Going Green
CARE INNOVATION 2014

Abstract Book

Towards a Resource Efficient Economy
10th International Symposium and Environmental Exhibition
An event to discuss future strategies, meet your clients and form strategic partnerships

November 17 – 20, 2014
Schoenbrunn Palace Conference Centre
Vienna, Austria
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1.1. End-of-Life Management

1.1.1. The inner values of IT products
K. Hieronymi, Hewlett-Packard, DE

IT is considered as one of the bigger users of raw materials, especially metals which people consider as ‘rare’. Within a recent research project, material composition of selected IT Products have been investigated and put in perspective with the raw materials used in other industries. The presentation will explain the outcomes of this research on the total amounts used as well as certain important elements. It will also explain material trends in the IT industry and mid-long term consequences for recycling. It will identify ways to capture sufficient value in current and future recycling to motivate various actors to collect and recycle electronic products today and in the future. The presentation will also identify potential gaps for the recycling of future IT product.

1.1.2. Sustaining the US Electronics Recycling Industry: New Challenges for a Maturing Market
E. Harris, ISRI, US

1.1.3. Depollution benchmarks for capacitors, batteries and printed wiring boards from waste electrical and electronic equipment (WEEE)
D. Savi, U. Kasser, Büro für Umweltchemie, CH; T. Ott, Zurich University of Applied Science, CH

The authors compiled and analysed sample data for toxic components removed from waste electrical and electronic equipment (WEEE). The control bodies of the Swiss take back schemes have been monitoring the activities of more than 30 WEEE recyclers in Switzerland for about 15 years. From this data, percentage shares of removed batteries and capacitors are calculated in relation to the amount of each respective WEEE category treated over the past ten years. A rationale is developed, why such an indicator should not be calculated for printed wiring boards. The distributions of these de-pollution indicators are analysed and their suitability for defining lower threshold values and benchmarks for the depollution of WEEE is discussed. Recommendations for benchmarks and threshold values for the removal of capacitors and batteries are given.

1.1.4. GIS Planning of Reverse Logistics Systems for Separated Household Waste Collection
R. Ladanyi, Bay Zoltan, HU

The Hungarian waste management sector is under transformation now. The new (2012/CLXXXV) Law on the Waste applies such requirements on the household waste collection enterprises that cause restructuring among the players on the waste market. Besides this, the deposit fee system (that are defined by 209/2005 government decree) proposed to be changed. The proposals are extending the scope of the products that are under this regulation towards the packaging materials, thus the paths of the flows of packaging waste between the consumers and the recycling factories will evade the traditional separated waste collection routes. The aim of the system transformation is enhancing the proportion of separately collected waste in accordance with the EU directives. Evaluation of the collection efficiency by collection methods and by application areas under practical boundary conditions seemed to be useful in the course of the transformation. Results of my research towards planning of efficient separated waste collection systems (by means of planning software tool development) are summarized in this paper.

1.1.5. Is “formalization” of the “informal sector” really the way to go? A view from the field in China
Y. Schulz, University of Neuchâtel, CH

This paper outlines the “formalization” of the WEEE management system promoted by academics, corporate representatives and state officials active at the national level in China. I observe that doing away with the “informal sector” is justified on environmental grounds in dominant discourses and argue that this eclipses important economic and political phenomena. Thus far, experts in charge of devising WEEE policies have paid remarkably little attention to the longstanding networks and established markets that determine the fate of most discarded electrical and electronic appliances in China. It should therefore not surprise that state action in this area lacks efficiency. I call for a more realistic approach, consisting in building up from the existence and crucial role of small economic actors and taking into account not only their limitations but also their capabilities and interests.
1.2. ICT

1.2.1. Activities of Green ICT in Telecom Company

We present the new procedure for estimating the reduction in CO2 emissions realized by using ICT services at a company level and an Eco-labelling System for ICT services provided by NTT Group. To develop a method for assessing the effect of using ICT services on the reduction in CO2 emissions, we divided ICT services into two levels, namely the application-service level and the network-service level. The Eco-labelling System of ICT services is a system for certifying ICT solutions provided by the NTT Group that exceed certain standards as regards the reduction of environmental impact as "environmentally friendly". We defined a 15% reduction of CO2 emissions compared with a conventional system as the standard for labelling.

1.2.2. Scenario Analysis of the Electricity Consumption in the Japanese Information and Communications Sector toward Green of ICT
K. Kuroda, Y. Kishita, Y. Yamaguchi, Y. Shimoda, Osaka University, JP; Y. Umeda, University of Tokyo, JP; M. Hara, H. Oka, J. Nakamura, NTT, JP

As the usage of ICT is increasing to make our life convenient, the reduction of the electricity consumption of ICT sectors (i.e., green of ICT) is indispensable to achieve a low-carbon society. To promote green of ICT, it is needed to analyze impacts on future electricity consumption of ICT sectors by changes in business environments and effects of electricity reduction by various countermeasures. To enable the analysis of these problems, we develop a model for forecasting future electricity consumption of ICT sectors. As a case study, we forecast the electricity consumption of the Japanese ICT sector in 2020. We assume three scenarios depending on the amount of information traffic. The results show that the electricity consumption in 2020 will be 1.1-1.9 times more than the 2011 level.

1.2.3. Green ICT Method for Evaluating CO2 Emission Reduction of ICT Services

Information and communication technology (ICT) services are expected to help reduce CO2 emissions. We developed a method for evaluating the amount of CO2 emission reduction of company-wide ICT services by using formulas for calculating such reduction from the sales data of services. We plotted the reduction data and sales data of several of our services on a graph and conducted a correlation analysis. In the analysis, we grouped the ICT services based on the similarity in emission reduction and calculation cost for companies and obtained a high correlation coefficient by classifying services based on the particular industry of service users. This method enables us to evaluate the annual reduction in CO2 emissions from sales data.

1.2.4. Holistic View on the Role of ICT in Environmental Sustainability
S. Aleksic, Vienna University of Technology, AT

Information and communication technology (ICT) has become an integral part of our everyday life including social interactions, business processes, technology and ecology. However, its potential benefits and risks for the environment are still not sufficiently explored. This is mainly because of the complex interdependencies between ICT and different other areas of business and society that together build a very complex ecosystem. In this paper, a holistic approach that treats ICT as a part of the global ecosystem is introduced. This approach combines data-centric methods that are typically used to analyze communication networks with widely applicable thermodynamic tools. The proposed approach is well suited to investigate complex heterogeneous systems and assess their environmental sustainability. Within this holistic framework, the whole lifecycle of ICT components and systems is considered. In particular, we briefly discuss the application of the presented approach on evaluating the sustainability of smartphones, notebooks, data centers, switches and access network equipment. Additionally, preliminary results of an exemplary model of cloud computing use in Austria are presented.

1.2.5. Full Scale Delivery of an Electronic System for Compliance with duty of Care Legislation, and Collection of Commercial Waste Data within the UK
V. Vaughan-Williams, C. Deed, K. Davis, Environment Agency, UK

The Environment Agency and its partners have developed a new electronic duty of care (edoc) solution to reduce: the administrative burden on businesses of completing an estimated 23 million
waste transfer notes (WTNs) each year; minimise paper storage requirements; and improve the quality of waste management data. Edoc will deliver a national, web-based system to capture the waste journey from production to collection, transportation and disposal. The new edoc system will modernise the existing paper-based system. For UK businesses, the system will improve data-capture and quality, provide reports to audit compliance and reduce administration costs. For governments, edoc will provide unprecedented information about the volumes and types of waste materials being produced.

1.3. ReUse & Refurbishment

1.3.1. Refurbishment of Medical Systems – Contribution to Circular Economy and Sustainability

R. Corridori, COCIR, BE; M. Plumeyer, Siemens, DE

This paper deals with the well-established practice in the medical imaging sector to take back used medical systems from users and to restore them into a condition of safety and effectiveness comparable to when new, including actions such as repair, rework, update and replacement of worn parts with original parts. The process, known as refurbishment, is the best way to unlock the residual value of used systems and contributes to the three pillars of sustainability:

- Economy: with a total turnover of more than 240 million euros the refurbishment business contributes to EU economy.
- Environment: reuse is considered the most effective way to prevent waste and to save resources and energy.
- Patients: refurbishment supplies high quality medical systems at affordable cost for hospitals and healthcare providers.

1.3.2. Defining an Ideal Used Electronics Management Program

C. Mars, Arizona State University, US; J. Mangold, M. Hutchins, University of California, US

One significant challenge of understanding the performance of used electronics management programs is a lack of a consistent method to assess program effectiveness. To address this need, The Sustainability Consortium launched a research program to develop a Used Electronics Management Program Effectiveness Scorecard. We present the results of the first phase of scorecard development – the Definition of an Ideal Used Electronics Program. The Definition was developed using Delphi methodology to solicit input from an expert panel consisting of representatives of five stakeholder groups (Government, Manufacturers, NGOs, Recyclers & Refurbishers, and Other interested parties) concerned with end-of-life electronics management. From this process, a definition plus five key characteristics for an ideal used electronics management program were developed. These results will be used in the second phase of research, Existing Metrics Evaluation, where the effectiveness of the identified metrics to assess the performance of a used electronics management program against the goal represented by the Ideal Program Definition will be determined.

1.3.3. Analysis of European Closed-Loop Supply Chain Network for WEEE – An OEM Perspective

D. Stindt, C. Nuss, University of Augsburg, DE

To profoundly analyze the viability of a European product recovery network from an OEM’s perspective, we develop a mixed-integer linear model. This quantitative decision-model aims to maximize profits generated from collection and reprocessing activities of a manufacturer for electrical and electronic equipment (EEE). Beside classic economic aspects we incorporate legal limitations (e.g. the WEEE-Directive and the Regulation on shipments of waste) into both the constraints and the objective function. Hence, legislative elements are considered as central influencing factors. Based on several scenarios, we examine the “critical mass” of potentially acquirable goods to profitably run a network for collection and recovery of WEEE. Our analyses base on real-world data that originate from cooperation with a globally acting manufacturer for IT. This enables the transfer of our results to business practice as well as to future legislative actions.
1.3.4. Reciprocal Features of Electronics Industry and Products in our Sustainable Society
M. Kitamura, H. Hayashi, EcoDesign Promotion Network (NPO) Tokyo, JP

The Reuse based resource conscious industry needs back-tracking schemes adding to methods of forwarding value added industrial resources. Small personal electronics device is highly integrated product that contains great added values with small amount of material resources. But total amount of resource needed becomes very large and the resource consumption depends on consumers’ behavior that will show preferences of both new high performance kind and yet old experienced one in use. Reciprocity in whole industry is proposed as Reciprocal Industrial Supply Chain (RIS-chain) and Reciprocal Manufacturing Robot (RM-robot).

