMPs on recycling waste electrical and electronic equipement

It was proposed to include environmental pressures such as emissions to soil and water compartments in the overview of the BEMPs of this section. Furthermore, it will be considered to change the title of this section in order to better represent design and re-use (e.g. design, reuse and recycling of WEEE). Definitions from CENELEC standard for WEEE and from British standard for refurbishment will also be included.

Concerning additional BEMPs, the design for 'refurbishability' / reparability have been proposed. Within such a BEMP, e.g. the minimisation of the number of used screws and bolts can be taken as a suitable performance indicator. **Julia** and **Conny** are invited to provide further input in this respect.

Marion proposed a new BEMP based on a self-declaration of manufacturers in order to waive export in developing countries and will provide more details on this approach. However, it needs to be considered that this aspect is already covered in the WEEE directive and other international fora (e.g. CENELEC standard on transport of WEEE).

Finally a BEMP on improving WEEE transport has been brought up, addressing the minimisation of disruption by reducing the number of loads and unloads of WEEE; **Julia** will provide more on this potential BEMP.

8. Conclusions / way forward

The JRC summarised the discussion on all the points addressed during the 2 day meeting and presented the actions arising from the discussions on each of the proposed BEMPs (as well as on the further potential BEMPs to be considered for development). These were agreed by the TWG.

The JRC closed the meeting by describing the next steps of the project and way forward.

ANNEX 1 – AGENDA

DAY 1

Monday 23 February 2015 – Albert Borschette Conference Centre, Room 3C	
Arrival and registration of participants	09:15 – 10:00
Opening and welcome	10:00 – 10:15
Introduction of experts	10:15 - 10:45
Purpose and goals of the meeting	10:45 - 11:00
Introduction of the sectoral reference documents on best environmental management practice (BEMP) and lessons learnt so far	11:00 - 11:15
Coffee break	11:15 - 11:30
Overview of the Electrical and Electronic Equipment Manufacturing sector and definition of the scope of the sectoral reference document	11:30 - 12:15
Environmental aspects of the Electrical and Electronic Equipment Manufacturing sector	12:15 - 12:45
Lunch break	12:45 - 14:00
Identification of Best Environmental Management Practices for manufacturing processes and operations (first part)	14:00 - 16:00
Coffee break	16:00 - 16:30
Identification of Best Environmental Management Practices for manufacturing processes and operations (second part)	16:30 - 17:45
Wrap-up and close of the day	17:45 - 18:15

DAY 2

Tuesday 24 February 2015 – Albert Borschette Conference Centre, Room 3C	
Opening of the day	09:00 - 09:15
Identification of Best Environmental Management Practices for supply chain management (first part)	09:15 - 11:00
Coffee Break	11:00 - 11:30
Identification of Best Environmental Management Practices for supply chain management (second part)	11:30 - 12:30
Lunch break	12:30 – 14:00
Identification of Best Environmental Management Practices for recycling of waste from electrical and electronic equipment: design for recycling	14:00 – 14:45
Identification of Best Environmental Management Practices for recycling of waste from electrical and electronic equipment: recycling operations	14:45 - 16:15
Summary of the working group discussions	16:15 - 16:45
Wrap-up and close of workshop	16:45 - 17:00

ANNEX 2 – LIST OF PARTICIPANTS

Name	Surname	Organisation	Country
Charisios	ACHILLAS	International Hellenic University	Greece
Ioannis	ANTONOPOULOS	Joint Research Centre, European Commission	EU
Maria	BANTI	DG Environment, European Commission	EU
Conny	BAKKER	Delft University of Technology	Netherlands
Paolo	CANFORA	Joint Research Centre, European Commission	EU
Miquel	COLS	Denso Barcelona SAU	Spain
Paul	CONWAY	Loughborough University	United Kingdom
Riccardo	CORRIDORI	COCIR - European coordination committee of the radiological, electromedical and healthcare IT industry	Belgium
Marco	DRI	Joint Research Centre, European Commission	EU
Sylvie	FEINDT	Digital Europe	Belgium
Paul	FRIGNE	Pneurop - European Association of manufacturers of compressors, vacuum pumps, pneumatic tools and allied equipment	Belgium
Pierre	GAUDILLAT	Joint Research Centre, European Commission	EU
Patroklos	GEORGIADIS	Aristotle University Thessaloniki	Greece
Marion	HAMMERL	Lake Constance Foundation	Germany
Evert	HASSINK	Friends of the Earth Netherlands - Milieudefensie	Netherlands
Silke	HERMANNS	Globalfoundries	Germany
Zdenek	HRUSKA	Solvay	Belgium
Winifred	IJOMAH	University of Strathclyde	United Kingdom
Marcel	JACOBS	Philips Electronics Netherlands, EICC – Electronic Industry Citizenship Coalition	Netherlands
Bernd	KAPPENBERG	Cefic – The European Chemical Industry Council	Belgium
Lars	KOCH	ORGALIME - European Engineering Industries Association	Belgium
Florian	KOHL	Albemarle Europe, EFRA - European Flame Retardants Association	Belgium
Sigrid	LINHER	ORGALIME - European Engineering Industries Association	Belgium
Federico	MAGALINI	United Nations University - Institute for the Advanced Study of Sustainability (UNU-IAS)	Germany
Andreas	MANHART	Oeko-Institut e.V.	Germany
Christina	MESKERS	Umicore Precious Metals Refining	Belgium
Martin	MÖLLER	Oeko-Institut e.V.	Germany
Bernd	NASS	Clariant Produkte (Deutschland) GmbH	Germany
Tom	NICKSON	Toshiba	United Kingdom
Sébastien	PAQUOT	DG Environment, European Commission	EU
Emmanuel	PETIT	Legrand	France
Stephane	PEYS	BIGARREN BIZI	France
Martin	PLUMEYER	Siemens AG	Germany

Siddharth	PRAKASH	Oeko-Institut e.V.	Germany
Sandeep	RANA	Samsung Electronics	United Kingdom
Michael	RIESS	VDE Testing and Certification Institute	Germany
Manfred	SANTEN	Greenpeace Germany	Germany
Bernhard	SCHEUREN	Vorwerk	Germany
Marko	SCHNARR	Miele & CIE	Germany
Kevin	STAIRS	Greenpeace EU	Belgium
Lein	TANGE	CL Industrial Products, EFRA - European Flame Retardants Association	Netherlands
Paolo	TOSORATTI	DG Energy, European Commission	EU
Dirk	VAN HESSCHE	Plastic Europe	Belgium
Jeroen	VITS	Agoria - Belgian federation of the technology industry	Belgium
Hans	WENDSCHLAG	Hewlett-Packard	Sweden
Ian	WILLIAMS	University of Southampton	United Kingdom
Julia	WOLF	Dr. Brüning Engineering UG	Germany
Marta	YUSTE	CECED - Committee of European Domestic Equipment Manufacturers	Belgium
Norbert	ZONNEVELD	EERA - European Electronics Recyclers Association	Netherlands

ANNEX 3 – PRESENTATIONS

Purposes and goals of the kick-off meeting

Marco Dri

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Sustainable Production and Consumption Unit

Institute for Prospective Technological Studies (IPTS)

Joint Research Centre (JRC)

European Commission

Title of the meeting: Kick-off meeting of the Technical Working Group for the EMAS sectoral reference documents on Best Environmental management Practices for the Electrical and Electronic Equipment Manufacturing Sector

What is it???

What is EMAS?

EU Eco-Management and Audit Scheme (EMAS) is established by EU regulation:

- ➔ Open for companies and other organisations
- ➔ Is a voluntary management tool to evaluate, report and improve the environmental performance

EMAS

The legal background

The latest revision of EMAS was carried-out in 2009,

REGULATION (EC) No 1221/2009

⬇

Promote best environmental performance

⬇

Develop of Sectoral Reference Documents on Best Environmental Management Practice

The Sectoral Reference Documents on Best Environmental Management Practice

→ Main elements

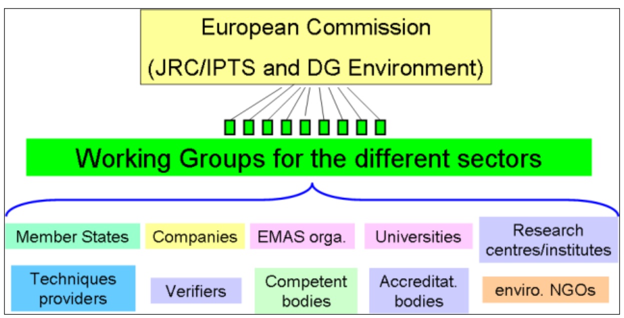
- → Best environmental management practices
- → Environmental performance indicators
- → Benchmarks of excellence

→ Not only for EMAS registered organisations but for all actors within the sectors covered who intend to improve their environmental performance

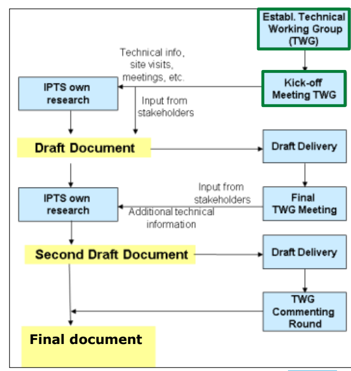
11 priority sectors

- Commission Communication (2011/C 358/02)

The Technical Working Group …



… and its key contribution



- Agree scope
- Discuss, suggest and agree BEMPs
- Provide comments and inputs

- Draw conclusions on environmental performance indicators and benchmarks of excellence

Purposes and goals of the meeting

- to get to know each other
- to exchange views
- to discuss the development of the Sectoral Reference Document (organisation of the information exchange)
- to discuss the timing

Purposes and goals of the meeting

To discuss:

- Scope of the document for the electrical and electronic equipment manufacturing sector
- Environmental aspects of the electronic equipment manufacturing sector
- Proposals for best environmental management practices
- First ideas about environmental performance indicators

Thank you!

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Introduction to the sectoral reference documents and lessons learnt

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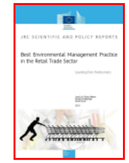
Main elements of the sectoral reference documents

The sectoral reference documents comprise 3 main elements:

An example from:

- Best environmental management practices (BEMPs)
  - Food waste minimisation by retailers

- Environmental performance indicators
  - Kg waste generation per m^2 of sales area
- Benchmarks of excellence
  - Zero food waste sent to landfill or incineration plant



Best Environmental Management Practices (BEMPs)

What is BEMP:

- those techniques, measures or actions that allow organisations of a given sector to **minimise their impact on the environment**
- **direct** and **indirect** aspects
- **technical/technological** as well as **management /organisational** type
- **fully implemented** by best performers
- technically **feasible** and economically **viable**

Best Environmental Management Practices (BEMPs)

BEMP is what goes well beyond common practice

but is already fully implemented

and widely applicable

What is not BEMP:

- Obsolete techniques
- Common practice
- Good practice
- Emerging techniques
  - are available and innovative
  - not yet proved their economic feasibility
  - not yet implemented at full scale

Best Environmental Management Practices (BEMPs)

Description of BEMPs (requires detailed technical information):

- Description
- Achieved environmental benefit
- Appropriate environmental indicator
- Cross-media effects
- Operational data
- Applicability
- Economics
- Driving force for implementation
- Reference organisations
- Reference literature

Structure similar to Best Available Technique Reference Documents (BREFs) according to Industrial Emission Directive