1.3.5. OREG – Optimal Resource Management of Electric and Electronic Devices
M. Dos Santos, KERP, AT; S. Eisenriegler, H. Reichl, R.U.S.Z., AT; W. Hauer, M. Merstallinger, TB HAUER, AT; R. Haubenberger-Hahn, T. Maier, ERA, AT; G. Waizinger, Waizinger, AT

The main objective of this project is to investigate the re-use potential of small and large Waste Electrical and Electronic Equipment (WEEE) collected at two municipal collection points. Other objectives of this project include estimating material composition (valuable and hazardous components), to develop strategies to increase the amounts of collected appliances for re-use purposes and to construct equipment for a gentle and safe collection, storage and transportation of devices. Since June 2014 a complete Re-Use circuit could be installed in one of the two targeted points. Old devices, which have been brought back from the inhabitants of one of the sites, have been stored, transported, proved, repaired and finally brought to a social-market.

1.4. Industry Feedback and Experiences on using the BOMcheck shared web database for REACH, RoHS and Conflict Minerals

This session includes presentations from Siemens, Philips, Carestream Health and ENVIRON to provide feedback and experiences on using the BOMcheck substances declarations web database for REACH, RoHS and Conflict Minerals. The session will conclude with a panel discussion to enable attendees to put their questions to the panel about any aspects of interest.

1.5. Design

1.5.1. Dell Ultrabook and Tablet Design for Recyclability Assessment per IEC 62635 standard
S. O’Connell, P. Shrivastava, T. Moriarty, S. Schafer, Dell, US

In last few years, Ultrabooks and Tablets have gained significant market share globally. At the end of their useful life these products will be returned to recyclers for end-of-life disposition. In this paper we will highlight results of a recently completed project on recyclability assessment for mainstream Dell Ultrabook and Tablet product. Two products were independently assessed by a lab to the IEC 62635 standard. The focus of this standard is on design for end-of-life treatment, information exchange between manufacturers and recyclers in order to “eco-design” products that fit recyclers’ capabilities to efficiently and effectively process WEEE, and calculation of recyclability rate. Results showed that both Dell Ultrabook and Tablet evaluated were over 96% recyclable. In this paper we share and discuss results and propose next steps.

1.5.2. Designer focused QuickScan recyclability assessment method
F. Fakhredin, C. Bakker, Delft University of Technology, NL; J. Geraedts, Delft University of Technology / Océ Technologies, NL

Recycling crosses the fields of resource engineering, metallurgy and materials sciences, and designers cannot be expected to master all these knowledge areas. However, designers need to have access to this knowledge in a simple and clear form, to be able to design products that allow an optimal recovery with minimum quality losses. This is achieved by developing a QuickScan recyclability assessment method based on an exploded view of a product, in which material compatibility and ease of separation of parts are indicated with a simple color scheme. The requirements for the method are derived based on understanding of the design process and
learnings from existing recycling tools. The QuickScan recyclability assessment method was tested on a MR16 LED Lamp for method enhancement.

1.5.3. Streamlined Method for Immediate Integration of Eco-Design in Product Development of Consumer Electronics
A. Andrae, Huawei, SE; G. Xu, Huawei, CN

In product development in the industry, it is important to estimate the environmental impact of each product in a logical and applicable way. However, the quantity of requirements can act as a barrier to introducing eco-design. Few methods have been presented that clearly describes how eco-design can really become a part of the traditional product development process. Several existing eco-design methods do not seem to be intended for rapid product development process where the eco-design is not the main objective. Here an approach for rapid introduction of eco-design of electronics in the product development process of any company is presented. The cost-effective method makes use of seven eco-metrics and rapid LCA giving quantified results which are easily understood by designers. The proposed method captures the essence of eco-design of electronics in a cost-effective manner with enough precision for use as designer information. The actual implementation and verification of eco-design changes are solved and moreover the proposed eco-design method does not require specific customization prior to use. The presented method is successfully demonstrated for the development of a mobile phone.

1.5.4. An Environmental Conscious Product Design Method for Sustainability of Product’s Value
S. Yamada, M. Inoue, Meiji Univ., JP; T. Yamada, UEC Tokyo, JP; K. Nakano, JEMAI, JP; S. Bracke, Univ. of Wuppertal, DE

This study describes an upgradeable-product design method that inhibits the disposal of an item by replacing only the few components related to its deterioration in value, as opposed to disposing the entire product. This method predicts the required future functions and beforehand designs products to be compatible with the anticipated upgrades. Therefore, designers are required to consider the uncertain design information associated with future predictions. Methods proposed in conventional research were unable to quantitatively reduce the amount of environmental load. Hence, this paper proposes an upgradeable-product design method that deals with required future product performance criteria, functions, and adverse effects related to product upgrading by concurrently applying a preference set-based design method that obtains ranged sets of design solutions to optimally satisfy multi-objective requirements. Additionally, we evaluate the amount of environmental load reduction in the overall product lifecycle by applying the proposed method to a laptop design case study.

1.5.5. Development of a Design for End-Of-Life Approach in a Strongly Guided Design Process. Application to High-Tech Products
M. Lemagnen, Sagem, FR; S. Pompidou, Univ. Bordeaux, FR; N. Perry, ParisTech, FR

In response to a growing concern for environmental problems and to waste management from mass production products, several regulations have appeared to tackle end-of-life (EoL) issues. They address for instance end-of-life vehicles or waste electrical and electronic equipment. EoL management mainly lays on both EoL industry and product design. Thus, new methods of design have already been implemented since the past decades to answer the regulation requirements, notably through material choices and product architecture. However, some high-tech products remain out of the scope of these legislations. But for some years, initiatives have emerged for these products, coming from governments, international programs or customers’ requirements which become increasingly strict. This paper focuses on a new design approach that would allow taking into account EoL considerations for such type of products, based on EoL strategies and adapted to aeronautic and defence products.
1.6. Plastics recycling

1.6.1. Microbial Fuel Cell-Based Bioelectronics System for Simultaneous Copper Recovery and Toxicity Detection in Domestic Wastewater

L. Zhang, L. Lai, S. Li, National University of Singapore, SG

In this study, a dual chamber microbial fuel cell (MFC) was constructed to provide a novel approach to solve multiple environmental and energy problems. In the anode chamber, organic compounds (COD 350 mg/L) present in real domestic sewage were bio-degraded to generate electricity. In the cathode chamber, Cu²⁺ ions (100 mg/L) which are commonly discharged from heavy metal processing plants were reduced to elemental Cu to recover metallic resources. A series of contaminated domestic wastewaters with final Cu²⁺ concentration of 0 mg/L (Level 0), 1 mg/L (Level 1), 2 mg/L (Level 2) and 5 mg/L (Level 5). During the respective sensing periods, simultaneous electric energy and copper recovery of 97 ± 5, 89 ± 3, 72 ± 1 and 65 ± 3 Wh/(kg Cu) were generated at the four contamination levels. With recovery of microbial bioactivity, those efficiency for power production and metallic resources reclamation could increase by 2 to 3 folds to as high as 266 ± 21, 214 ± 23, 157 ± 22 and 129 ± 20 Wh/(kg Cu) in the 90 min operating period. This study demonstrated that an MFC could be a promising candidate for simultaneous wastewater treatment, energy generation, metallic copper recovery and toxicity sensing.

1.6.2. Learnings from Philips Consumer Lifestyle Recycled plastics program

E. Smit, Philips, NL

This paper describes the learnings from the recycled plastics program at Philips Consumer Lifestyle from 2010 onwards. It will give a short overview of the plastics market and will describe the benefits of using recycled plastics. It will also explain which hurdles need to be overcome when using recycled plastics in electronic equipment. Recycled plastic is still very different from virgin plastic and this means that introducing recycled plastics requires changes in a company's strategy. Recycled plastics both have different mechanical and visual properties, which means that parts in which recycled plastics can be used must be carefully selected. Suppliers of recycled plastics are also very different from the traditional virgin suppliers and this requires a change in the company's supply chain management. The paper will conclude with suggested steps that can be taken to introduce recycled plastics in a product.

1.6.3. Closing the Loop for Plastics in Electronic Products

S. O’Connell, P. Shrivastava, Dell, US; M. Stutz, Dell, DE

Plastics are lightweight and durable materials, which can be readily molded into a variety of products that find use in a wide range of applications. As a result, the production of plastics has increased rapidly over the last 60 years. The majority of plastics are made exclusively from oil or other fossil fuel derivatives. Computer products use plastics in chassis, bezel, internal components etc. Currently, plastics recycling from electronics is low due to supply, cost and technical challenges so it generally ends up being downcycled. At Dell, we challenged ourselves to create a closed loop supply of plastics, whereby, Dell can make plastics parts for personal computers using plastics recycled from older electronic equipment (a closed loop system). Dell announced the partnership for closed loop plastics with our ODM partner Wistron and the Dell-Goodwill Reconnect Program. With this program, plastic from obsolete IT products are collected, disassembled and sorted. After a shredding and purification process, it is compounded to produce plastic pellets. This compounded plastic is then molded into plastic parts such as the back panel or stand of an All-in-One or Display or front bezel of a desktop. This paper describes this closed loop recycling program and highlights some of the benefits and opportunities for closed loop plastics within the IT industry.

1.6.4. Recycling WEEE plastics, a challenge to achieve the WEEE directive targets!

L. Tange, ICL-IP Europe, NL; J. R. Peeters, P. Vanegas, KU Leuven, BE

The European Flame Retardant Association (EFRA) has since long been following closely the WEEE directive in relation to plastics recycling and the upcoming WEEE targets. EFRA’s aim is to get a better understanding of recycling of plastics including flame retardants via practical projects. The recast of the WEEE directive (February 2014) sets ambitious recycle targets for 2015 and 2019. This is a new challenge to address for OEMs and recyclers, mainly because WEEE contains an increasing amount of different types of plastics. We have carried out many trials and made efforts with all relevant players in the value chain to identify, sort and test the reuse of different types of plastics used in LCD TVs. The results show that it is possible to manage plastics waste E&E in an environmentally sound manner, via mechanical recycling while at the same time complying with the
objectives set by the WEEE Directive and meeting stringent emissions regulations.

1.7. ReUse & Repair

1.7.1. Repairability Overview: Teardown of Smartphones and Tablets
K. Wiens, M. Huisken, iFixit, US

iFixit takes you on a tour inside the latest electronics. iFixit's world-renowned teardown engineers will discuss the tradeoffs and decisions made by the product designers. We'll investigate the tradeoffs of extending the life of products versus energy efficiency. What are the battery removability vs durability tradeoffs? We'll discuss the impacts of glued in batteries on recyclability and repairability. How are recyclers dismantling iPads and Android tablets like the Kindle and Galaxy Tab? What design characteristics make some devices more difficult to repair and recycle?

The development of a repair infrastructure has the potential to create more jobs than recycling and disposal. But to be successful, a repair infrastructure needs access to spare parts and service manuals. Spare parts for phones and tablets are generally not available through manufacturers, leading repair facilities to rely on harvesting parts from other products, which depending on availability can limit the repair of some tablet makes and models.