Environmental Performance Indicators and Benchmarks of Excellence

- **Environmental performance indicators**
  - "specific expression that allows measurement of an organisation's environmental performance" (EMAS Regulation)

already in use | environmentally meaningful | can be a proxy

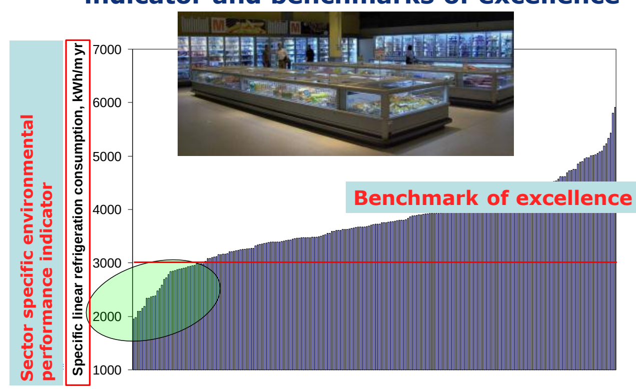
- **Benchmarks of excellence**
  - exemplary environmental performance

very ambitious | achieved by frontrunners | not a target but a measure of what is possible

How to identify BEMPs

The frontrunner approach

An example of BEMP, environmental performance indicator and benchmarks of excellence



Development of EMAS Sectoral Reference Documents: Two final outputs

The documents produced so far…

Best practice reports

Sectoral Reference Documents

Use of the EMAS SRDs

- **EMAS registered organisations**: According to the EMAS regulation "Where sectoral reference documents […] are available for the specific sector, the assessment of the organisation's environmental performance shall take into account the relevant document" (Regulation EC 1221/2009 Article 4.1(d)).
  - Information on (likely) most relevant environmental aspects.
  - Inspiration on what measures can be implemented next for continuous environmental performance improvement.
  - Recommended environmental performance indicators.
- Value beyond EMAS: Reference documents for all organisations in the sectors covered which intend to improve their environmental performance

Lessons learnt

Environmental performance indicators and benchmarks

- In many cases, clear conclusions on environmental indicators and also on benchmarks of excellence could be drawn.
- Quantitative distribution not always available but other effective methods for benchmarking can be used.
- A key role of the technical working group is to validate the findings, and to draw conclusions on environmental performance indicators and benchmarks of excellence

Lessons learnt

Technical Working Group:

- allows access to a wider network
- constructive and supportive but very different contribution intensities
- composition may change from kick-off to final meeting

Feedback framework

- comments were submitted in an informal way (no template).
- using a template may discourage to send comments

Thank you!

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Best Environmental Management Practices for the Electrical and Electronic Equipment manufacturing sector

Öko-Institut e.V.

Martin Möller, Yifaat Baron, Andreas Manhart, Katja Moch, Andreas R. Köhler, Siddharth Prakash, Rasmus Prieß

Kick-off Meeting of the Technical Working Group
Brussels, 23-24 February 2015

Öko-Institut e.V. Institut für angewandte Ökologie Institute for Applied Ecology

Overview of the Electrical and Electronic Equipment Manufacturing sector and definition of the scope of the sectoral reference document

Martin Möller

Öko-Institut e.V.

Definition

The term electronic and electrical equipment (**EEE**) covers a **wide variety of products and devices**, including the following product categories:

- **IT and telecommunications equipment;**
- **Large household appliances;**
- Small household appliances;
- Consumer equipment and photovoltaic panels;
- 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;
- Automatic dispensers.

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Structural overview according to NACE code

- **26 Manufacture of computer, electronic and optical products**
  - 26.1 Manufacture of electronic components and boards
  - 26.2 Manufacture of computers and peripheral equipment
  - 26.30 Manufacture of communication equipment
  - 26.4 Manufacture of consumer electronics
  - 26.5 Manufacture of instruments and appliances for measuring, testing and navigation, watches and clocks
  - 26.6 Manufacture of irradiation, electromedical and electrotherapeutic equipment
  - 26.7 Manufacture of optical instruments and photographic equipment
  - 26.8 Manufacture of magnetic and optical media

Structural overview according to NACE code

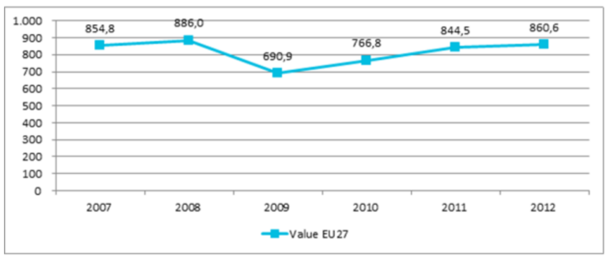
- **27 Manufacture of electrical equipment**
  - 27.1 Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
  - 27.11 Manufacture of electric motors, generators and transformers
  - 27.12 Manufacture of electricity distribution and control apparatus
  - 27.2 Manufacture of batteries and accumulators
  - 27.3 Manufacture of wiring and wiring devices
  - 27.4 Manufacture of electric lighting equipment
  - 27.5 Manufacture of domestic appliances
  - 27.9 Manufacture of other electrical equipment

Structural overview according to NACE code

- **28 Manufacture of machinery and equipment n.e.c.**
  - 28.1 Manufacture of general-purpose machinery
    - …
    - 28.12 Manufacture of fluid power equipment
    - 28.13 Manufacture of other pumps and compressors
  - 28.2 Manufacture of other general-purpose machinery
    - …
    - 28.22 Manufacture of lifting and handling equipment
    - 28.23 Manufacture of office machinery and equipment (except computers and peripheral equipment)
    - 28.24 Manufacture of power-driven hand tools
    - …

Economic relevance of the EEE sector

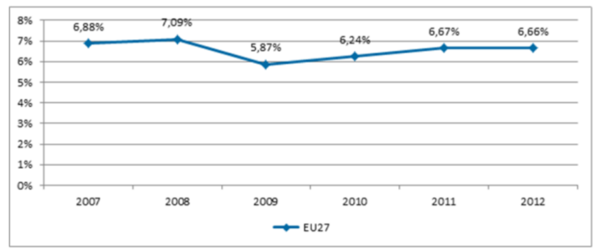
Figure 3-8: Value of EEE production between 2007-2012, EU 27 (in billion €)



Source: Own compilation, data based on EUROSTAT Statistics on the production of manufactured goods for the years 2007-2012

Economic relevance of the EEE sector

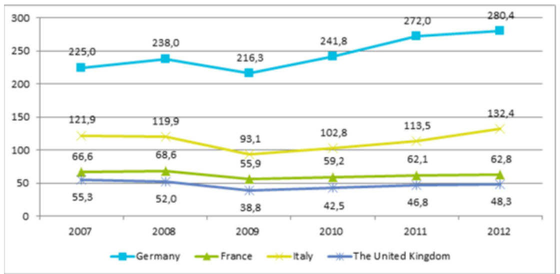
Figure 3-9: Contribution of EEE Production Value to GDP, EU27 (%)



Source: Own compilation, data based on EUROSTAT Statistics on the production of manufactured goods for the years 2007-2012 and EUROSTAT „GDP and main components – Current prices [nama_gdp_c]" for the years 2007-2012

Contribution of EU Member States

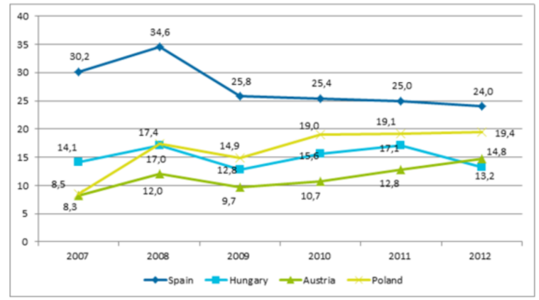
Figure 3-10: Contribution of EEE Production Value to GDP for Germany, Italy, France, and the UK (in billion €)



Source: Own compilation, data based on EUROSTAT Statistics on the production of manufactured goods for the years 2007-2012 and EUROSTAT „GDP and main components – Current prices [nama_gdp_c]" for the years 2007-2012

Contribution of EU Member States

Figure 3-12: Value of EEE Production Between 2007 and 2012, for Spain, Austria, Hungary, and Poland (in billion €)



Source: Own compilation, data based on EUROSTAT Statistics on the production of manufactured goods for the years 2007-2012

Enterprise structure

- Over 190,000 enterprises in the EU who manufacture products or components of EEE
- More than 90% of these enterprises are defined as small enterprises, with less than 50 employees
  - 51% in manufacture of machinery and equipment
  - 22% in manufacture of computer, electronic and optical products
  - 27% in manufacture of other electrical equipment
- Most enterprises are located in Italy, Germany and the Czech Republic, followed by the UK, Spain, France and Poland
- Number of enterprises does not always correspond to the value of production (e.g. Czech Republic, Spain)

Employment situation in the EEE sector

- Over 5.5 million individuals employed in EU Member States
  - 53% in the manufacture of machinery and equipment
  - 27% in the manufacture of electrical equipment
  - 20% in the manufacture of computer, electronic and optical products
- Employment in different member states
  - Germany: almost 2 million employed persons
  - Italy (700,000 persons employed), France and the UK (over 400,000 employed persons each) are also significant players
  - Followed by Poland, the Czech Republic and Spain who all employ over 200,000 persons in the EEE sector

Life-cycle thinking approach ("from cradle to grave") as guiding principle

- Process and technology-oriented approach
- Helps to detect existing conflicts as well as shifting of problems
  - Trade-offs between the individual life cycle phases (e.g. environmental pollution being transferred from the manufacture to the use phase)
  - Trade-offs between different environmental aspects or media (e.g. CO_2 emissions in the air and acidifying substances in water and soil).
- Helps to identify and monitor benefits from an integrated view
- Three relevant perspectives
  - Location-based perspective (within the "gate"): manufacturing
  - Upstream perspective (towards "cradle"): supply chain management
  - Downstream perspective ("from gate to grave"): recycling of waste from EEE

Scoping of the study

Component filter: setting priorities regarding the scale of relevance of electronic and electrical equipment and components

↓

Geographical filter: setting priorities regarding the place of manufacturing of electronic and electrical equipment

↓

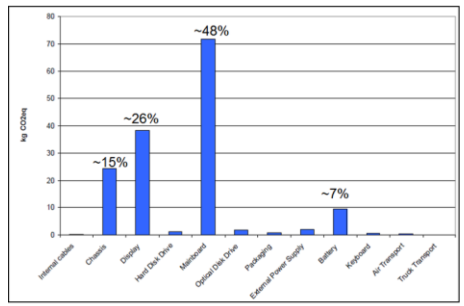
Environmental filter: setting priorities regarding the environmental performance of EEE in various life-cycle phases

Component filter

- EEE product may consist of hundreds, even thousands of various components
- Not all components have the same potential of contributing to the reduction of environmental impacts
- Screening of various components and their relative contribution to the environmental performance of products recommends to focus on
  - **Integrated Circuits (IC):** used in practically all EEE appliances, require ultrapure chemicals in workrooms that must meet cleanroom standards, large amounts of materials and energy are required for their production processes, use of perfluorocompound (PFC) gases
  - **Printed Circuit Boards (PCB):** also nearly ubiquitous in EEE, highly complex chemicals and water consuming print and etch processes, the content of hazardous substances, and aspects of recyclability

Relevance of key components

Figure 3-4: Breakdown of component-specific greenhouse gas emissions (CO_2e) from the production phase of a Dell notebook



Source: O'Connell & Stutz (2010)

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Geographical filter

- Further distinction is to be made between products and components that are manufactured, at least to some degree, in the **EU-28**, and between those produced outside the EU
- Relevant for understanding **how BEMP requirements are to be formulated towards all relevant manufacturers**, as in some cases, production takes place both within and without the EU
  - Can European manufacturers directly influence the environmental performance of the process / technique?
  - Can they at least influence indirectly (e.g. via supply chain management)?
- Attention shall be given to **distribution of manufacturing facilities** throughout the EU, regarding areas where manufacturing is mainly done by **SMEs** as compared to areas where production by **large enterprises** is dominant.

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Environmental filter

- The **environmental impacts** and existing **improvement potentials** associated with a process or technology are a key aspect for the identification of potential BEMP candidates to be reviewed in the course of the project.
- Thus, components with a high relevance identified by means of the component filter are thoroughly screened during each of their life cycle stages in order to determine **processes and manufacturing techniques** with higher contributions towards both environmental impacts and improvement potentials.
- Finally, the environmental filter ensures that all **environmental pressures** considered relevant for the EEE sector are covered (see following agenda item).

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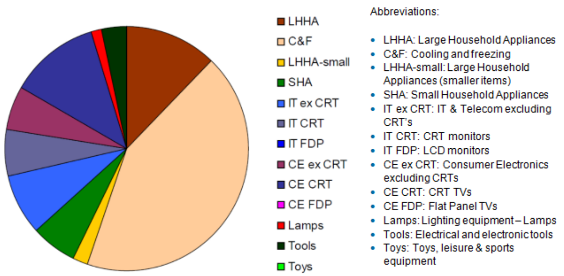
Focus on ICT equipment and household appliances due to their environmental relevance

Figure 3-7: Contribution of categories to environmental impacts of WEEE total (Eco Indicator '99 H/A)



Source: UNU (2008)

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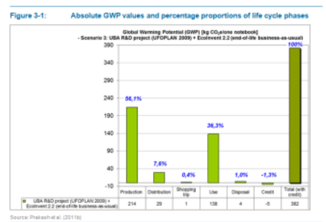
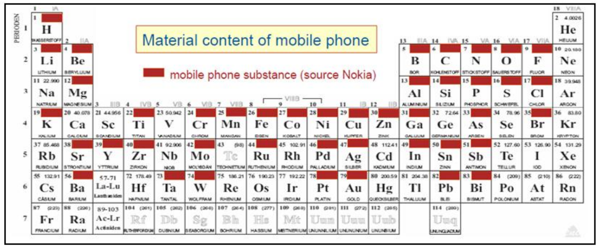
Relevance of the production phase of ICT equipment

- Most relevant and most innovative concerning environmental issues
  - Important contribution to mitigating climate change totalling around 7.8 billion t CO2e worldwide in the year 2020
  - Representing around 15% of the global emissions (Climate Group 2008)
- Insufficient attention is often given to the environmental impacts arising during the production phase of ICT equipment
  - e.g. notebook computers: more than 60 percent of the total environmental impact



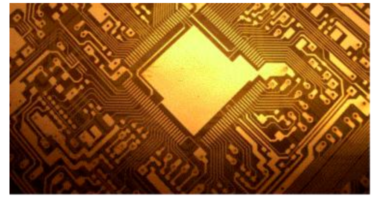
Relevance of ICT within supply chain management

Figure 3-3: Metals in a mobile phone



Source: Hagelüken & Buchert (2008)

Thank you for your attention!



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Environmental aspects of the Electrical and Electronic Equipment Manufacturing sector

Martin Möller

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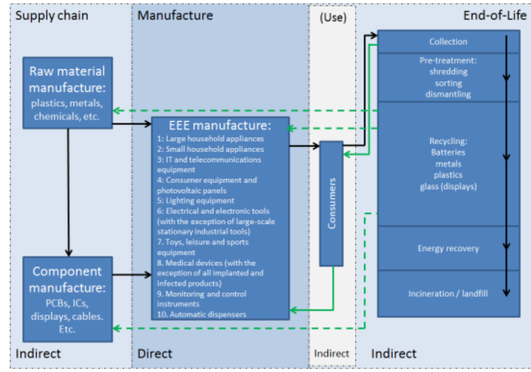
Main flows of materials in the various life cycle phases of EEE products (EEE manufacturers' perspective)



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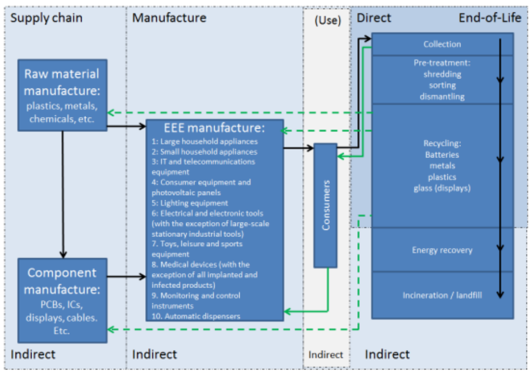
Main flows of materials in the various life cycle phases of EEE products (EEE recyclers' perspective)



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Fundamental findings and regulatory links

- EEE are of significant relevance in terms of environmental impacts.
- Aspects relevant for the use phase, such as energy consumption and greenhouse gas emissions, have been the focus of various studies initiated by the European Commission and thus are out of scope of the BEMP perspective
- Further aspects are addressed through additional EU regulative framework, such as schemes developed for
  - the labelling of products with higher environmental performance, or
  - for promoting public procurement of such products
- Additionally, various guidelines and regulations exist to promote design for dismantling and recycling as well as other practices viewed as beneficial in terms of environmental impacts.

Covered environmental pressures

The following environmental pressures were identified:

- **Resource efficiency**: recycling of chemicals and recycled plastic;
- **Water**: less consumption, also influences electricity consumption and waste water treatment;
- **Waste:** rising quantities as well as hazardous nature;
- **Emissions to air**: especially VOC with risks of toxicity and flammability as well as dust;
- **Energy and climate change**: on-site produced and purchased energy carriers, e.g. electricity, heat, cooling energy;
- **Biodiversity**: impact of a site on its surrounding environment;
- **Hazardous substances**: substances covered by RoHS Directive as well as SVHC like BFR in PCB, PVC in cables and arsenic in glass.

Environmental aspects and associated environmental pressures (EEE manufacturers' perspective)

	Environmental pressures addressed						
Environmental aspects (activities)	Resource efficiency	Water	Waste	Emissi-ons to air	Energy & climate change	Bio-diversity	Hazar-dous sub-stances
Product design (e.g. LCA, design for recycling)	x	x	x	x	x		x
Supply chain management	x				x		x
Component manufacturing (especially, IC and PCB)	x	x	x	x	x		x
Component assembly (e.g. soldering)	x			x	x		
Final assembly					x		
Support functions (e.g. cleanroom conditions, ecosystem)	x				x	x	x
Plant utilities (e.g. electricity, heat, cooling energy, compressed air, chemicals)	x	x	x	x	x	x	
Quality control			x				
Logistics, storage and transportation				x	x		x
Extended producer responsibility (e.g. IPSO, refurbishment)	x		x		x		

Environmental aspects and associated environmental pressures (EEE recyclers' perspective)

	Environmental pressures addressed						
Environmental aspects (activities)	Resource efficiency	Water	Waste	Emissi-ons to air	Energy & climate change	Bio-diversity	Hazar-dous sub-stances
Collection, transportation and storage				x	x		x
Pre-treatment (e.g. removal of batteries)	x		x				x
Shredding			x	x	x		x
Sorting (e.g. sorting of plastics)	x		x				
Dismantling (e.g. extraction of PCB)	x		x				x
Recycling of components and materials (e.g. batteries, plastics, metals, glass)	x	x	x	x	x		x
Plant utilities (e.g. electricity, heat, chemicals)	x	x	x	x	x	x	
Quality control			x				

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Identification of Best Environmental Management Practices for manufacturing processes and operations

Martin Möller

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Overview of the developed BEMPs

No.	Title of BEMPs	Environmental pressures addressed						
		Resource efficiency	Water	Waste	Emis-sions to air	Energy & climate change	Bio-diversity	Hazar-dous sub-stances
	MANUFACTURING							
1	Energy-efficient cleanroom technology	X				X		
2	Efficient supply and substitution of compressed air	X				X		
3	Energy-efficient cooling technology	X				X		
4	Energy-efficient soldering	X			X	X		
5	Minimising the use of PFC				X	X		X
6	Substitution / reuse of VOC-based solvents	X		X	X			X
7	Water savings and recovery in cascade rinsing systems		X	X				
8	On-site recycling of metals in process chemicals	X	X	X				
9	Protecting and enhancing biodiversity						X	
10	Use of renewable energy in EEE manufacturing	X				X		

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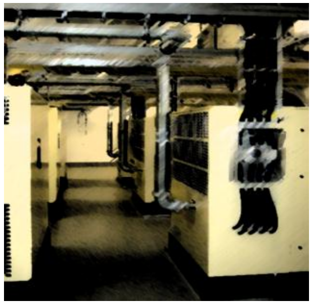
Efficient supply and substitution of compressed air



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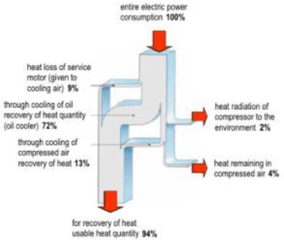
Justification and approach

- Peripheral processes that is used **throughout the EEE sector**
- Highly useful for certain applications, but **least efficient** and thus **most expensive** of all energy carriers
- **5 major approaches** for sustainable use of compressed air
  - 1. Assess **substitution** of compressed tools by electrically driven tools
  - 2. Identify and eliminate **leaks**
  - 3. Increase the compressed air **system's overall energy efficiency**
  - 4. Increase the specific energy efficiency of system **components**
  - 5. Install waste **heat recovery**



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Environmental benefits and environmental performance indicators

- Efficient supply enables overall savings in terms of electricity demand and CO_2 emissions of more than **50%**
  - Best practice compressed air system can save approx. **0.05 kg CO_2e/m³**
  - **Substitution** of compressed air operated tools can be substituted by motor-driven tools opens up savings potentials **>90%**
- **Energy Performance Indicator** according to ISO 50001
  - Metric defined as kilowatt hours of electricity needed per cubic meter of compressed air (**kWh/m³**)
  - Indicator should refer to the entire compressed air system
  - Values refer to standard cubic meters (calculated on the basis of standard conditions: at a pressure of 1.01325 bars and at a temperature of 20°C)
  - Pressure level of the compressed air system has to be indicated

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Applicability and economics

- Approaches in principle applicable for all companies, however
  - Optimization of systems design especially relevant for systems that have "grown" over decades and need revision (50% of all systems)
  - Centralized system require enough space for additional components
  - Use of waste heat requires a continuous demand for process heat
- Energy and cost savings of up to **90%** are possible

Measure	Payback time (months)
Optimizing end use devices	18
Reducing air leaks	6
Overall system design	18
Drives with high efficiency motors	12
Drives with speed control	9
Recovering waste heat	6

Source: Own table with selected data from Radgen & Blaustein 2001

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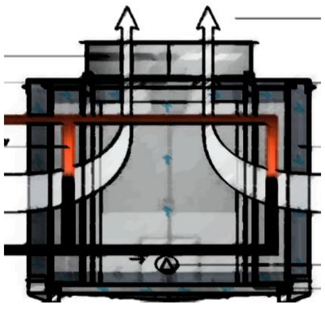
Energy-efficient cooling technology



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Justification and approach

- Continuing trend towards **increasingly fine structures** (and thus low manufacturing tolerances) makes cooling systems increasingly important in the EEE sector (especially IC and PCB manufacturing)
- **4 major approaches** for sustainable cooling technology
  - 1. Assessment and optimization of the **required room temperatures** (each °C saves 50 kWh/m³ electricity p.a.)
  - 2. Use of **cooling cascades** (e.g. 6/12°C and 12/18°C flow/return system)
  - 3. Use of **free cooling** (in particular direct cooling, free dry cooling and free wet cooling)
  - 4. Use of **absorption cooling technology** (using waste heat / heat from CHP plants)

Principle of Operation

Environmental benefits and environmental performance indicators

- Substantial lower electricity demand can be achieved, e.g.: free cooling: **75% savings** compared to compressor chilling unit
- Cross-media effects
  - Substantial **water use** is caused by wet cooling units (e.g. 0.5 m³/h/MW_{th} for a hybrid cooling tower); may also cause fogging
  - Positive side-effect: free cooling units do not require ecologically problematic **refrigerants** (such as R-410A) with a high GWP
- **Environmental performance** of systems that allow for quantification of their cooling energy demand: $\mathbf{kWh_{electricity} / kWh_{cooling\ energy}}$
- Otherwise, an indicator on a qualitative basis needs to be taken into consideration focusing on the different options of free cooling

Applicability and economics

- For free cooling a **5-10°C** temperature difference between indoor and outdoor air is required; continental climate is favoured
- For free cooling and absorption cooling, a **year-round cooling load** and enough space on the outside area must be available
- For absorption cooling, **waste heat** is continuously required
- Substantial cost savings already through simple measures, e.g.: 1°C higher temperature in a hall (400 m², 4,5 m high) saves 13,000 € p.a.