This overview of the marketplace will cover product designs and trends and assess their impact on the aftermarket.

1.7.2. A Quantitative Analysis of Material Flow of Used Mobile Phones in Japan
N. Mishima, O. Honma, Akita University, JP; K. Mishima, Keio University, JP

From April 2013, a legislation to promote recycling of small-sized e-waste including use mobile phones has started, in Japan. In order to consider appropriate methods to promote recycling of used mobile phones, the first step should be the understanding of current situations of end-of-life flow of used mobile phones.

This paper first illustrates a precise material flow of used mobile phones. Then, by applying sensitivity analysis to the factors of the material flow. By assigning a variable to each factor of the material flow, it is possible to calculate the change in environmental impact when the factors will change. The result indicates which factors are the keys in reducing environmental impact. Through the investigation, the paper concludes that “product reuse” can be a solution to reduce consumptions of virgin materials. As a future work, practical countermeasures to enhance key factors should be discussed based on the analysis.

1.7.3. Smart Disposal of Mobile Phones - The Bavarian Way
O. Gantner, A. Reller, University of Augsburg, DE; U. Teipel, Technische Hochschule Nürnberg, DE; C. Hagelüken, Umicore, DE

Smart disposal of mobile phones was a Bavarian voluntary collection to overcome low recycling rates, identify deficits in the disposal chain and derive specific recommendations for future mobile phones recycling. Nearly 70,000 obsolete mobile phones were collected, of which 8% were refurbished and 92% recycled in a state-of-the-art facility. Besides the number of collected units, brand and type specific information of weight, type of battery, number of cameras and display type have been determined and obviously proven a transition in technology by the year 2002. Mapping the results with GIS a comprehensive realisation and participation was one of the outcomes of this study. Further findings are a homogeneous spatial distribution for the participation, information on the number of collected mobile phones, distributions of mobile phones for recycling and refurbishment, marketing ratio and lifetimes. In conclusion future collections should again be performed in a spatially comprehensive manner. The study also underlined the need to closely monitor flows of collected phones throughout the reuse and recycling chain in order to secure that the full potential of recovering valuable and critical raw materials from mobile phones is finally realised.

1.7.4. Re-Use Initiatives in Central Europe, Based on the Approach of the CERREC Project
E. Garamvölgyi, Z. István, P. Chrabák, Bay Zoltán, HU

Re-use is a dedicated new approach in the EU waste management introduced in the Waste Framework Directive (Directive 2008/98/EC on waste). Despite re-use is in initial phase in most countries: centres for re-use are available in some, but re-use oriented networks are still missing. The project CERREC – “Central Europe Repair & Re-use Centres and Networks” – is an EU funded
project implemented through the CENTRAL EUROPE Programme and co-financed by the ERDF with the aim of fostering re-use in CE countries. 9 partners from 7 Central European countries carry out the evaluation, development and dissemination activities in the field of re-use and repair of waste considered products as a new form of waste treatment both on national and transnational level. Based on the project approach, pilots are being developed in the Central European area to test the CERREC developments and evaluate the outcomes. Besides, action plans are being created in all participating countries to foster implementation of re-use in all countries.

1.7.5. Social Enterprise Changing Policy – Repair and Service Center R.U.S.Z.
S. Eisenriegler, R.U.S.Z., AT

ReUse activities in the social economy sector arose out of market failure and the lack of proper repair services coupled with planned product obsolescence. Profits generated by repair centres were not sufficient for private enterprises to take interest, with the result that social entrepreneurship has flourished here, providing added environmental, social and economic value. Marginalized groups such as retired people and longterm unemployed have a value and a purpose in the social economy.

1.8. What happened to producers’ responsibility?

The results of the European WEEE legislation since 2003 are not encouraging. The non-harmonized implementation of the European WEEE Directives 2002/96/EC and 2012/19/EU in the EU 28 has for more than 10 years created an unlevelled playing field for recyclers. The results are: a negative price spiral for treating WEEE leading to low quality treatment and export of WEEE where legislation is more lenient, absent or not enforced. Disinterest of politicians and authorities and the lack of enforcement of the WEEE legislation has led to shady business practices where on average at least 2/3 of the WEEE that is discarded from households and businesses is not treated in compliance with the WEEE legislation. In order to lay a fundament for quality in the market standards on collection, transport and treatment of WEEE are required. Such standards should be legally binding in all 28 EU Member States in order to secure a level playing field for legitimate recyclers. The European Commission mandated Cenelec to develop EN standards. This paper focusses on the present status of development of these EN standards and on the auditing and certification of these standards.

1.8.3. WEEE recycle in Teamwork
C. Slijkhuis, MGG, AT

The Müller-Guttenbrunn Group (MGG) has developed an innovative modular recycling system for the efficient recycling of this growing and complex waste stream and is already capable to recover over 85%, which is more than what is targeted by the new EU E-Waste Directive for 2018. 4 Innovations have been the key success factors for the success of the Müller-Guttenbrunn Group (MGG):
1. Removal of hazardous and valuable parts from E-Waste with the patented - „Smasher“
2. Improved Shredder Process for E-Waste - „EVA“
3. Recovery of Non-Ferrous Metals including very low concentration metals - „Metran“

2.1. Ecodesign

2.1.1. Potential Future Market Requirements for Green Electronics
J. Omelchuck, Green Electronics Council, US

2.1.2. Industry Self-Commitment in the Ecodesign of Medical Imaging Equipment
R. Corridori, COCIR, BE

The objective of this paper is to illustrate the achievements and results of the COCIR Self-Regulatory Initiative (SRI) in the ecodesign of medical equipment. COCIR, the European coordination Committee of the Radiological, Electromedical and healthcare IT Industry launched in 2008 a SRI with the European Commission in compliance with the requirements specified by the ErP directive, to reduce the environmental impact of medical imaging equipment through ecodesign. The initiative, officially acknowledged in 2012 by the EU Commission has already provided significant results and the findings have been already used in the project, launched by the European Commission, to develop criteria for the Green Public Procurement of medical devices.
2.1.3. **Case Studies of Innovative Eco-Design**  
*S. Seok, Y. Jung, H. Lee, KEITI, KR*

There are two main key features of our Eco-design Project. The first involves selecting ideas on how to solve certain environmental problems in Korea, such as excessive energy use, water shortages, harmful contaminants, etc., through eco-friendly means. The second feature involves the implementation of these ideas in the market. The above approaches differ from many prior eco-design approaches that depended on life cycle assessment. The aim of this study is to introduce 10 innovative products and services that will be available in 2014. Through the use of these products and services, consumers will be able to clearly see the benefits of eco-value. Moreover, the improved convenience will lead to sustainable consumption.

2.1.4. **Ecodesign Requirements for Servers – From Single Product Groups to Extended System Approach**  
*N. Nissen, L. Stobbe, Fraunhofer IZM, DE; T. Faninger, A. Berwald, BIO by Deloitte, FR; K. Lang, Fraunhofer IZM / TU Berlin, DE*

The currently ongoing ENTR Lot 9 preparatory study for ecodesign of enterprise server and storage equipment raises a number of methodological questions as the investigation requirements shift further from a pure product scope to extended system analysis. The paper will give insight into the current status of the study. However, the core part of the paper will focus on the methodological aspects of addressing ecodesign on an individual product level while at the same time reflecting the extended system. The paper will explain the ecodesign implications of the various system levels, i.e. the sub-system (IT product) and extended system (support infrastructure) relationship. We then explore the options on how to cope with extended system aspects on a product scope level. The analysis will then examine existing and needed test standards, which are especially crucial for sub-system requirements.

2.1.5. **User-Centred Eco-Design: Identifying the Potential Benefits for the Electr(on)ics Sector - A State-of-the-art Review.**  
*L. Domingo, E. Dekoninck, University of Bath, UK*

Electr(on)ic manufacturers are concentrated on improving the environmental efficiency of their products. Technical improvements for energy efficiency, legislative compliance and design for end-of-life have been the main focus for product eco-design. Yet, one of the main contributors to the environmental performance of the product has been disregarded so far: the user. This paper reviews how user integration in eco-design of electronic products can support the development of more environmentally-friendly electronics. The review shows the potential for the electr(on)ic sector to develop products to support sustainable behaviour by, for example, automation and feedback provision to users.

2.2. **Market driven developments**

2.2.1. **Consumers’ views on eco-friendliness as a dimension of a high-tech brand**  
*U. Saari, S. Mäkinen, P. Alinikula, Tampere University of Technology, FI*

High-tech companies are facing the need to perform deeper analysis of how consumers view the eco-friendliness of their brands, in order to create green product and marketing strategies. The focus of this paper is to study whether consumers associate eco-friendliness with high-tech brands, and what kinds of consumers are most pro-environmental based on demographics. The key finding of this research is that consumers consider also eco-friendly aspects when reflecting on high-tech brands on four dimensions also used to measure general brand experience: the sensory, affective, behavioral and intellectual dimensions. Demographically, women consider eco-friendliness more in association with high-tech brands than men across all of the four brand experience dimensions. In addition, mature consumers consider on the intellectual and sensory brand dimensions more eco-friendly aspects than young consumers. There are no statistically significant differences in the responses based on the educational background of the respondents.
2.2.2. 20 years experience of eco label and product environmental declarations – critical success factors and business impact.
H. Wendschlag, Hewlett-Packard, SE

There is growing business importance to communication product environmental attributes to customers. This paper deals with our more than 20 years experience of using select eco labels as well as the industry IT Eco Declaration, the ECMA-370 standard. The paper deals with critical success factors, i.e. explains why certain systems are successful whilst others don’t seem to attract any applicants.

2.2.3. Buying greener electronics: A review of purchasing policies and practices
C. Bocher, DEKRA, DE; A. O’Rourke, Industrial Economics, US; J. Copper, Tomorrows Business, DE

Government institutional purchases make up to 20-30% of GDP, and many are now seeking to “green” that spend, with electronics being a key category. Oftentimes, implementation of sustainable or green public purchasing policies takes the form of guidelines for their purchasers that include the criteria, eco-labels and attributes they wish suppliers to meet. However, the criteria being applied are not always consistent, and the extent to which the green product attributes are weighted in the final purchase decision is somewhat unknown. We analysed the green criteria for electronics product categories (computers, printers, imaging equipment) as found in over 1000 sustainable purchasing guidelines worldwide and investigated implementation of these guidelines. According to our evaluation, there is a diversity of approaches to defining what counts as “greener”, and moreover, there is a gap between policy & practice of sustainable purchasing and supply chain management. Organisations have serious ambitions to purchase more sustainable products, when price and quality requirements are met, but there appears to be a disconnect between the questions asked, the responses provided and the factors that influence the purchasing decisions. This disconnect restricts organisations from weighting product sustainability requirements in their design process in a meaningful way.

2.2.4. Survey on Industry Requirements and Drivers for the Development of a Process-related Certification Scheme for Ecodesign Implementation and Management
D. Pigosso, M. Jakobsen, T. McAloone, Technical University of Denmark, DK

Despite the existence of a large amount of eco-labels and eco-standards for product declaration, there is still limited research for the development of process-related certification schemes dealing with ecodesign implementation and management. In order to identify companies’ drivers, barriers and expected benefits in regards to the development and application of process-related ecodesign certification schemes, a survey was carried out in this research. This paper presents and discusses the main results obtained in the survey, which comprised the participation of more than 100 professionals from more than 25 countries. The results will be employed for the development of an ecodesign process-related certification scheme based on the Ecodesign Maturity Model (EcoM2).

2.2.5. Disassembly Targets for Improving Resource Efficiency: Analysis of Environmental Relevance for Flat Panel Displays
P. Vanegas, University of Cuenca, EC / KU Leuven, BE; J. Peeters, W. Dewulf, D. Cattrysse, J. Duflou, KU Leuven, BE

In industrialized countries, recycling of complex products, such as electronics, is predominantly based on mechanical comminution and automated material sorting. This recycling scheme is characterized by high recovery rates for certain materials, such as steel and aluminium, but underperforms for other materials like precious metals, critical metals and plastics, which are of high importance from both an environmental and economic perspective. On the other hand, disassembly of certain components can significantly increase the recovery rate of these materials. Recent initiatives to revise the European eco-label for electronic products recognize this issue, and aim to influence the design of electronic products in a way that disassembly becomes economically preferable for key components at end-of-life. For example, in the draft version of the eco-label criteria for LCD televisions, maximum disassembly times are proposed for PWBs and plastic components. The aim of this article is to analyse the environmental relevance of such an approach, and to provide insights to manufacturers on the improvements required to decrease disassembly time. Therefore, an in-depth analysis of both material composition and disassembly times for LCD TVs and monitors is performed. Environmental assessment is carried out by means of LCA techniques.
2.3. HydroWEEE: Innovative Hydrometallurgical Processes to recover critical metals from WEEE

2.3.2. Hydrometallurgical Processes for the Recovery of precious and critical metals from Spent Lamps and Cathode Ray Tubes
V. Innocenzi, M. Centofanti, F. Vegliò, University of L’Aquila, IT; I. DeMichelis, EcoRecycling, IT

In this manuscript two hydrometallurgical processes to recover rare earths (RE) from fluorescent powders of lamps and cathode ray tubes (CRTs) are presented. These treatments are been studied within European HydroWEEE projects in the ambit of FP Work Program. Processes were tested in lab and pilot scale and included: leaching with acid, filtration, precipitation of RE as oxalates and wastewater treatment. During the tests, several implementations were performed with the goals to reduce the consumption of reagents, the amount of wastewater to disposal and to increase the recovery and the purity of the final products. The last results for lamps’ process showed that the purity of final oxides and the total recovery of RE are 97% and 93%, respectively; for CRTs the purity of the final oxide is 96% and the recovery is 74%.

Actually the processes are testing in the HydroWEEE industrial plants (stationary and mobile plant).

2.3.3. Hydrometallurgical Processes for the Recovery of precious and critical metals from Liquid Crystal Displays
F. Beolchini, L. Rocchetti, A. Amato, V. Fonti, Polytechnic University of Marche, IT; S. Ubaldini, CNRS, IT; I. De Michelis, F. Vegliò, University of L’Aquila, IT; B. Kopacek, ISL, AT

In 2010 indium was identified by the European Commission as a critical raw material for its economic importance and the supply risk. This metal represents a component of many electronic equipment and therefore its request is high; this fact favors indium recycling. The present study has been carried within the European project FP7 308549 HydroWEEE Demo. It deals with the recovery process of indium from end-of-life liquid crystal displays (LCDs). We carried out a hydrometallurgical process that included a stage of LCD washing followed by metal leaching in a sulfuric acid solution using a cross-current design. The final step of the treatment consisted of zinc cementation that allowed to obtain the transfer in the solid phase of indium present in the leach liquor. The whole process reached an indium recovery efficiency > 90%, and thanks to the cross-current leaching a lower amount of acid was used compared to conventional leaching.

2.3.4. Hydrometallurgical processing of waste printed circuit boards for Cu, Au and Ag recovery
I. Birloaga, F. Vegliò, University of L’Aquila, IT; I. De Michelis, EcoRecycling, IT; B. Kopacek, ISL, AT

Here we summarize the results obtained from hydrometallurgical processes waste printed circuit boards in the ambit of the HydroWEEE-Demo European Project. This hydrometallurgical processing has as main core recovery Cu, Au and Ag in a safe and economical manner. For copper leaching the leaching system comprised of sulphuric acid and hydrogen peroxide has been tested and was founded that a complete dissolution of it was obtained with small consumption of reagents by a two-step counter-current oxidative leaching procedure. The thiourea cross-leaching procedure has revealed two main advantages, namely: minimization of chemicals consumption and obtaining of solution with high content of precious metals. To recover the interest metals in theirs metallic form, the solutions purification was performed with zinc metal powder. The wastewater treatment coming from after the cementation process of precious metals was efficiently performed by Fenton reagent and lime. No liquid discharge was produced as all the residual water was reintegrated into the process.

2.3.5. Hydrometallurgical Processes for the Recovery of precious and critical metals from End-of-Life Batteries, such as Lithium ones.
F. Pagnanelli, E. Moscardini, P. Altimari, T. Abo Atia, L. Toro, Sapienza University of Rome, IT

In this work experimental results of leaching and purification tests for Co recovery from Lithium Ion Batteries were reported. Two pretreatment routes in pilot scale were considered. Electrode powders were recovered and characterized for metal content. Recovery yield and composition of electrode powders resulted strongly affected by the type of pretreatment operations used. The hydrometallurgical route used for Co recovery included: leaching (in acid reducing conditions), primary purification (by precipitation of metal impurities as hydroxides), solvent extraction (optional for reducing metal impurities) and cobalt recovery (by precipitation as carbonate). Optimal conditions were determined for leaching (1:10 as solid/liquid ratio; +100% stoichiometric excess of acid),
precipitation (pH 3.8), and solvent extraction with D2EHPA (pH 4; Mn/ D2EHPA= 4; TBP 15%; two sequential extractive steps). Co carbonate obtained after solvent extraction presented increased amount of Co (250 mg/g) and decreased metal impurities with respect to the sample obtained after precipitation.

2.3.6. Hydrometallurgical Processes for the Recovery of precious and critical metals from catalysts
F. Veglio, V. Innocenzi, F. Ferrante, University of L’Aquila, IT; I. De Michelis, EcoRecycling, IT

In this manuscript, two hydrometallurgical processes about the recovery of rare earths (RE), in particular lanthanum and cerium from FCC spent catalysts, are presented. The first treatment includes: leaching with sulfuric acid and selective precipitation of rare earths sulphates. The second, instead, includes: leaching with nitric acid, solvent extraction using D2EHPA dissolved in n-heptanes or kerosene, stripping with nitric acid and recovery of rare earths oxalates after precipitation by oxalic acid. The results of lab tests have showed that the purity of RE sulphates obtained in the first treatment and the total recovery of rare earths (La and Ce) were 80-85% and 80-90%, respectively; instead for the second process the purity of the final products was greater than 90% and the total recovery was 80-90%.

2.4. Renewable Energy

2.4.1. Control scheme for distributed n-to-n power exchange between solar systems including batteries
A. Werth, University of Tokyo / Sony, JP; N. Kitamura, K. Tanaka, University of Tokyo, JP

To ease the implementation of microgrids and thus to support a high penetration of renewables, we propose a DC-based Open Energy System (OES) that consists of a community of interconnected nanogrids. Each nanogrid can be seen as a small DC microgrid for individual houses, including PV panes and batteries. The interconnection is done using bidirectional DC/DC converters that can send or receive energy via a DC power bus line to neighbors. By using a combination of voltage and current controlled units, we built a higher level control software independent from the physical process. A further software layer is then added for autonomous control in order to handle power exchange based on a fully-distributed agent-based system without central knowledge. In parallel to the software development, we simulated a 4-node OES on which the we can test the improved solar usage when running on different control-systems, for instance, to compare the solar energy utilization with and without power interchange and to optimize the system parameters. This research is currently tested on a real scale community of 22 houses where we have demonstrated the feasibility of n-to-n distributed power exchange.

2.4.2. A New Proposal of Sustainable PV Gigafloat System
H. Kubo, Chiba Institute of Technology, JP

“PV Gigafloat”, so-called sea type of PV raft system, has many merits, for example, freedom of installed space, regionally generated and consumed, movability, durability for disaster, recyclability, etc. and also many issues, for example, cost reduction, higher efficiency, salty breezes, strong wind and billow, mooring, power transmission, stain, maintenance, etc. In order to solve these issues, step by step, three stages R&D plan was proposed based on Project Management technique. In this study, firstly, the cost of PV Gigafloat is estimated based on the recent actual price of PV system. Secondly, in order to clarify the concrete plan of 1MW PV system, so-called “PV Megafloat”, the specifications, structure, required technologies, cost estimation and schedule are investigated assuming to construct it in unused port of Urayasu-city in Chiba prefecture. As the result, the possibility of 1GW class PV Gigafloat is shown from the technical and economical point of view.

2.4.3. Geothermal power generation by thermoelectric devices
W. Fernandes, Z. Tamus, Budapest University of Technology and Economics, HU

Geothermal energy has been used for bathing since Roman times. At the moment, due the technology evolution, it is also possible to generate electrical energy with heat stored in the Earth. Hot water can be used to produce electricity in large power plants. The aim of this research is to propose a different method by Peltier cells using an experimental arrangement which simulates geothermal power generation. Nowadays, this method is not so common due its implementing costs. On the other hand, many places have no conditions to generate power using common methods because of low water temperature. Therefore, semiconducting method by using thermoelectric
devices, can be another choice for geothermal power generation.

2.5. Materials & Design

2.5.1. Next Generation Bio-plastics in Consumer Electronics  
*C. Holmes, Microsoft, US*

Polylactide (PLA) resins have been used to create compostable beverage cups and other food-related products since 2006, and in 2010 it had the second highest consumption volume of any bio-plastic in the world. Bio-plastics is a growing sector aspiring to reduce the world’s dependency on petroleum based resins, but the adoption in consumer electronics has been slow. Research was undertaken to evaluate the performance of a new PLA resin in an existing ABS mold. This paper provides a side-by-side comparison of two versions of a consumer electronic product, one made with ABS and other made with the new PLA resin.