Measure	Investment costs (€)	Operational costs p.a. (€)	Annual savings (€)	Payback time (months)
Direct cooling (for production hall)	-	34,000	262,000	1.3
Free cooling (for milling process)	45,000	2,090	28,560	20
Free cooling (for wet processing equipment)	15,000	670	8,610	23
Free cooling (for image-setter)	5,000	100	3,780	17
Absorption cooling technology	290,000	24,000	112,000	40

Energy-efficient cleanroom technology

Justification and approach

- **Ultra-clean production conditions** are essential for the quality of many electronic components and devices, especially applicable for **IC** and **PCB** manufacturing
- Cleanrooms constitute the **most important energy consuming system** within a typical semiconductor production site
  - Encompass heating, ventilation and air conditioning (HVAC) systems
  - Accounting for **36–67%** of the total facility energy demand
- **3 major approaches** for sustainable use of cleanroom technology
  - 1. Optimized **sizing** / design of cleanrooms (e.g. low face velocity design)
  - 2. **Reducing heat load** (e.g. removal of excess heat)
  - 3. Use of **highly efficient components** (e.g. fan motors, variable-frequency drives, upsize passive components)

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Environmental benefits and environmental performance indicators

- Consumption of electricity as most important environmental aspect
  - Reduction potential of **50%** can be achieved, also the corresponding CO_2 emissions can be cut by half
  - Reduction of **air change rate** as most important overarching approach: a 30% lower air change rate can reduce electricity consumption by 66%
- Air change rate as a first step in order to identify efficiency potentials of cleanrooms
- Measuring environmental performance should be based on its overall energy productivity in case a clear output measure exists
  - Semiconductor / IC facilities: **kWh/cm²** of processed silicon wafers
  - PCB: **kWh/m²** of processed printed circuit board

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Applicability and economics

- Approaches **applicable to all companies** operating or planning to invest in a cleanroom facility (new facilities and retrofit solutions)
- Efforts regarding **insuring and adjusting the quality requirements** of the cleanroom might be necessary
- **Electricity costs** account for 65-75% of the total costs associated with cleanroom operation and maintenance
  - Savings potentials of approaches according to percentage of achieved electricity saving
- Cost savings potentials of single measures
  - **Fan motors**: efficiency improvements make most retrofit solutions cost-effective since these components consume their capital equipment cost value in electricity roughly every month
  - **Chillers** with variable speed drives: payback times of about one year

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Energy-efficient soldering

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Justification and approach

- Soldering causes **70%** of the energy demand within the production process of surface-mounted devices (as a part of PCB manufacturing)
- Within the context of miniaturisation of EEE **reflow soldering** is by far the **most relevant soldering technology**, both in terms of production volume and ecological optimization potential
- **4 major approaches** for sustainable soldering technology
  - 1. **Maximize throughput** of existing reflow soldering equipment (software based solutions, multitrack systems)
  - 2. **Retrofit insulation** for existing soldering equipment
  - 3. Installation of **new soldering equipment** (e.g. featuring stand-by and dormant mode as well as direct-current fan motors)
  - 4. **Avoid the use of nitrogen** for less delicate applications

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Environmental benefits and environmental performance indicators

- Best practice reflow systems are characterized by at least **20% lower electricity consumption** (up to 26,000 kWh per line p.a.)
- Environmental performance indicator should be defined as: **kWh (of electricity) / m² (of PCB)**
- Parameters such as
  - the type of PCB (multilayer, double-sided, etc.)
  - as well as the amount of components and
  - the used solder paste

  need to be provided as reference information

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Applicability and economics

- Approaches are in general applicable for all companies, whereas
  - Maximization of throughput as well as on retrofit insulation are especially applicable for existing equipment
  - Improved power management systems and optimised use of nitrogen can only be implemented when installing a new soldering line
  - Measures aiming to avoid the use of nitrogen are applicable both for existing and newly installed equipment
- Total cost of ownership and **thus low operating costs** get more and more relevant concerning the economics of soldering systems
  - 20-25% less energy consumption results in annual cost savings of up to **5,000 EUR** per soldering line
  - Best practice soldering facilities also improve process safety (and thus less discard) and raise throughput (less floor space required)

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Minimizing the use of perfluorocompounds

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Justification and approach

- Perflourocompound (PFC) emissions are the most relevant contribution to a semiconductor's fab **global warming potential beyond energy use** and are mainly by plasma etching and cleaning of chemical vapour deposition (CVD) reactors
- **5 major approaches** for minimizing the use of PFC
  - 1. **Process optimization** (focused on CVD chamber cleaning)
  - 2. **Substitution** of PFC gases (e.g. replacement of C_2F_6 by C_3F_8, focused on CVD chamber cleaning)
  - 3. **Remote plasma cleaning** technology (NF_3 instead of C_2F_6 and CF_4)
  - 4. **Point-of-use abatement** during plasma etching (small plasma source)
  - 5. Installation of **end-of pipe purification techniques** for contaminated exhaust air (removal efficiency of up to 99%)

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Environmental benefits and environmental performance indicators

- Environmental benefits can be achieved
  - If a gas with a very high GWP can be replaced by a **substitute** with a lower value
  - If the **conversion rate** of PFCs at their designated process use can be increased, and thus emissions in the environment can be avoided

Table 4-8: Global warming potential (GWP) of relevant PFC gases

PFC gas	Chemical Formula	GWP characterization factor
Hexafluoroethane	C_2F_6	12,200
Tetrafluoromethane	CF_4	7,390
Trifluoromethane	CHF_3	14,800
Octofluoropropane	C_3F_8	8,830
Octofluorocyclobutane	$c\text{-}C_4F_8$	10,300
Nitrogen Triflouride	NF_3	17,200
Sulphur Hexafluoride SF6	SF_6	22,800

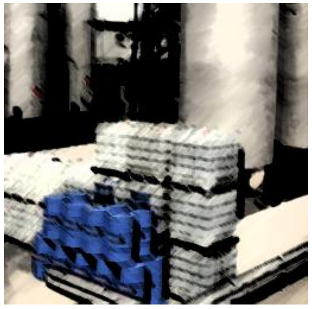
Source: IPPC (2007)

- Environmental performance should be defined as **kg CO_2e/cm²**; already established in the semiconductor industry as an indicator for monitoring the implementation of best practice within the context of existing voluntary agreements

Applicability and economics

- **Process optimization** as an effective measure for existing production facilities, but also applicable in new CVD cleaning processes
- **Substitution of PFC gases** is technically not feasible in few cases (especially not for plasma etching with its increasingly stringent requirements)
- **Remote plasma cleaning** and **point-of-use plasma etching** abatement are applicable to all fabrication facilities; however innovation cycle needs to be respected due to economical restrictions
- Currently **only process optimization** is considered to be a **cost-effective** due to lower gas consumption and better throughput
- All the other measures are associated with substantial costs
  - Remote CVD cleaning system: 50,000 € investment costs per chamber, plus net annual costs of approx. 12,000 € per chamber
  - Plasma abatement technology: 30,000 € investment costs per etching chamber, plus operational expenses of about 800 € per etch chamber

Substitution and optimized use of VOC-based solvents



Justification and approach

- VOC-based solvents represent the **most relevant airborne pollutant** of EEE manufacturing besides greenhouse gas emissions
- Used in **processes** throughout the EEE sector, in particular during
  - **Stripping** of polymer-like residues after etching of the wafers: solvents based on hydroxylamine (HDA) and isopropanol
  - Various **cleaning und degreasing** processes in semiconductors and PCB manufacturing as well as in many other sub-sectors of EEE
- **2 major approaches** for the sustainable use of VOC-based solvents
  - 1. **Substitution of VOC-based solvents** by semi-aqueous chemicals (replacement of HDA by dilute acid formulations of sulphuric acid (H_2SO_4), hydrogen peroxide (H_2O_2) and hydrofluoric acid (HF))
  - 2. On-site **solvent recovery** (both control of vapour emissions and manufacture of secondary solvents)

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Environmental benefits and environmental performance indicators

- Substitution / efficient use of (mostly crude oil based) solvents reduces energy demand, resource depletion and greenhouse gases
- Substituting hydroxylamine (HDA) lowers the health risk for the service and maintenance staff, and also cuts the environmental impact
- Consideration of cross-media effects
  - Substitution requires a **case-by-case analysis** / LCA to be recommended
  - Regarding solvent recovery the production process of the virgin solvent and energy demand of the recovery process need to be taken into account
- Environmental performance indicators
  - **Substitution** of solvents: has to be detected with a **qualitative metric** whether such a substitution could be **implemented (y/n)**
  - **Solvent recovery**: best practice can be quantified by the **solvent recovery rate** (i.e. share of recovered solvent vs. used amount of solvent)

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Applicability and economics

- **Substitution of HDA** is only applicable for the semiconductor industry
- Fundamental **principles** regarding substitution (of VOC-based solvents by semi-aqueous / water soluble chemicals) are considered to be important and feasible throughout the EEE sector
- **Solvent recovery** also generally applicable for the EEE sector, in particular where the quantity of solvents is large, the value of the solvents is high, or the solvents contain chlorine, bromine, fluorine or nitrogen
- Substitution of HDA opens up significant cost saving potentials (>90% in terms of chemical costs)
- Solvent recovery helps to save costs, both related to purchasing and disposal, whereas the overall economic feasibility depends of the cost structure of specific situation

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Water savings and recovery in cascade rinsing systems

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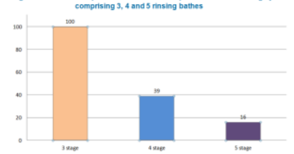
Justification and approach

- Management and protection of water resources are especially relevant with the phenomenon of **water scarcity and drought** becoming increasingly frequent in the EU
- Within the EEE sector, wet processes cause substantial water demand, especially during the PCB manufacturing (rinsing technique)
- As for **new installations**, multiple cascade rinsing systems with **four stages** are currently best practice
- Water savings in **existing installations**
  - Water intake in rinsing bathes according to conductance value
  - Re-use (double use) of rinsing bath water

Figure 4-15: Comparison of water consumption in cascade rinsing systems comprising 3, 4 and 5 rinsing bathes



Source: Wolfer (2014)

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Environmental benefits and environmental performance indicators

- Best practice in cascade rinsing systems helps protect the environment by conserving **drinking water and** contributes to a reduction of **waste water**
- Due to great differences between the specific rinsing water demand for the different types of PCB and varying product portfolios processed at the different companies, a metric based on rinsing water demand per m² of PCB cannot be recommended
- Environmental performance should be defined as the number of cascade rinsing systems with at least **four stages** compared to the total number of necessary rinsing systems within PCB production
  - Given as a share; expressed in %
  - Taking into account the limited technological and economic feasibility as well as cross-media effects of five-stage cascade rinsing systems