2.5.2. Enabling innovative applications in electronics with high performance halogen free plastics  
*R. Borggreve, DSM, NL*

Green Design has recently gained significant interest in the electronics industry. The electronics industry is facing growing regulatory demands and OEM requests related to the elimination of substances of hazardous concern, requiring, for example, halogen-free technology and solutions for lead-free soldering. Next to the increasingly restricting the use of certain halogens as flame retardant substances in plastics, also reduction of consumed energy is a key topic. Moreover, producers of key electronic components, such as connectors, lighting and wire & cables are looking to advance miniaturization, system cost reduction and integration of components. This requires materials with higher mechanical, thermal and processing performance over conventional high temperature polyamide materials such as higher temperature performance and flow, thin wall strength, high reflectivity and Glow Wire Ignition Temperature (GWIT) at end use part level. Building on many years of experience as a leading solution provider in the industry, DSM offers a complete product portfolio of halogen free high performance engineering plastics for robust solutions which extends customers’ choice with performance.

2.5.3. Development of a toolbox for the implementation of sustainability in the product development processes at Grundfos Holding A/S  
*D. Pigosso, T. McAloone, Technical University of Denmark, DK; A. Pattis, Grundfos Holding, DK*

Grundfos, one of the world’s leading pump manufacturers, has been actively engaged in sustainability integration into its business over the last decades. This paper presents the approach followed by the company to develop a toolbox that aims to systematically integrate sustainability into the processes for strategic planning, frontloading and product development, following a life cycle approach. The methodology for development, validation and implementation of the toolbox was based on an action research framework, leading to the development of a tailored approach according to Grundfos’ culture and internal processes. The main elements and tools of the SPS toolbox and key learnings within its development are presented in this paper, which can inspire companies in the approach to be followed when developing, customizing and developing new tools for integrating sustainability in their business processes.

2.5.4. Eco-Innovation of the Atmospheric Plasma Etching System by Combination of TRIZ Methods and Computer-Aided Innovation Software  
*J. Chen, F. Yang, National Cheng Kung University, TW; J. Hsu, C. Chang, ITRI, TW*

This paper presents a methodology for eco-innovation by combining an improving method of using TRIZ contradiction matrix to get suitable inventive principles with the root cause analysis and patent search functions in computer-aided innovation software Goldfire. Atmospheric pressure plasma etching system is demonstrated as case study to illustrate the capabilities of proposed method. The results showed that those methods can give effectively suggestions for improvement atmospheric pressure plasma etching system problems.
2.5.5. Development of resource efficiency measures for products
L. Talens Peiró, F. Ardente, F. Mathieux, DG-JRC, IES, IT

The environmental impact for the extraction, manufacturing and end of life (EoL) of certain products is becoming a higher concern, especially for those containing electronic components. Detailed analyses in certain products are needed to improve the resource use and potential environmental impacts. JRC-IES has developed the resource efficiency assessment of products (REAPro) method to provide scientific evidence and technical support in the assessment of products. The REAPro method helps estimate quantitatively the benefits of aspects such as recyclability/recoverability, the recycled content and durability, all from a life cycle perspective. In this paper, we explain how the methodology works, an example of its application, how it can help manufacturers in the design of more innovative and sustainable products, and contribute to a more circular economy.

2.6. Supply chain management

2.6.1. Using Scaled Product Life Cycle Assessment to reduce the impact of IT Products
J. Ord, A. Degher, T. Etheridge, Hewlett-Packard, NL

HP is a world leader in the use of environmental analysis tools like Life Cycle Assessment (LCA) and the GreenScreen chemical assessment method to understand and reduce the environmental impacts of our products and solutions. This talk will describe how HP solved technical and business challenges scaling LCA product level analysis across its personal computer and printer businesses by collaboratively building two very different LCA toolsets. The first toolset - “PAIA”- is a personal computer carbon footprinting tool borne from a joint industry, academic and NGO effort that streamlines and harmonizes carbon footprinting across manufacturers. The second toolset- HP’s printing LCA platform - “modularized” traditional LCA so that HP could conduct LCAs across HP’s printing business. Thanks to these tools, HP was among the first companies globally to publish its full “scope 3” (product use and end-of-life) carbon footprint in 2013.

2.6.2. Gathering a product’s footprint for materials traceability, safety and collaborative sustainability
R. Vazirani, TÜV Rheinland, HK

A digital database Platform could allow manufacturers and their supply chain visibility of their products’ compliance status against constantly changing environmental requirements, thus supporting their endeavor of proactive design for compliance against RoHS, REACh, Cal Prop 65, Conflict Minerals, etc.

2.6.3. Developing a Sustainable Supply Chain – The BT Better Future Supplier Forum Initiative
J. Spear, epi Consulting, UK

BT believes that by close collaboration with its supply chain, it can reduce its carbon impact and harness innovation which will help it to develop sustainable products and services which will reduce BT’s product carbon impact, assist customers to reduce their own carbon impact and facilitate BT meeting its 3:1 Net Good goal to help its customers reduce emissions by at least three times the end-to-end carbon impact of BT’s business. To engage with the supply chain, BT created the Better Future Supplier Forum (BFSF), a collaborative forum that is built around a sustainability best practice assessment and benchmarking improvement model. Within the Forum, innovation is delivered through a process called the Game Changing Challenge. Results in 2013 include delivering over 250,000 tonnes of carbon emissions reduction and numerous stand-out product innovations that include the reduction of user energy consumption in one case by up to 40% and in another a product with a carbon footprint reduced by 30% and cost by 20%.

2.6.4. Energy Efficiency-Based Supply Chain Configuration
E. Colangelo, Fraunhofer IPA, DE; T. Bauernhansl, Fraunhofer IPA / University of Stuttgart, DE

Considering the economic growth in terms of production and the limited resources, that are necessary for power generation, energy efficiency is a strongly discussed topic at the moment. But how to achieve the desired improvements without having to recur to high investment in equipment, production and product re-design? This paper addresses this subject by using two complementary approaches. First, the internal efficiency is examined by optimizing the status of the machines and
peripheral equipment. In an extended consideration, the estimated energy consumption is used as a base to decide upon a specific partner in a supply chain

2.6.5. Sustainhub – A Software Solution for Sustainable Supply Chain Management in the Electronics Industry
R. Baumgartner, M. Fritz, J. Schlögl, University of Graz, AT; A. Schiffleitner, KERP, AT; K. Resel, denkstatt, AT

How sustainable supply chain management can be facilitated in the electronics industry is explored by the project Sustainability Data Exchange Hub - SustainHub, funded under the 7th Framework Programme. SustainHub aims at developing a software solution, which enables companies along a supply chain to request, report and exchange sustainability related information such as REACH/RoHS compliance, GHG-emissions and social working conditions.

2.7. HydroWEEE: Innovative Hydrometallurgical Processes to recover critical metals from WEEE

2.7.1. Design and construction of the stationary and hydrometallurgical plants for the recovery of metals from WEEE
P. Altimari, I. De Michelis, L. Toro, EcoRecycling, IT; F. Beolchini, Polytechnic University of Marche, IT; B. Ferrari, S. Giorgetti, Relight, IT; V. Innocenzi, University of L’Aquila, IT; B. Kopacek, ISL, AT; E. Moscardini, F. Pagnanelli, Sapienza Università di Roma, IT; N. Panjevac, Inst. Mihailo Pupin, RS

Recovery of metals from end-life electric and electronic devices (WEEE) can prevent the adverse environmental impact of direct waste disposal and provide industry with a fundamental source of secondary raw materials. Central role is played in this framework by the scale-up of processes allowing for the separation of metals from WEEE. In this contribution, we illustrate the design and construction of a mobile (loaded on two containers) and of a stationary plant realized in the framework of the FP7 European Project HydroWEEE Demo to recover metals from WEEE. The two plants have been realized to demonstrate technical and economic feasibility of the implemented hydrometallurgical processes. A brief overview of the processes carried on within the plants is presented. The analysis is followed by a discussion of the procedure adopted in plant design and by the description of the constructed plants and their processing potential.

2.7.2. Plant Automation for Hydrometallurgical Process of Material Recovery from WEEE
N. Panjevac, M. Stojanovic, Inst. Mihailo Pupin, RS; B. Kopacek, ISL, AT

Recovery of valuable materials from Waste from Electrical and Electronic Equipment (WEEE) is a complex technological process requiring constant process control for obtaining maximum results in quality of end product, and process safety during production. During process development it was taken into account need for high output capacity and 24/7 plant operation which also requires fully automated controller guided process. Nature of WEEE processing, where input materials are geographically distributed to WEEE collection centres and contains dangerous substances (like lead and mercury), created a need for mobile plant design. For mobility of such technology it was necessary to adapt process and process hardware to have flexibility of accepting different input materials, local resources and harsh exploitation conditions.

2.7.3. Automated disassembly of components from Printed Circuit Boards
P. Kopacek, B. Kopacek, ISL, AT

The main idea of this paper is to find an economic way for reducing the amount of material for the recovery process and to recognize reusable parts on printed circuit boards (PCBs). Usually the hydrometallurgical recovery process is very time consuming and therefore the recovery rate currently relatively low. In addition there are reusable parts on PCBs which have a reasonable high value on the market. For these must be decided selling or recovery.

One possibility is the use of robotized, semi-automated, flexible disassembly cells for PCBs for minimising the amount of scrap for recovering rare materials. The cell is based on modular disassembly cells developed some years ago for removing re-useable electronic components from old as well as new PCB’s. and consists of a transportation system, a vision system and heating-de-soldering stations. Feeding and removing of the cell is done manually.
2.7.4. Urban Mining of Rare Earths from WEEE: A Successful Experience with the stationary plant

B. Ferrari, S. Giorgetti, S. Sgarioto, F. Bacchetta, Relight, IT; D. Romilio, University of L’Aquila, IT

The main objective of this paper is the presentation of a successful case study of urban mining dealing with two research projects funded within the European FP7 framework: HydroWEEE (2009-2012) and its follow up HydroWEEE Demo (2012-2016). The first project HydroWEEE dealt with the recovery of rare and precious metals from WEEE including spent lamps and cathode ray tubes (CRT). Innovative processes feasible for SMEs were developed and a pilot prototype was performed. The objective of the HydroWEEE Demo project is to build 2 industrial demonstration plants (1 stationary and 1 mobile) in order to test the performance and prove the viability of the processes from an integrated point of view (technical, economical, operational, social) including the assessment of its risks and benefits to the society and the environment.

Relight is a leader company in the recycling trade; it held the pilot prototype and holds now the stationary plant with an innovative hydro-metallurgical process for the recovery of Rare Earths.

2.7.5. Introduction to Greentronics and practical experiences with the pilot plant

D. Modoran, Greentronics, RO

2.8. Energy Efficiency

2.8.2. Local Energy Brokerage

K. Macek, T. Hrdlička, Honeywell, CZ; A. Quadrelli, ENEL, IT

The present paper provides a novel algorithm for the local energy brokerage where multiple participants in a neighborhood exchange the locally generated power. The provided algorithm allows fully automated operation that is configured by several configuration parameters. A set of potential suppliers provide their proposals where the less probable generation is proposed for a higher price with respect to the present risk. Consequently a common pricing profile is constructed and the proposals are paired with the demands.

2.8.3. Short-Term Power Demand Curve Forecast Based on Support Vector Machine and Deep Learning

H. Chin, Y. Kobayashi, B. Hollerit, K. Tanaka, R. Abe, Univ. of Tokyo, JP

We performed a short-term power demand curve forecast based on Support Vector Machine and Deep Learning. Demand and supply balancing is the key technology for power management and high efficiency planning. Previously, some Non-linear Regression Analysis models were proposed in several researches. In our research, we aimed to develop a power demand-forecast platform that can have adequate Non-linear Regression Analysis model selection and overcome feature value with high accuracy. In this paper, we have compared the result with the recently developed demand curve forecast result based on non-linear regression model as the first step of our research goal. Furthermore, we attempted to adapt the state of art machine learning method – Deep Learning – in order to check the forecast capacity. As the result, we could achieve better forecast by adapting Non-linear Regression Analysis models.

2.8.4. The Autonomous DC Microgrid System for Residential Community

A. Werth, Sony / Univ. of Tokyo, JP; N. Kitamura, K. Tanaka, University of Tokyo, JP

In the Fifth Assessment Report, the IPCC predicts that the average temperature rise of the earth and the cumulative amount of generated carbon dioxide since the industrial revolution until the end of this century would be approximately proportional. The global warming may lead to climate change on a global scale that threatens the survival of all creatures. In addition, a sustainable society would not be coming because of the limit to the reserved energy resources. Today we know that the direct use of sunlight can cover the annual energy demand of all human activity. Hence, it is now that we have to make a serious decision concerning the sustainability of our society. In this study, we propose an autonomous DC microgrid system with distributed power exchange control to increase the utilization of renewable natural energy and to ensure minimal energy supply in the event of a large-scale disaster. In addition, we examined the feasibility and potential for residential community through a case study using various power exchange control systems with a variety of DC microgrid system configurations. This shows that the DC microgrid systems can improve the solar energy utilization with smaller investment in solar power system, storage system or the AC grid power system.
stabilizer than conventional AC grid.

2.8.5. Energy Saving Measures Obtained from Large-Scale Power Monitoring Experiments in Convenience Stores
J. Fujimoto, A. Suzuki, National Institute of Advanced Industrial Science and Technology, JP; S. Furusawa, Seven-Eleven, JP

Power monitoring experiments using wireless sensor nodes were conducted in 2,000 convenience stores (CVS) from 2010 to 2014 in order to achieve a 10% electric power reduction. These experiments aimed to reduce power consumption by comparing the electric current values between a large number of stores with similar equipment type & function and floor space. Around 20,000 wireless sensor nodes (2.4GHz & 920 MHz radio frequency), which monitored electric current, temperature & humidity were installed into individual stores. Through large-scale experiments, a number of factors which seem to have restricted the penetration of power saving measures or stable wireless communication into society were revealed. Benefits and issues regarding wireless sensor node systems were investigated.

2.9. Eco-Design and Product Life Cycle Management - A perfect match?

Companies developing products across a wide range of industries face increasing complexity in their products and value chains. Meeting substance/ material-focused product and supplier compliance regulations is a difficult problem for companies seeking to compete in global markets. To successfully develop environmentally friendly products, companies must implement a sustainability framework (often known as Eco-Design). Global OEMs and their supply chains not only need to choose materials that are compliant with regulations, but they also need to move beyond basic compliance with a sustainability strategy that phases out or replaces current components and materials with new "green" ones. Noncompliance costs can range from fines to more severe penalties, including being prevented from selling your products in key markets. Lack of visibility to compliance information can also lead to increased inventory costs and excessive product redesign costs.

2.10. Impacts of Legislation

2.10.1. Approach on substance management and substitution
M. Rahko, Microsoft Mobile, FI; P. Saavalainen, Microsoft Mobile / University of Oulu, FI

Legal requirements are the basis for creating and maintaining methodology for substances and materials management in EEE (electrical and electronic equipment). Main substance and material level restrictions and requirements are initiated from global and local legislation. Many companies have also introduced materials restrictions on a voluntary basis based on the precautionary principle. This has generated phase-outs of some hazardous chemicals from the components and parts of EEE. In order to fulfill the material declaration requirement, there are many methodologies to use for declaration of product compliance. The main methods are Full Material Declarations (FMD), chemical analysis testing, or a combination of both. FMD offers many possibilities to react to new requirements and restrictions that cannot be reached only with testing. When substitution of certain substances is introduced, an analysis of the business impact on the technological, environmental and socio-economic issues must also be considered.

2.10.2. Overview of the differences in new producer compliance obligations in EU Member States new WEEE Recast Regulations to implement the WEEE Recast Directive 2012/19/EU
H. Stimpson, ENVIRON, UK

This presentation provides an overview of the new requirements in the EU Waste Electrical and Electronic Equipment (WEEE) Recast Directive 2012/19/EU and highlights key differences in how these requirements are being implemented in national WEEE Recast Regulations in the 28 EU Member States. Selected examples contrast the different requirements in different countries and highlight the practical options available to overseas companies to register as a WEEE producer in different EU Member States. This presentation is of particular benefit to companies wishing to register as a WEEE producer on behalf of resellers and distributors in each EU Member State, and to companies selling products from one country directly to end-users in another EU Member State.
2.10.3. The WEEE recast – status of national implementation and new legal requirements for producers and distributors across Europe

M. Ruoff, WEEElogic, DE

The new WEEE Directive (Directive 2012/19/EU, aka “WEEE Recast”) entered into force on August 13, 2012. Member States were required to transpose the WEEE Recast into national law by February 14, 2014. At that time, the “old” WEEE Directive, 2002/96/EC, was repealed. To date, however, only thirteen EU Member States have implemented the WEEE Recast into national law. All the other EU countries are behind schedule.

The intention of this presentation is to give an overview of the status of implementation of the WEEE Recast in Europe and to provide insight into the already passed new WEEE laws. Major changes for producer and distributors selling EEE across Europe will be highlighted.

2.10.4. Filling the Gap of the WEEE Framework in the European Union – Private European Initiative Towards Simplification and Harmonization

M. Ruoff, R. Letenneur, WEEElogic, DE

The EU published a WEEE legal framework to be enforced by Member States. It confirms producers as the obligated parties to develop and finance means of collection to guarantee the state of the art collection and recycling of WEEE. Consequently producers have to put in place compliance solutions in order to assume both B2C and B2B obligations, indeed operational solutions designed for the purpose of household and non-household WEEE. To some extent, producers have been quite efficient in setting up the relevant private initiatives to manage B2C obligations. However, as legal targets have been reinforced, producers face challenges in both contributing to the achievement of the collection targets and developing B2B collection integrated within their commercial activities. The presentation will navigate the audience through these basic principles and disclose the key stakes that producers and the private sector need to develop to achieve the legal requirements.

2.10.5. Complexity of Regulations Relevant for Returns of used or defective products a barrier to waste hierarchy?

J. Terry, 1cc, DE

Operating centralized repair centers is for many producers of electrical and electronic equipment an option to keep repair costs at an acceptable level. The Waste Framework Directive and Waste Shipment Regulation but also special laws such as the ‘new’ WEEE Directive 2012/19/EU and its national implementing regulations, apply an order in waste prevention and management principles, prioritizing direct re-use and preparation for re-use before recycling and recovery and, at the same time, hinder economically reasonable operations by restricting import and export of used equipment. The complexity of regulations for companies intending to establish repair and refurbishment programs creates additional obstacles in the implementation of such operations. This contribution will assess from a legal and business perspective the stipulations impacting producers’ remarketing, repair, re-use and refurbishment operations. The goal is to evaluate whether these present a barrier to the waste hierarchy principle.

2.11. RECLAIM: Reclamation of Gallium, Indium and Rare-Earth Elements from Photovoltaics, Solid-State Lighting and Electronics Waste

2.11.1. Reclamation of Gallium, Indium and Rare-Earth elements from photovoltaics, Lighting and electronic waste – REclaim project and outlook

M. van Kleef, R. Bisselink, T. Ansems, TNO, NL; B. Kopacek, SAT, AT

Modern technologies for green electronics like photovoltaic systems and solid-state lighting require increasing amounts of scarce metals. Global demand and price of these materials is expected to increase significantly the coming decades. If not controlled well some of these resources may be exhausted within 20-30 years.

Europe is considered to be a fertile ground for establishing an advanced recycling infrastructure for key metals from E-waste as (1) it is an important and growing market for Photovoltaics (PV), Solid State Lighting (SSL) and electronics, (2) there is a recognized need to expand manufacturing
technology to provide the high added value required to remain globally competitive, (3) it will contribute to becoming less dependent for raw material supply, and (4) aligns well with the positive societal attitudes towards recycling and support for the necessary waste collection systems.

Objectives of the RECLAIM project are to find technological solutions for disconnection, sorting, concentration and purification of indium, gallium and rare-earth metals (yttrium, europium) that relieve current bottlenecks and demonstrate their application potential by means of pilot implementations in an industrial setting.

2.11.2. Characterization and selection of feed from the e-Waste streams out of WEEE, Determination of the recycling potential and the prospective recycling quality of e-Waste streams in view of the targeted key metals

A. Branderhorst, Coolrec, NL

This paper describes in detail the raw material potential in the FPD’s, PV and PCB’s and SSL of the above mentioned waste in order to reclaim the precious and rare metals contained in selected WEEE-streams.

2.11.3. Technologies for pre-treatment, disconnection and sorting under development within RECLAIM Project

D. Guarde, A. Egia, J. Sánchez, Indumetal Recycling, ES

The “RECLAIM Project”, is an European initiative looking for a substantial development on the existing treatment and recycling processes of E-Waste to feasibly reclaim strategic materials presented in green technologies such as flat panel displays (FPD), photovoltaic panels (PV), printed circuit boards (PCBs) and solid-state lighting (SSL). They are yet unexploited and growing deposits of key materials in these terms. Therefore, pre-treatment, sorting and disconnection of the parts with the targeted materials are being deeply faced within the project as one of the main bottlenecks to be solved is the final idea to provide new recovered fractions that truly can be used as secondary materials.

2.11.4. Recovery of precious and critical metals from Lamps: treatment and preparation of the powders from a recyclers’ perspective

S. Giorgetti, B. Ferrari, Relight, IT

In this paper is described in detail the raw material potential in the Fluorescent Lamps (SSL) together with pre-treatment and treatment of the above mentioned waste in order to reclaim the precious and rare metals contained in the fluorescent phosphor powders.

2.12. Standardization & Climate change

2.12.1. Data Exchange Standards For the Management of Substance Restrictions and Conflict Minerals in a Global Supply Chain

F. Abrams, IPC, US

Global substance restrictions and reporting requirements including RoHS, REACH, and Dodd-Frank Conflict Minerals have necessitated the tracing and tracking of substances contained in electronic products. This paper will examine the evolving need to trace substances in a product through a complex global supply chain and the emergence of solutions developed by industry to facilitate that exchange. This paper will include a review of industry standards, particularly the IPC 175x series of data exchange standards and the IEC 62474 Materials Declaration Standard.