Operational data

- In cascade rinsing systems with four and more stages, there is a far greater **risk of germ contamination** by bacteria and fungus, which constitutes a major obstacle to the realization of water savings
  - New installations are therefore usually equipped with **UV lamps**
  - As an alternative technique anti-microbial **contact catalyst** (specifically structured and coated silver surface) can be used

Figure 4-16: Baskets with AGXX®-Raschig rings for antimicrobial protection of basins and tanks

Source: Largentec, http://www.agxx.de/en/decontamination-cooling-water.htm

Applicability and economics

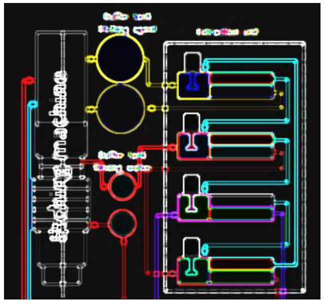
- The measures described for existing installations can be applied by any companies using cascade rinsing systems
- For **new installations**, the available **space** in the facility might be a limiting factor and needs to be taken into account
- Cost savings and payback periods of the different measures depend on the **local water and waste water tariffs**

Table 4-11: Water saving measures in cascade rinsing systems and their pay-back periods in Southern Germany

Water Savings achieved through:	Pay-back period in years
Installation of a 4-stage cascade rinsing system in new installations	2–3
Installations of a 5-stage cascade rinsing system in new installations	> 3
Reduction measures in existing installations if implementation (development of software tool, plant modifications) can be done in-house	< 1
Reduction measures in existing installations if implementation (development of software tool, plant modifications) cannot be done in-house	~ 2

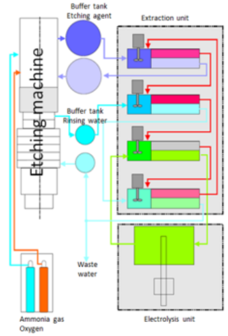
Source: Wolfer (2014)

On-site recycling of metals in process chemicals



Justification and approach

- On-site recycling of metals also addresses wet processes of PCB manufacturing and is focused on **copper**, large quantities of which are contained in basic **etching solutions** and rinsing water
- Copper recycling from the etching solutions in PCB production can be performed in a **separate system**
  - Comprising several stages where an organic solution is loaded with the copper from used etchant and rinse water, using a **solvent extraction** process
  - Copper is then transferred to an acid electrolyte and led into an electrowinning unit (**electrolysis**)



Source: Wolfer (2014)

Environmental benefits and environmental performance indicators

- Environmental benefits at various levels
  - **Resource efficiency** (and thus less environmental impacts during manufacturing of metals)
  - Extended use of the etching agent; thereby, the amount of the **alkali etching agent is reduced by more than 95%**
  - Lower **waste water / waste generation** due to treatment/ recycling of rinsing water and less sludge in the rinse section
  - **Transports** of used etching agents (classified as dangerous goods) can be reduced substantially due to closed-loop on-site recycling, resulting in a reduced risk for environmental contamination
- Environmental performance can only be measured qualitatively by **installation of a copper recycling system**; allows an estimation of the various environmental benefits independent from current production

Environmental benefits and environmental performance indicators

- Approach is applicable for any PCB production facility
- Limiting factors
  - **60 tons of recycled copper p.a.** necessary for feasible payback times
  - Electrowinning system requires between **50 and 80 m² space**, depending on the arrangement of the installation and the volume of the buffer tanks
- **Cost savings** due to **reduced operational costs** for replenisher, rinse water and chemicals for water treatment; **revenues** from copper
- **Payback time** of the investment usually ranges between **6 and 18** months depending on the amount of sold high quality copper
  - 14 months – if an amount of 90 tonnes recycled copper p.a. is achieved
  - 18 months with 60 tonnes of recycled copper p.a.
  - (48 months if only 7 tonnes of recycled copper p.a.)

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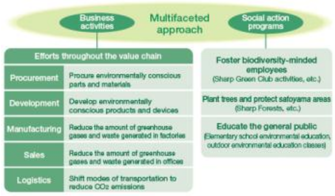
Protecting and enhancing biodiversity

Justification and approach

- Rising relevance of biodiversity within the general environmental debate: growing recognition as an **global asset**
- EEE manufacturing sites usually impact biodiversity through **land use and soil sealing**, but they can also **benefit** from **ecosystem services**
- General **measures** may include activities such as
  - Planting **trees**, reintroducing **native species** or creation of **wetlands** into sites where the natural environment has been destroyed in the past
  - Surveys of flora and fauna, aimed at documenting and monitoring the state of biodiversity at a specific site



Source: SHARP (2014a)

Environmental benefits and environmental performance indicators

- Direct benefits can be an enhanced diversity of local species (both flora and fauna) as well as the establishment of better conditions for their development; healthier environment also facilitates the provision of various **ecosystem services**
- **Cross-media effects**: introduction of new species into a habitat where natural enemies do not exist can lead to **uncontrollable development** of the new species, resulting in negative impacts on the wellbeing of other species
- Environmental performance should be monitored with **checklist-based qualitative metrics** by comparing the progress of companies in terms of the implementation of biodiversity strategies, e.g. including:
  - Regulation (including regional planning initiatives aimed at enhancing biodiversity)
  - Conduct survey of biodiversity on facility grounds every 3 years
  - Implementation of greening efforts on facility grounds

Applicability and economics

- Approach is only applicable to facilities surrounded by natural areas; enhancing biodiversity in urban areas is equally important
- **Costs** depend on various factors, e.g. the amount of work done by volunteering employee and special equipment
- **Donations** (financing and/or equipment) are possibilities of reducing costs and can therefore also act as a driving force
- **Benefits** are much more difficult to quantify, though they can be addressed at least qualitatively at the level of **ecosystem services:**
  - Vegetation has been shown to regulate extreme temperatures by 2-3°C, often allowing savings in costs for **air conditioning** respectively
  - Wetlands may also assist in **treatment of slightly contaminated run-off water** from facility grounds, or as biological remediation
  - Green areas within or adjacent to a facility can also serve **employees** as a place to take a break in a more natural environment, contributing to their **well-being**

Use of renewable energy

Justification and approach

- Even though the use of renewable energy resources (RES-E) plays only a minor role in today's energy supply of EEE manufacturing, the **future potentials** are substantial and need to be developed
- **3 major approaches** for the use of RES-E within EEE manufacturing
  - **Purchase of green electricity** with additional environmental benefit (according to the basic principle of additionality)
  - **Own production of electricity** from RES-E (e.g. photovoltaic cells installed on the manufacturing buildings, use or re-activation of existing water power potentials)
  - **Own production of heat** from RES-E (solar heating, substitution of conventional feedstock by biomass for the operation of CHP plants)

Environmental benefits and environmental performance indicators

- Environmental benefits of **green electricity** are particularly high in countries with a low share of renewables in the national electricity mix
- Concerning **renewable heat** the demand in the EU for medium and medium-high temperatures is estimated to reach **300 TWh**; renewable heat technologies could abate **120 Mt of CO_2** by 2030
- Environmental performance in the field of **green electricity** should be measured with the following two indicators:
  - Share of electricity from renewable sources (RES-E) in electricity mix of the company, contributing to an extension of green electricity production in the respective country
  - GHG emissions (in CO_2-equivalents) of the company-specific electricity mix
- The use of **heat from RES-E** should be monitored by the following metrics:
  - Share of heat from renewable sources (RES-E) in heat energy mix of the company
  - GHG emissions (in CO_2-equivalents) of the company-specific heat energy mix

Applicability and economics

- Concerning **green electricity** it needs to be considered that products with additionality are not explicitly offered in each EU Member State
- In terms of **renewable heat**, a number of challenges limit the applicability of renewable heat deployment:
  - **Technical barriers**, e.g. incompatibility with temperature demands, difficulties in integrating renewable sources into the existing conventional systems
  - In contrast to other sectors (like e.g. food and beverages), where integration of solar heat in processes is considered to be easier due to on-site availability of suitable feedstock, the **potentials in the EEE sector are relatively low**
- The purchase of **green electricity** causes only very low **additional charges**
- Concerning the use of **heat from RES-E**, costs are significantly higher than from conventional sources (0.04-0.12 EUR/kWh vs. 0.01 EUR/kWh); investment in solar system is often rejected due to recent installation of a **CHP plant**, which often produces an excess of heat

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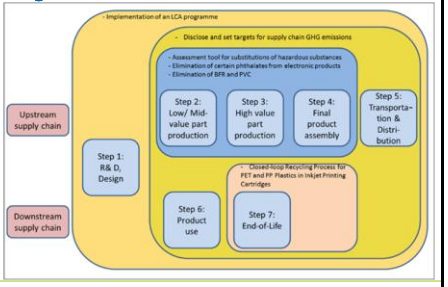
Identification of Best Environmental Management Practices for Supply Chain Management in the EEE sector

Siddharth Prakash



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Overview of the developed BEMPs

No.	Title of BEMPs	Environmental pressures addressed: Resource efficiency	Water	Waste	Emis-sions to air	Energy & climate change	Bio-diversity	Hazar-dous sub-stances
	SUPPLY-CHAIN MANAGEMENT							
11	Assessment tools for substitu-tion of hazardous substances							X
12	Elimination of certain phthalates							X
13	Elimination of BFR and PVC							X
14	Disclose and set targets for supply chain GHG emissions					X		
15	Conducting LCA		X	X	X	X		
16	Increasing the content of recycled plastics in EEE	X				X		

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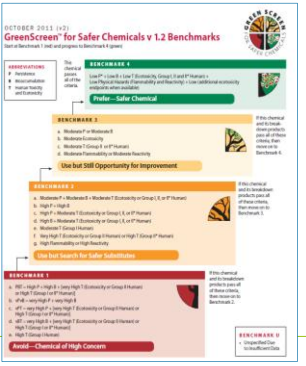
Assessment tools for cost-effective and environmentally sound substitution of hazardous substances



Source: Clean Production Action (2011)

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Justification and approach

- Few assessment tools available for identifying chemicals of high concern & alternatives; Helpful for OEMs to regulate their suppliers towards the use of **substances with lower environmental and health impacts**
- On the basis of an analysis of **reliability, user-friendliness and limitations**, Green Screen ® for Safer Chemicals & Pollution Prevention Options Analysis System (P2OASys) can be recommended
- **SMEs** need a much more simplified approach (3-Step)

Assessment/Substitution Tool	Elaborated by	Source
Column Model for Chemical Substitutes Assessment	Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (IFA, Institute for Occupational Safety and Health of the German Social Accident Insurance)	http://www.dguv.de/ifa/Praxishilfen/GHS-Spaltenmodell-zur-Substitutionspr%C3%BCfung/index-2.jsp
COSHH Essentials (control of substances hazardous to health)	UK Health and Safety Executive	http://www.hse.gov.uk/coshh/essentials/index.htm
Technical Rules for Hazardous Substances (TRGS) 600 "Substitution"	German Committee on Hazardous Substances (AGS), 2008	http://www.baua.de/cln_135/en/Topics-from-A-to-Z/Hazardous-Substances/TRGS/TRGS-600.html
GreenScreen® for Safer Chemicals	Clean Production Action (CPA)[80]	http://www.greenscreenchemicals.org/
Determination and work with code numbered products (MAL Code)	National Working Environment Authority, Denmark	http://webcache.googleusercontent.com/search?q=cache:YHbrHw3LkHkJ:arbejdstilsynet.dk/~/media/48245F6E041C4FBBA99EFC6E1FA322A2.ashx+&cd=2&hl=de&ct=clnk&gl=de
Pollution Prevention Options Analysis System (P2OASys)	Toxic Use Reduction Institute of Massachusetts (TURI)	http://www.turi.org/home/hot_topics/cleaner_production/p2oasys_tool_to_compare_materials
Priority-Setting Guide (PRIO)	Swedish Chemicals Inspectorate (KEMI)	http://www2.kemi.se/templates/PRIOEngframes____4144.aspx
Quick Scan	Dutch Ministry of Housing, Spatial Planning and Environment	http://www.rijksoverheid.nl/documenten-en-publicaties/brochures
Stockholm Convention Alternatives Guidance	Persistent Organic Pollutants Review Committee of the Stockholm Convention on Persistent Organic Pollutants, 2009	http://chm.pops.int/Convention/POPsReviewCommittee/hrPOPRCMeetings/POPRC5/POPRC5Documents/tabid/592/language/en-US/Default.aspx
Stoffenmanager	Safe and Healthy Work Department of the Ministry of Social Affairs and Employment of Netherlands	https://stoffenmanager.nl/

Source: www.subsport.eu; accessed: 08.09.2014

Environmental benefits and environmental performance indicators

- Green Screen ® for Safer Chemicals: 18 hazard points, divided into three levels of concern: high, moderate, and low. Two hazards, persistence and bioaccumulation, have an additional level of concern, "very high"
- Hazard categories evaluated by P2OASys include: Acute and chronic human effects; Physical and chemical hazards; Atmospheric hazards (ozone layer depletion, greenhouse effect); Aquatic toxicity; Waste generation; Energy/resource use; Product hazard; Exposure potential
- Environmental performance indicators for the usage of the BEMP:
  - Major OEM suppliers (in terms of % of supply chain expenditure) provide a **Full Material Declaration**; and/ or
  - Major OEM suppliers (in terms of % of supply chain expenditure) issue a **Supplier Declaration of Conformity** for company-specific list of restrictions, complemented by a certification (preferably third-party) based on laboratory testing
  - OEM publishes the information on its **web-site** and **annual sustainability reports** disclosing the % of suppliers (in terms of % of supply chain expenditure) complying with the above-mentioned requirements.

Applicability and economics

- P2OASys can be used to compare products, processes and technologies.
- GreenScreen® is only used to assess and compare individual chemicals, not products, processes or alternative technologies.
- Most of the tools are publicly available and provide comprehensive guidance on accessing publicly available data for the assessment
- Costs depend upon the complexity of assessment, need to fill data gaps and conduct laboratory tests
  - 18-25 hours for a comprehensive full GreenScreen® assessment; With Licensed GreenScreen® Profiler, costs can range from ~US$ 850-1500 per chemical; Costs increase when additional requirements pertaining to modelling, tests etc. are put from the client; GreenScreen® List Translator is easy to use and can be used with a subscription to Pharos (30 day free trial or around US$ 190/year)
  - The 3-step approach proposed for SMEs requires only few hours and hence entails low and affordable costs.

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Elimination of certain phthalates


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Justification and approach

- Most common application of phthalates in EEE is related to PVC insulation of cables and wires; Many phthalates have been assessed as being **toxic for reproduction** & are known to cause **endocrine disrupting effects**
- Besides DEHP, DBP, BBP and DIBP, further nine phthalates are included as **Substances of Very High Concern in the REACH Candidate List**
- Although DEHP, DBP, BBP, and DIBP are listed in REACH Annex XIV, i.e. they cannot be applied in substance form in the manufacturing of EEE components and products in the EU after 21st Feb 2015, **imported articles are not effected by this ban**
- The restrictions under REACH Annex XVII for a number of phthalates (DEHP, DBP, BBP, DINP, DIDP and DNOP) **do not affect the use in EEE** as these restrictions apply for use in toys and childcare articles
- As EEE components are often acquired from the supply chain, the **four phthalates DEHP, DBP, BBP and DIBP can still be used in EEE**, if the components are manufactured in non-EU countries
- The supply chain management for the elimination of the four phthalates (DEHP, DBP, BBP and DIBP) takes place by a restriction or ban by the company which is laid down in a company-specific document; **Threshold value: 0,1% by weight for homogeneous materials**, articles or components

Environmental benefits and environmental performance indicators

- Many phthalates have been assessed as being **toxic for reproduction** & are known to cause **endocrine disrupting effects**
- The main sources of exposure to the four phthalates (DEHP, DBP, BBP and DIBP via **dermal contact and indoor environment via inhalation**
- DIDP and DINP are the dominant alternatives to DEHP in wires and cables; But serious health issues related to DIDP and DINP are known
- Appropriate indicators for monitoring the implementation of the BEMP and/ or its environmental benefits would be:
  - Major OEM suppliers (in terms of % of supply chain expenditure) issue a **Supplier Declaration of Conformity** for company-specific list of restrictions, complemented by a certification (preferably third-party) based on laboratory testing
  - OEM publishes the information on its **web-site** and **annual sustainability reports** disclosing the % of suppliers (in terms of % of supply chain expenditure) that have phased-out four phthalates DEHP, DBP, BBP and DIBP

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Applicability and economics

- The applicability of the proactive elimination of certain phthalates is more prevalent in the ICT sector
- A threshold value of 0.1% by weight (of homogenous material) is applicable → usual value given for restricted substances under the RoHS Directive.
- **Ban of the four phthalates is reportedly not associated with higher costs**
- A ban of all phthalates respectively a switch to PVC-free cables, however, is reported to have a high cost impact.
- Costs of R&D and investments in equipment is low compared to the costs of the plasticizers for the substitution in cables (Danish EPA 2013)
- Total costs for the substitution of DEHP by DIDP in EU: 1,300,000 € in 2007 (ECHA RC SEAC, 2012)
  - If all costs are passed on to the end-user, the increase in costs incurred for cables have been estimated at 0.5% in the beginning of the substitution of DEHP as suppliers had to change the production.
  - The costs for end-user decreased to 0.05% after complete substitution

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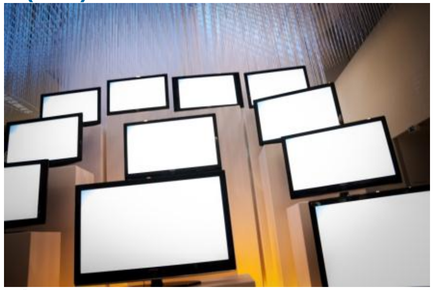
Elimination of brominated flame retardants (BFR) and polyvinyl chloride (PVC)



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Justification and approach

- Br and Cl compounds are the most common halogens in electronic products, and are the most likely to be used to achieve flame retardancy
- Some Br and Cl compounds are already regulated in EU legislation, such as RoHS, REACH Annex XIV and Annex XVII, Stockholm Conv.
- There are various approaches for phasing-out BFRs:
  - **Substitution of FR**: The HFR are replaced in the polymer material by a drop-in chemical substitute → inorganic substances (metal hydroxides), phosphorus-based and nitrogen-based FR → Implemented by polymer processor or compounder
  - **Substitution of polymer material or resin** → Implemented by polymer processor/compounder or by the end-product manufacturer
  - **Redesigning of the product** → Implemented by the end-product manufacturer
- Although PVC is not classified to be hazardous according to the EU CLP Regulation, nor it is classified as a PBT substance or a SVHC, its toxicity aspects are related to the use of a number of restricted additives (plasticizers, namely the phthalates DEHP, DBP, BBP) → **PVC substitution eliminates the need of plasticizers**

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Environmental benefits and environmental performance indicators

- A main concern related to Br & Cl compounds is tied to the incineration of plastics → emissions of dioxins & furans; BFRs are potentially bio-accumulative, relatively persistent and possess degradation products that are more toxic and accumulative than the original substance
- Following thresholds for phasing-out chlorinated and brominated compounds are proposed:
  - **Br < 900 ppm (or mg substance per kg homogenous material)**;
  - **Cl < 900 ppm (or mg substance per kg homogenous material)**;
  - **paired with a total threshold of Br+Cl < 1500 ppm (or mg substance per kg homogenous material)**.
- Appropriate indicators for monitoring the implementation of the BEMP and/ or its environmental benefits would be:
  - Major OEM suppliers (in terms of % of supply chain expenditure) issue a **Supplier Declaration of Conformity** for company-specific list of restrictions, complemented by a certification (preferably third-party) based on laboratory testing.
  - OEM publishes the information on its **web-site** and **annual sustainability reports** disclosing the % of suppliers (in terms of % of supply chain expenditure) that have phased-out BFR and PVC.

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Applicability and economics

- Applicability

Figure 5-15: Availability, Reliability, Cost & Safety of PIN FRs

Availability, reliability, cost & safety of PIN FRs

	Availability		Safety	Cost differential		Technology
Component categories	Do products exist?	Meet fire safety standard?	Health & environment	on material level	in finished product	Remaining issues to be resolved for shift (e.g.)
Wire & cable	✓	✓	Nordic & German gov't studies concluded there are sufficient PIN FRs of a good health & envi. profile to provide replacements; REACH registrations	~ 20%	Represents 1% ... 5% of the retail price of end product (fridge, TV...)	Some cable standards geared to certain materials
Enclosures	✓	✓		~ 20%		Need to shift from HIPS and ABS to polymer blends (e.g. PC-ABS)
Components	✓	✓		10% ... 20%		Some technical challenges, e.g. very thin parts, glow wire test
Wiring boards	✓	✓		10% ... 30%		Capacity build-up for alternatives; tests for long-term reliability

Source: PINFA (2010), RoHS Directive recast: Alternatives to brominated flame retardants – Presentation for Meetings in the European Parliament 23 March 2010, available under: http://www.endseurope.com/docs/100412b.pdf

- Costs depend upon the method of substitution, i.e. drop-in, change of resin, change of design;
- When using halogen-free alternatives, most substances will result in additional costs of 5-20% of the material

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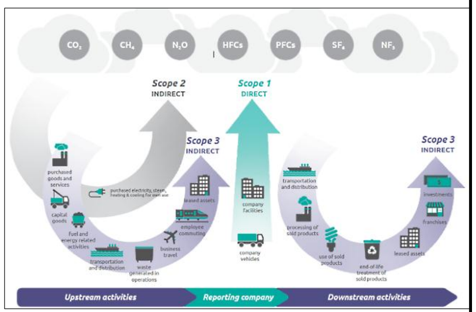
Disclose and set targets for supply chain GHG emissions



Source: GHG Protocol (2013)

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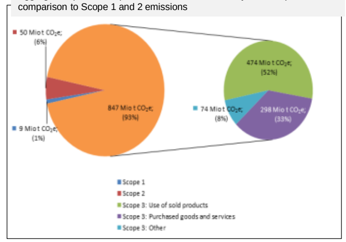
Justification and approach

- **Scope 3 emissions** typically make up a major share of overall corporate GHG emissions, often exceeding Scope 1 and 2 emissions significantly.
- **Standards for comprehensive Scope 3 accounting remain limited**.
- **<u>Disclosure alone is not best practice</u>** and, to a certain degree, common practice among large EEE manufacturers

Aggregate reported Scope 3 emissions to the CDP by ICT companies and comparison to Scope 1 and 2 emissions



Source: Own illustration based on CDP (2014)

- The BEMP aims at reducing Scope 3 GHG emissions, through
  - **publicly disclosing significant supply chain emissions according to recognised standard(s)** and
  - **setting and meeting (absolute and relative) targets for their reduction**

Environmental benefits and environmental performance indicators

- **Actually achieved absolute emission reductions may be lower than disclosed achieved emission reductions**, when (1) BEMP represents BAU, (2) Suppliers may be part of multiple manufacturers supply chains, who would each report on the progress of their supply chain GHG emissions, effectively reporting on the same achieved emission reductions
- **<u>Higher achieved emission reductions than reported</u>**, when (1) Emission reductions achieved at supplier facilities or in supplier procurement due to actions from the company implementing the BEMP may lead to reduced supply chain GHG emissions also of other companies, (2) Innovation and knowledge gained in emission reductions are transferred and scaled to other processes/ companies
- The implementation and environmental benefit of the BEMP can be monitored by the following performance indicators:
  - **Periodically published (e.g. annual) report according to recognised standard**;
  - **Number and extent of Scope 3 emissions/emission categories covered**;
  - **Disclosure of absolute or relative GHG emission reduction targets** in the periodically published (e.g. annual) report
  - **Absolute and/or relative emission reductions** demonstrated based on same standard.