2.12.2. IEC 62474 – The Evolution of Material Declaration

W. Jager, ECD Compliance, CA; R. Friedman, Siemens, US; L. Young, Intel, US; K. Bodenhöfer, Sony, DE

IEC 62474, the International Standard for material declaration in the electrotechnical industry, represents an evolution in material and substance declaration to meet current and future requirements. The standard includes a declaration procedure, an internationally recognized Declarable Substance List (taken over from the JIG-101 which was retired in early 2014), a list of material classes, and an XML-schema for data exchange. The IEC 62474 material declaration procedure is a flexible approach with minimum (base) requirements to ensure that users can calculate conformity to regulations but with flexibility to provide full material declaration and inclusion
of environmentally conscious design information that may be useful to downstream manufacturers. This paper discusses the IEC 62474 declaration format and how the standard and its features and flexibility may be used.

2.12.3. Does the EU ETS Encourage Corporations´ Innovation Activity?
E. Inoue, Kyoto University, JP

This study scrutinises how corporate reactions towards the EU ETS influence innovation activity of EU major corporations. Using firm-level panel data of EU corporations, which is constructed based on the data of corporate responses to the “Carbon Disclosure Project”, “EU industrial R&D Investment”, and corporations’ CSR reports, I estimate two dynamic panel models using system GMM estimator. Innovation activity is measured by R&D investment of the corporations. The findings show that corporations which have a policy or a strategy to comply with the EU ETS or to react proactively before being regulated by the EU ETS are more likely to encourage R&D investment. The process of reacting towards the EU ETS may provide an opportunity for corporations to closely examine the relationship between corporate performances and the climate change issue and to recognise the importance of R&D investment for future competitiveness in the market.

2.12.4. Energy Efficiency Application in Yanbu Industrial City
M. Al-Gobbi, Royal Commission, SA

The Industrial City of Yanbu was established by Royal Commission of Yanbu (RCY) on the Red Sea to develop major energy intensive industries on petrochemicals. Oils from Eastern province are sent to the industrial city to save time and fuel during oil export. Saving time & energy is one of the commitments of today’s modern city of Yanbu and be a model amongst the industrial city for energy efficiency. The city is dedicated to attract energy saving industries, support efficient use of land community zoning, develop carbon footprint calculation system, promote green technologies, encourage energy efficient industrial land use, and support industries that promote technology that are fuel efficient.

The existing infrastructure, housing & building facilities in the city is energy efficient and likewise advocate the use of renewable solar energy. Funding is provided for renewable wind energy project. The overall energy design concept is the blueprint of RCY to achieve an energy efficient industrial city.

2.12.5. Real-Time Embedded Control System for a Portable Meteorological Station
A. Montero, M. Moya, G. Guerrón, A. Reyes, INER, EC

The aim of this work is to design and code an embedded system for a portable automatic weather station. The portable station includes high performance sensors to measure parameters such as: i) wind speed and direction, micro perturbations and wind gusts, ii) air temperature, iii) solar radiation, iv) relative humidity, and v) atmospheric pressure. The main contribution of this work is the development of an embedded control system operating in real time. This system is based on a Field Programmable Gate Array (FPGA) device. The method developed guarantees high-resolution data acquisition of a number of samples in real time. The samples obtained are grouped and stored in a database, which will be used as a starting point for further analysis.

2.13. Eco-Design and Product Life Cycle Management - A perfect match?

Companies developing products across a wide range of industries face increasing complexity in their products and value chains. Meeting substance/ material-focused product and supplier compliance regulations is a difficult problem for companies seeking to compete in global markets. To successfully develop environmentally friendly products, companies must implement a sustainability framework (often known as Eco-Design). Global OEMs and their supply chains not only need to choose materials that are compliant with regulations, but they also need to move beyond basic compliance with a sustainability strategy that phases out or replaces current components and materials with new “green” ones. Noncompliance costs can range from fines to more severe penalties, including being prevented from selling your products in key markets. Lack of visibility to compliance information can also lead to increased inventory costs and excessive product redesign costs.


J. Auer, B. Weis, Siemens, DE

In the context of the energy related product directive (ErP), which is addressing various products in terms of energy efficiency, a new European standard series (EN 50598) was developed to support ecodesign of complete drive systems with regards to the application, e.g. pumps. It provides a general methodology to energy efficiency standardization for any extended product including a motor system by using the methodological guidance of the extended product approach (EPA) and introduces energy efficiency indicators (EEI) for the respective drive system, including the measurement and calculation methods. It enables product committees for driven equipment with included motor systems to interact with the relative power losses of the included motor system (e.g. PDS) in order to determine the system energy efficiency aspects for the extended product by calculation. It is based on specified calculation models for speed/load profiles, the load-time profiles and relative power losses of appropriate torque versus speed operating points. The standard also covers requirements for environmental declarations and product category rules for life cycle assessments of motor systems.

2.14.2. The Impact of RoHS and Reach on the Medical Device Industry

F. Schroeder, M. Mueller, Siemens, DE

This paper covers challenges and solutions for the medical device (MD) industry regarding restriction of hazardous substances (e.g. RoHS and REACH) in medical devices, as well as the risks to healthcare if hazardous substances can’t be used in MDs. The intention of the European RoHS and Reach regulations is to reduce the high number of hazardous substances contained in products. COCIR supports this goal, but through flexible approaches that take into account benefits and risks. The function of medical devices is to save lives and to improve patients’ quality of life. To achieve the performance desired to diagnose and treat diseases, medical devices require the use of some restricted substances. Imaging products, for example, contain RoHS and REACH substances. The bottom line is that without RoHS substances like lead and cadmium, there would be no ultra-sound, x-ray, magnetic resonance tomography or positron emission tomography devices to save patient lives.

2.14.3. SIN List, a driver for innovation

F. Hök, ChemSec, SE

In 2008 ChemSec launched the first version of the SIN (Substitute It Now) List. The initiative was well timed to provide a model of what the REACH Candidate List could look like at a time when the forthcoming development was uncertain. Since then, the SIN List has been much referenced to, used and debated. Building upon past success ChemSec will launch an update of the SIN List in October 2014. This update adds a number of important new substances, but also takes the concept one step further by introducing grouping of the SIN List and a tool for assessing substances similar to the SIN substances: “Sinimilarity”. This new tool makes it possible to see if a substance has a similar structure as any substance on the SIN List, and by that companies can more easily avoid regrettable substitution.

2.14.4. Comparative assessment of present legislation and policies

T. Dumortier, C. Baudon, Y. Dvorak-Miyata, Enhesa, US

Very few regulations are ever written from scratch. On rare occasions a regulator in one country will take an initiative that is unique and stands out amongst the rest. If it fails, everybody will forget about it. If it works, it will garner attention and be replicated. With every copy made somewhere around the world, one has to ask the question, is the regulation the same or is it different? Looking at the practical examples of eco-labels, packaging, batteries, equipment, eco-design, chemicals, and conflict minerals, we can see that there is not one country that is the master of all regulations. Which regulations have been successful? What regulatory initiatives in the pipeline will shape the regulatory frameworks and concepts in the coming years? From a business perspective, what lessons can be learned? How do we need to design and market product in 2015 given the current regulatory developments?
2.14.5. Upcoming Energy efficiency Requirements in Latin American Countries as a Challenge for Producers of it Equipment

M. Krug, 1cc, DE

Energy Efficiency has become an important issue for Latin American Countries (LACs). As LACs are becoming more and more an interesting market for manufacturer of IT devices, they have to be aware of the respective product requirements. National energy efficiency obligations might require local testing, certification and the labelling of products. The following paper will give an overview about today’s regulatory situation in four selected countries – Ecuador, Peru, Uruguay, and Venezuela – with respect to energy efficiency requirements and labelling. Regulation in place show that the national requirements are often based on EU energy efficiency legislation, as EU Directive 2009/125/EC (ecodesign) and EU Directive 2010/30/EU (labelling) and the respective EU regulations for certain products.

2.15. RECLAIM: Reclamation of Gallium, Indium and Rare-Earth Elements from Photovoltaics, Solid-State Lighting and Electronics Waste

2.15.1. Recovery of Galium and Indium from Liquid Crystal Displays and CIGS Photovoltaic modules

W. Steeghs, ONDEO, NL; R. Bisselink, J. Brouwer, TNO, NL

The increasing amount of electronics, such as consumer products and green technologies (e.g. solar PV cells) increases the demand of metals such as indium and gallium. This increasing demand together with the dependency on import of these metals drives research on recycling of waste electronics from secondary sources, so called urban mining. A hydrometallurgical process for the recovery of indium and gallium from flat panel displays and photovoltaic panels is under development within the RECLAIM project. Characterisation of flat panel displays and photovoltaic cell has been performed and has been compared with manual and automatic disassembly. Results indicate that mineral acids can be used to release indium and gallium. Preliminary results of recovery and purification processes are presented and further research regarding these processes is outlined.

2.15.2. Chemical analysis and Computer vision based recognition of electronics waste

M. Kampel, F. Kleber, C. Pramerdorfer, CVL, AT; B. Comanesco, E. Stanciu, Optoelectronica, RO

The increasing demand of gallium, indium and rare-earth elements for the production of electronics, e.g. solid state-lighting, photovoltaics, integrated circuits, and liquid crystal displays, will exceed the world-wide supply according to current forecasts. Recycling systems to reclaim these materials are not yet in place, which challenges the sustainability of these technologies. This paper proposes a classification unit for the recycling of printed circuit boards based on an automated classification and a light-induced breakdown strategy as chemical pre-analysis. Computer vision methods are applied to classify entire circuit boards and individual SMD components, using different sensors (2D and 3D). The light-induced breakdown strategy allows for a rapid chemical analysis to define components which contain the desired components.

2.15.3. Environmental and economic assessment of selected treatment routes

T. Ansems, R. van Gijlswijk, TNO, NL

The present routes for the treatment of different E-waste fractions are based on the stages of disassembly, shredding, separation, sorting, concentration and purification, including collection and logistics. The disadvantage of the current routes is that critical metals such as indium, gallium and rare earths disappear in slags, sludges or waste residues. The objective of the RECLAIM project is to develop novel treatment routes to avoid the leakage of these critical metals and to create recycling options for these metals. This is done for four fractions: flat panel displays, CIGS solar panels, energy efficient lighting, and printed circuit boards. In this article, the novel routes are described. In future work the routes will be evaluated from environmental and economic perspective, using methodologies described in the latter part of this article. The environmental and economic evaluation will give direction to improvements and innovations of the considered treatment routes within the RECLAIM project.
2.16. Sustainability

2.16.1. How Sustainability Management Converts Product Environmental Footprint (PEF) into Profitable Business

*C. Herrmann, A. Saraev, PE INTERNATIONAL, DE*

Companies from various markets manage sustainability properly providing vital contribution towards advantageous business. Sustainability drives innovation, supports products improvement, helps streamlining processes, fosters company culture, aligns employees and shapes brand and image of a company.