Applicability and economics

- This BEMP, in principle, is applicable to all organisations. Sector specific guidance is applicable.
- Specific measures to reduce Scope 3 emissions are often the same as for Scope 1 and 2 emissions, except that they are not implemented in the company itself but at partner companies in the supply chain.
- Analysis of all ICT companies reporting to the CDP showed that **3/4th of implemented reduction activities have payback times within 3 years**
- In a study of EU COM, ICT companies were asked about one-off costs of the implementation of organisational carbon footprinting.
  - Four reported **out-of-pocket costs between 200k and 500k Euro per year**, one company reported **no out-of-pocket costs**,
  - Four companies estimated **1 to 5 full-time equivalents** (though it is not clear from the report over what time period), one company reported **7.5 full-time equivalents**; additionally four companies reported **10-30 non-full-time** people involved in the study;
  - **Full implementation time was estimated at 1 months to 3 years**.

Conducting Life-Cycle Assessment

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Justification and approach

- Although EEE-industry is increasingly motivated to implement LCA, only few companies have institutionalised the **<u>Life Cycle Thinking (LCT)</u>** in their strategic planning to develop green products or select greener suppliers
- Companies, especially SMEs, consider LCA to be very **<u>complicated, impractical in daily business and expensive</u>**
- Need to **<u>systematically analyse, evaluate, and improve the environmental performance of company's overall activities</u>**;
- Several approaches of easy LCA implementation are available:
  - Free LCA software (e.g. LCA-to-go, OpenLCA, LiMaS etc.)
  - Commercial LCA software (e.g. Gabi, SimaPro, Umberto)
  - Life cycle inventory databases: repositories for ready-made data of materials and processes (e.g. European reference Life Cycle Database, ProBas, Ecoinvent v3.1 etc.)
  - Fast-track LCA methods that allow streamlined impact assessments of products (e.g. LCA-to-go, Eco-costs, PCF etc.)

Environmental benefits and environmental performance indicators

- Companies can use LCA to **better understand the environmental aspects** of their products and the value creation process.
- Helps prioritising **environmental impacts** and **avoid shifting environmental problems** as well as **analysing and evaluating trade-offs** between the environmental implications of different design alternatives.
- Frontrunners in LCA application use the tool not only for a single purpose but rather in **support of strategic decisions in the environmentally conscious management** of a company
- Key environmental performance indicators would be:
  - Presence of the **Life-Cycle Thinking (LCT)** in the preamble of the company, while mentioning the importance of applying LCA
  - Application of **standard-conform LCAs** for major decisions, such as strategic portfolio planning, eco-design, selection of suppliers etc.
  - Close cooperation with key suppliers for collecting **site-specific primary data** for most important (e.g. 80% of overall purchased goods & materials) and environmentally relevant processes (e.g. 80% of overall GHG emissions)
  - Availability of **competent personnel as well as resources** (e.g. software) for conducting LCA

Applicability and economics

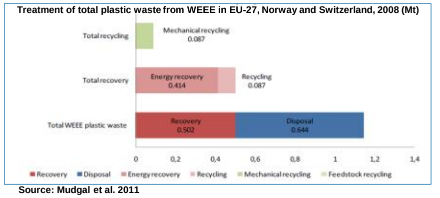
- This BEMP is applicable to all EEE organisations
  - Only 10% of the SMEs in the electronic sector have already conducted LCAs
- The costs of LCA depend on the objectives of the company that want to conduct an environmental analysis. In economic terms, the direct costs can be separated into the following aspects:
  - costs of workforce (skilled staff is necessary to collect primary life cycle data and to undertake the data analysis and interpretation of results),
  - costs of software licences (licence costs of € 5,000 to € 10,000 for full versions of commercial LCA software, free open source software available)
  - costs of secondary data sets (licence costs of € 2.000 to € 3.000 for commercial LCI databases) (usually included in commercial LCA software)
  - a robust and high-quality (fully ISO 14040 conform) LCA project for an average product may consume between 30 and 40 full working days for skilled LCA experts; As a rough estimate, the price range of specialized external LCA consultants ranges between € 13.000 (for a rough scoping study) and € 60.000 (for a comprehensive) LCA project
  - **Free tools, databases & software as well as simplified methods available**

Increasing the content of recycled plastics in EEE – Case study of closed-loop recycling process for polyethylene terephthalate (PET) and polypropylene (PP) plastics in inkjet printing cartridges

Source: Appears courtesy of PDR Recycling GmbH + Co KG and HP, 2014

Justification and approach

- Low recycling rates for waste plastic from WEEE
- Case study: Closed-loop recycling process for PET (rPET) & PP (rPP) plastics in inkjet printing cartridges



Source: Mudgal et al. 2011

- It is estimated that 300-500 million ink cartridges and 10-20 million toner cartridges are annually sold in the EU-27; In total volume per year, **40 -70% of these cartridges end up in landfills and/or incinerators** (Kougoulis et al. 2013)
- Major issues related to the use of recycled plastic content: **Properties & quality** not comparable to that of virgin materials and **low collection rate**
- Thus, involving various actors in the supply chain is essential, both for the **success of collection schemes** as well as in the **processing of used cart-ridges into post-consumer recycled plastic** to be used in the manufacture of new cartridges

Environmental benefits and environmental performance indicators

- While the recycling of inkjet printing cartridges can be considered as a BEMP within the category of establishing and implementing an efficient collection and recycling process in order to generate sufficient input to manufacture recycled cartridges, it is important to know that **the largest potential for reducing a printer's environmental footprint lies in saving the natural resources (oil, aluminum, timber) by not having to produce a new toner of inkjet cartridge, but remanufacturing it for its (multiple) re-use.**

Impact category	Unit	RPET (2013 Model)	Virgin PET	RPET as % of Virgin	Use of recycled plastics vs. virgin plastic
Climate change	kg CO2 eq	2.06	3.06	67%	33% less
Ozone depletion	kg CFC-11 eq	1.2 E-07	1.1 E-07	106%	6% more
Terrestrial acidification	kg SO2 eq	0.01	0.01	93%	7% less
Freshwater eutrophication	kg P eq	2.5 E-04	7.5 E-04	33%	67% less
Human toxicity	kg 1,4-DB eq	0.32	0.44	72%	28% less
Photochemical oxidant formation	kg NMVOC	0.01	0.01	102%	2% more
Particulate matter formation	kg PM10 eq	4.7 E-03	5.5 E-03	85%	15% less
Terrestrial ecotoxicity	kg 1,4-DB eq	2.0 E-04	2.0 E-04	96%	4% less
Freshwater ecotoxicity	kg 1,4-DB eq	1.9 E-03	6.3 E-04	302%	202% more
Water depletion	m3	1.38	5.76	24%	76% less
Fossil depletion	kg oil eq	0.69	1.51	46%	54% less
Cumulative energy demand	MJ	33.80	72.27	47%	53% less

Source: Four Elements (2014)

Environmental benefits and environmental performance indicators

- Per Product
  - Enabled recycled content per cartridge in terms of the amount of recycled plastic polymers from the total amount of plastic polymers used per cartridge (%)
  - Closed-loop post-consumer recycled content from other waste streams in the total amount of plastic polymers used per cartridge
- Per Manufacturer
  - Collection scheme efficiency - Percentage of cartridges recycled from total cartridges sold per manufacturer
  - Percent of cartridges manufactured with recycled content from total amount of cartridges sold by manufacturer.
- Per Recycler
  - % mass of cartridges recycled into materials suitable for reuse
  - % mass of cartridges recycled thermally

Applicability and economics

- The practice is suitable for using recycled plastic in EEE in general.
- WRAP (2010) demonstrated that using recycled WEEE-derived plastics in high-performance electrical products could be a viable technical and economic option.
- According to HP, just nine months after implementing the rPP program, some cartridges are likely heading into their 4th or 5th lifecycle; In parallel, with rPET, plastic from these supplies might have already been through ten or more cycles (HP 2014)
- In general, the price of rPET and rPP is competitive with the price of virgin material. rPET and rPP may be a bit more expensive on average, but their prices are also more stable in light of the changes in demand affecting the prices of virgin plastics
- With the exception of collection costs, the recycling processing costs can largely be offset through the recovery and re-use of the plastics and precious metals resulting from the process

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Identification of Best Environmental Management Practices for recycling of waste from electrical and electronic equipment

Andreas Manhart

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Overview of the developed BEMPs

No.	Title of BEMPs	Environmental pressures addressed: Resource efficiency	Water	Waste	Emissions to air	Energy & climate change	Biodiversity	Hazardous substances
	END-OF LIFE							
17	End-of-life removability of rechargeable batteries	X		X				X
18	Integrated Product Service Offerings	X		X		X		
19	High quality refurbishment of used products	X		X		X		
20	Non-destructive extraction of circuit boards	X		X	X	X		X
21	Innovative sorting solutions for black plastics from WEEE	X		X				

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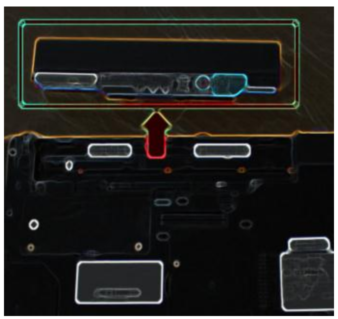
End-of-life removability of rechargeable batteries



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Justification and approach

- Rechargeable batteries (Li-Ion and NiMH) contain many critical and valuable materials such as cobalt, lithium and rare earth elements.
- These materials can be recycled if the batteries are fed into facilities specifically designed for battery recycling.
- Therefore, batteries need to be extracted from end-of-life devices such as portable electronics prior to end-processing.
- It is important that the batteries are not damaged or broken as this can lead to short-cuts, overheating and fire.
- This BEMP describes options for the design of products facilitating a sound and cost-efficient removal of rechargeable batteries from EEE.

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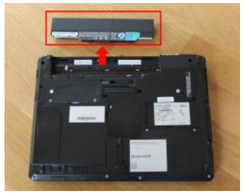
Operational data



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Environmental benefits and environmental performance indicators

- Between 50% and 72% of the world's primary cobalt supply is mined in the Democratic Republic of the Congo (DRC).
  - There, mining is often associated with informality and absence of social and environmental standards.
  - In addition, some deposits are associated with radioactive substances and heavy metals.
- Environmental performance should be measured by the percentage of devices brought on the market that comply with the following criteria:

  Rechargeable Batteries are removable
  - Without damage to the batteries,
  - Without the use of tools,
  - With manual labour input of not more than a few seconds per device

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Applicability and economics

- Large number of producers in the field of cordless power tools, notebooks and digital cameras.
- Less common for tablet PCs and smartphones.
- For the latter: To date, non of the big producers implements this BEMP over its whole product range.

- Implementation of the new Article 11of the Battery Directive will become mandatory on 1st July 2015.
- This will offer potential synergies.
- Benefits will result from improved recycling.
- As producers carry the costs for end-of-life management (extended producer responsibility), this will also benefit producers.

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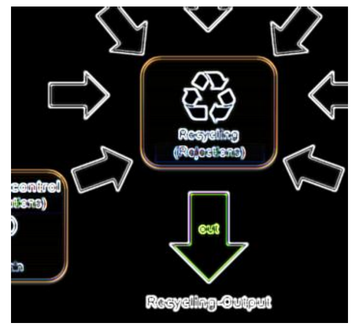
Integrated Product Serve Offerings (IPSO)



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Justification and approach

- In B2C segment, collection-rates for most WEEE-categories are unsatisfactory in most member states.
- Also potentials from repair and reuse are not yet exploited.
- Business-models are needed where OEMs have direct benefits from improved collection, re-use and recycling.
- The concept of Integrated Product Service Offerings (IPSO) describes such innovative business models.

(in other contexts, IPSO is often referred to as *Product Service Systems - PPS*)

- Currently, IPSO models are most common in the B2B segment with limited application in the C2B segment.

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Description and operational data

UNEP defines a Product-Service System "as the result of *an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands" (Manzini & Vezzoli 2002).*

Examples:

- Xerox: Hardware belongs to the OEM, charges ion the bases of the number of copies / printouts.
- Deutsche Telekom: Users pay for the service of internet access. The hardware (modem, router…) is installed at the customers' premises but owned by DT.
- Electrolux: Textile cleaning in private households (pay per wash)

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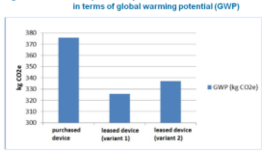
Environmental benefits and environmental performance indicators

- Typically, 100% collection-rate.
- Optimised processes for repair and reuse.
- Ideally, optimised processes for recycling as well as feedback-loops for improved product design.

Figure 6-7: Comparison of purchased vs. leased[179] Internet routers in terms of global warming potential (GWP)



Source: Prakash et al. (2011)

- Environmental performance should be assessed by monitoring the development of the following direct indicators
  - Take-back rates per product category (in percent),
  - Reused devices in relation to all devices installed (in percent),
  - Average life-time of hardware,
  - Re-use rate,
  - Recycling rate.

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Applicability and economics

- The combination of hardware and service activities becomes increasingly relevant in many competitive segments of the EEE industry.
- This is particular the case for product segments requiring specific know-how, attention and maintenance during installation and use.
- Producers mainly focusing on equipment sale are likely to face difficulties in such market segments.

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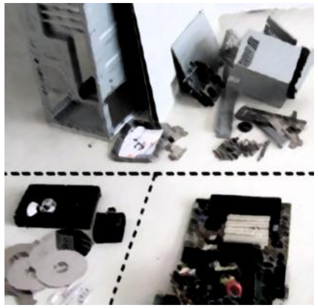
High quality refurbishment of used products



Background

Figure 6-1: The EU Waste Hierarchy

Source: European Commission: Information on the Waste Framework Directive. Internet: http://ec.europa.eu/environment/waste/framework/ (retrieved: 31.10.2014).

Justification and approach

- Many electrical and electronic products are replaced not because they have reached their technical end-of-life, but because users favour the purchase of new devices.
- For most types of devices, extension of use-phase is an important means to reduce overall environmental impacts.
- While repair, reuse and refurbishment can help to extend product-life time, many offers meet limited demand/acceptance by consumers.
- This is partly due to the fact that there is limited quality insurance in relation to the second-hand products.
- This, this BEMP explicitly addresses high-quality refurbishing models (“as good as when new”).

Operational data

In total, 5 steps are needed:

1. Selection
2. Sourcing
3. Technical Refurbishment
4. Sale/Delivery
5. Warranty

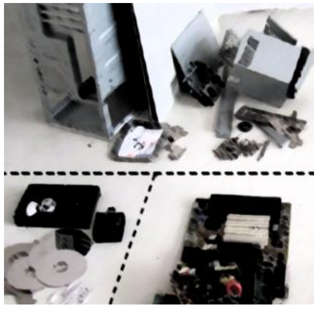
Environmental benefits and environmental performance indicators

- Proved positive environmental net-impacts for many types of EEE (e.g. ICTs, consumer electronics).
- This general assertion needs to be confirmed for equipment that
  - Has high energy consumptions in the use-phase
  - That might undergo significant efficiency improvements in the near future
- The environmental net benefits are difficult to be determined at an impact level, such as primary energy consumption or greenhouse gas emissions – at least during day-to-day operations. Therefore, it is advised to base monitoring on two pillars:
  - Demonstrate that refurbishing activities have environmental net benefits, also in light of energy efficiency gains of new product models.
  - Sales numbers in relation to the sale of new equipment (10%...?).

Applicability and economics

- Typically, applicability is higher for devices that are mid- or high-capital intensive, as the re-use market for products with purchasing prices below around 700 – 1,000 Euros for new equipment is not strongly developed.
- High quality refurbishment of capital-intensive products is reported to be economically profitable.
- The market for high quality refurbishment products usually does not negatively affect the sales volumes of new devices as it addresses a market segment of consumers that are cost- and quality-conscious customers.
- Where trade-in incentives are used, such activity may even encourage some consumers to purchase new equipment.

Non-destructive extraction of circuit boards



Justification and approach

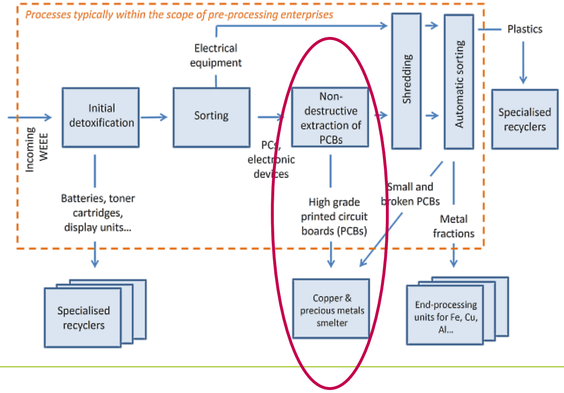
- Printed circuit boards (PCBs) are part of most electronic (and partly also electric) equipment.
- Electronic PCBs contain both, hazardous substances and valuable metals (e.g. gold, silver, palladium, tin).
- Non-destructive extraction of PCBs significantly reduces the precious metals losses compared to destructive extraction measures.

Table 6-5: Recovery Rates for Gold, Silver and Palladium Yielded in a Mechanical Extraction of Printed Circuit Boards

Material	Amount contained in a 1 t test volume of WEEE	Amount sorted into output fractions for precious metals recycling	Amount unintendedly sorted into other fractions	Recovery rate
Gold	22.2 ± 2.5 g	~ 5.7 g	~ 16.5 g	~ 25.6%
Silver	313.3 ± 35.0 g	~ 36 g	~ 277 g	~ 11,5%
Palladium	7.16 ± 0.87 g	~ 1.9 g	~ 5.3 g	~ 25,6%

Source: Chancerel et al. (2009)

Operational data

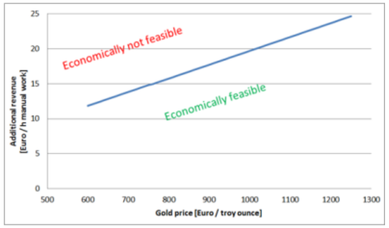


Environmental benefits and environmental performance indicators

- Environmental benefits result from reduced demand for primary materials.
- Recycling of precious metals from WEEE requires between 93% and 98% less primary energy and emits 87% to 95% less greenhouse gases.
- Non-destructive extraction of large printed circuit boards yields additional 4 g of gold per tonne of waste desktop PCs.
- This results into a saving potential of 68 kg CO_2 equivalents (CO_{2e}) per tonne of treated waste desktop PCs.
- In addition, non-destructive extraction methods generate less dust emission in recycling facilities.

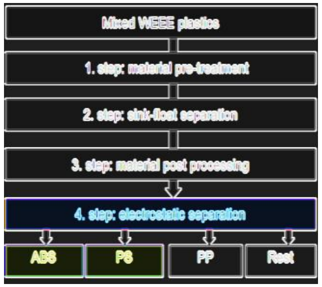
Applicability and economics

- For non-destructive extraction of PCBs from 1 t of desktop PCs, around 5 to 10 hours of manual labour are required.
- This yields on average 4 g of additional gold.
- Balance between labour input and revenues needed.



Source: Own calculation

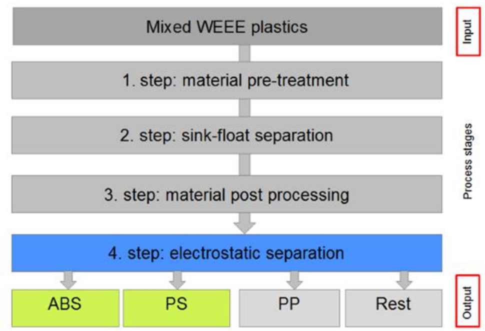
Innovative sorting solutions for black plastics from waste electrical and electronic equipment



Justification and approach

- Thermoplastics are used in all types of EEE.
- For recycling, plastics from WEEE needs to be sorted according to main polymer types and its level of contamination with flame retardants.
- ABS and PS are the most common polymer types in WEEE-plastics (50-55% of all WEEE-plastics).
- These polymers have the same density (prohibits density separation)
- Sensor based technologies have difficulties with black plastics (no reflection of sensor beam).
- The share of black plastics is constantly increasing in the waste stream.

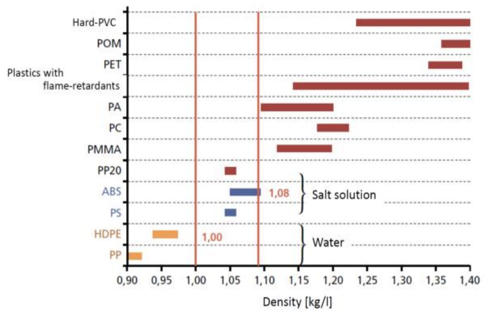
Operational data



Source: Own figure according to Hamos & WERSAG (n. y.)

Operational data

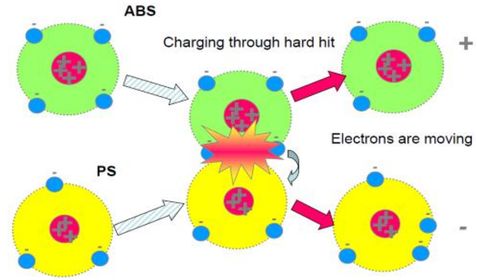
Different densities as basis for sink-float separation



Source: Köhnlechner (2014a)

Operational data

The principle of tribo-electric charging used for electrostatic separation of ABS and PS



Source: Hamos & WERSAG (no year)

Environmental benefits and environmental performance indicators

- Recycling of plastics from WEEE reduces the demand for primary resources – in this case crude oil.
- The recycling of 1 metric tonne of ABS and PS replaces around 2 tonnes of crude oil.
- It is estimated that 3 million tonnes of plastics from WEEE will require appropriate management in 2019 in the EU, whereof 50-55% of this volume is expected to be ABS and PS
- The required process-energy (electricity) is by far overcompensated by the resource savings.

Applicability and economics

- The approach is suited for recyclers of mixed plastic streams from WEEE and end-of-life vehicles (ELV).
- Contamination of the input stream with glass and/or metal parts is acceptable as these particles are effectively sorted out during sink-float separation and therefore cannot cause any damage to equipment.
- The costs for the electrostatic sorting of 1 t of plastics range between 20 and 25 Euros
  - including costs for electricity, maintenance and depreciation.
  - The costs for process steps 1-3 are not accounted for in this figure.
- Virgin plastic resin is traded at a price ranging between 450 and 620 Euro/t for PS and 355 and 575 Euro/t for ABS (referring to prices in August 2014).

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