One of the established tools supporting the environmental column of sustainability is Life Cycle Assessment (LCA). Though it can be used to manage product innovation, foster brand value and proof advantages of products, it is still often perceived as cost driver, because of too much uncertainty and lack of harmonization. Specifically in IT/ICT industry, reliability in LCA data and models and relatively weak information from supply chains need improvement.

This is given by the Product Environmental Footprint (PEF) approach. It will harmonize environmental information, to allow comparability and benchmarking of environmental aspects of products and will incentivize environmental improvement through market mechanisms (the fittest survives). Thus, PEF in combination with existing sustainability management supports profitable and healthy business.

2.16.2. Reconcile societal values and economic value in the age of virtuality: identifying and evaluating emerging assets.

*C. Gans-Combe, REEDS- Univ. of Versailles, FR; C. Kuszla, Angers University, FR*

Still confronted to a major ambivalence: economic actors being torn between their craving for a larger slice of the cake, and their outcry for a better, just, ethical, sustainable world, the need for a new, frugal and fairer model of growth based on Rawls, Sen, Braungart and others is nonetheless being called for.

The rising importance of new economic sectors based on data usage technologies offers a chance to reconcile these two seemingly very opposite views. Indeed, for economic actors, it is acceptable to introduce novel practices if these:

1. are shared,
2. do not introduce market flaws or imbalance and, in the end,
3. produce economic value visible in their balance sheet.

The actual conjunction of elements brought together by markets and technological acceleration – both on the road to the technological singularity - make the demonstration of this assertion possible. In this respect, as a growing sector, the case of search engines, social networks, etc. and their economic environment is particularly interesting as it makes tangible the existing tension between preservation of access to the data (the right to privacy) and the need for immediate access to it, in the search for an applicable economic model. These tensions are not so irreconcilable than foreseen as the implementation by economic agents of ethically compliant production and deployment practices - respecting both end users and economic agents - are at the end – and even if it is at first not evident - reflected in their balance sheet.

2.16.3. Scientometric Analysis of Publications on Sustainable Companies

*M. Martínez, J. del Río, K. Ricalde, Universidad Nacional Autónoma de México, MX; K. Cedano, Centro Lavín para el Desarrollo de Innovación y Transferencia Tecnológica, MX*

The global research performance in the field of sustainable companies has been analyzed. We present a scientometric analysis of all the research papers published in the Web of Science on this topic (sustain AND compan), from 1990 to March 2014. We applied text-mining algorithms to all such records and the result shows 2,932 papers. We found the journals where most of the research is being published; the name of the most prolific authors, as well as the most cited; the collaboration with other institutions and counties; the strongest areas in the field; the evolution of the community as a whole; and the most relevant words and phrases published in the papers under study. The results reveal the interests and the behavior of the scientific, technical and management research communities on this topic.

2.16.4. Beyond Green Office Guide

*T. Tyng, Nets Printwork, MY*

Office is often seen as a place where administrative work is done. In fact, the office activities are more than just paper management. The existing Green Office Guide (GOG) provides indications of
the company's environment performance. Besides, green purchasing help to reduce long term cost through energy saving. This study try to work beyond the GOG by highlighting the interdisciplinary management effort to nurture good corporate citizen through Green Engagement and to encourage company to offer eco related business as well as job opportunity through Green Growth concept. The paper redefined Eco Office as a workplace that influences individual behaviours, attitudes and habits through green purchasing, green operation, and green engagement to allow employees work productively towards green economy growth. This paper, through a case study of a company is to evaluate the effectiveness of implementing the proposed Eco Office model. The study derives assessment methodologies based on sustainability dimensions.

2.16.5. Up-to-date progress on Sustainable development and the development of Eco-efficient life from the Local Community

M. Kano, Tokyo University of Science, JP

To date we have been aiming to create a recycling-based society, and to this end we have set the goal of establishing a citizen participating, decentralized, recycling-based society with a view from the activities of the Earth System Ryokuin-Juku We will point out to have the global environmental governance; we have to solve the problems such as the deterioration of the global environment, economic disparities between the North and the South, encroachment of national sovereignty. Then, we will find a way to realize the sustainable society in which human and many forms of life can coexist.

3.1. Sustainability & Environmental Assessment

3.1.1. Sustainability assessments as value proposition for both buyer and seller

S. Feickert, SAP, DE

The need of selling sustainable products from sustainable suppliers becomes more and more important for the success of large retail companies. “Selling products that sustain people and the environment” is the global responsibility Walmart for example takes regarding the environmental sustainability of products. Not the customer at the store should have to choose between products that are more sustainable and products they can effort. For reaching this goal Walmart have started the Sustainability Index – a new retail standard that will assess and improve the sustainability of their products – into their business. Walmart, SAP and The Sustainability Consortium closely work together to bring this into reality with harmonized content from The Sustainability Consortium (TSC®), and an easy to use business network application by SAP. In this paper we share some insight into the delivery of a product sustainability assessment program from a technology point of view.

3.1.2. Comparison of two different Approaches for a simplified life cycle assessment of electronics

J. Auer, Siemens, DE; A. Zintl, B. Berninger, Univ. of Applied Sciences Amberg-Weiden, DE; N. Bey, Univ. of Denmark, DK

In order for life cycle assessment (LCA) and environmental footprinting to come into effect in the electronics industry practice as a quantitative eco design approach, it needs to be implemented and applied in an effective way. The goal within this study was to reduce the necessary efforts in matching the components to the references in the life cycle inventory for these types of products. Based on previous life cycle assessment case studies of converters two different approaches of simplifying the evaluation of potential environmental impacts via LCA for the assembled printed circuit boards (APCB) were compared in terms of possible accuracy and needed effort. One approach was to build an application specific reference APCB and linear approximation of the environmental impacts. The other approach was based on the reduction of the components to the most significant ones to reduce the effort for a matching within the life cycle inventory.

3.1.3. How to enhance the life cycle concept among small and medium sized enterprises: a proposal for a simplified LCA for household appliances.

M. Mengarelli, Università Politecnica delle Marche, IT; P. Buttol, S. Cortesi, P. Porta, S. Scalbi, A. Zamagni, ENEA, IT

Many approaches and strategies have been developed to implement sustainability aspects in the product development process. Within these approaches, Life Cycle Assessment has been claimed to
be the best framework for assessing the potential environmental impact of products throughout their life cycle. However, the use and interpretation of LCA results are still being debated. In particular, the implementation of the life cycle approach and of the LCA method in small and medium sized enterprises (SMEs) is still not properly and consistently integrated into the management practice. The challenge is to undertake simplifying in order to ease the interaction with users who may be unfamiliar with environmental aspects, but who can strongly affect the product performance by intervening at the product design stage.

This paper presents a Simplified LCA methodology, customized for the household appliances product category. The simplification strategies have been defined at different levels, including a customisation that takes into account the characteristics of the product category, and a user-friendly interface to support less-skilled users.

3.1.4. Quantifying the Ecological Impact of IT Service Management of Hardware Assets by Reformulating ITIL-Processes

D. Pauwels, D. Cattrysse, J. Duffou, Univ. of Leuven, BE; H. Mulder, Antwerp Management School, BE

The ecological impact of a (set of) Information Technology hardware asset(s) over its life cycle is defined by the ecological impact of the phases of its lifecycle, ranging from design and production over deployment, use, maintenance and retirement to end-of-life processing. Related to the phases of deployment, maintenance and retirement, the Information Technology Infrastructure Library provides specific process-definitions related to the activities that contribute to the ecological impact of the concerned hardware. Ontology-based and modular reformulation of these process-definitions enables the calculation of the ecological impact of the concerned processes using elementary instances of Life Cycle Assessment, which can form the basis for quantitative decision support related to the management of the concerned hardware from an ecological perspective.

3.1.5. Technology Convergence and Environmental Impacts from Electronic Devices: Case Study of Tablet PC

K. Son, S. Lim, Kangwon National Univ., KR

New electronic devices are developed by integrating the functions of existing ones into a product. This technology convergence can make environmental problems decreased by reducing overlapped and unnecessary parts, or increased due to the requirement of new materials and technology. This study investigates how much technology convergence can increase or decrease metal resource depletion and toxicity potentials through a case study on tablet PC. Tablet PC can displace laptop computer, camera, GPS navigation system, MP3 player, cell phone, electronic dictionary. The metal contents of these devices were analyzed and used to evaluate resource depletion and toxicity potentials. The potential of a tablet PC was compared to the total of those of the other devices that a tablet PC can displace. The results of this study showed that the technology convergence can significantly reduce environmental impacts from electronic devices. Thus, technology convergence can be utilized as a new strategy to prevent environmental impacts.

3.2. Conflict minerals & e-waste

3.2.1. Conflict Mineral Compliance as Joint Supply Chain Achievement

F. Kroeber, E. Bachmann, SAP, DE

Conflict minerals compliance is a topic that especially affects companies listed on the US Securities and Exchange Commission (SEC), as they are required to file a special report as part of their annual balance. To fulfill conflict minerals requirements, these US companies rely on the participation of their supply chains, for which conflict minerals regulations apply as a customer-specific requirement. However, the conflict minerals topic does not only involve requesting data from suppliers through a reasonable country of origin inquiry (RCOI). It also involves analyzing and continuously optimizing supply chain performance over time. Once this process has been set in motion, supply chain collaboration must be continued over the course of several years to maintain a current smelter repository. In addition, conflict minerals activities may be accompanied by more general responsible sourcing projects or set into relation to existing product declaration topics. Each of these issues can only be solved through the collaboration of companies building today’s supply chains and supply networks. Therefore, a robust global infrastructure such as SAP Product Stewardship Network is necessary to enable this collaboration and to create reasonable results without allowing the involved efforts and costs to explode.
3.2.2. Quantifying The Use of Conflict Minerals in the ICT Sector
C. Fitzpatrick, University of Limerick, IE; E. Olivetti, R. Roth, R. Kirchain, Massachusetts Institute of Technology, US

The supply chains for tin, tungsten, tantalum and gold (3TG) have come under increased scrutiny in recent years due to their connection with conflict in the eastern part of the Democratic Republic of Congo (DRC). The most notable reaction to this has been the Dodd Frank Act which requires public companies to disclose their use of 3TG emanating from DRC. This has resulted in a number of initiatives, mostly championed by the information and communication technology (ICT) sector, to provide transparency in the supply chain which is many layers removed from electronics producers. In an effort to understand what portion of the market for 3TG that this sector makes up this paper has developed a bottom up model of per product use of 3TG in a number of widely used ICT products including desktops, laptops, servers, smart phones and tablets and scaled up using global sales figures for these products. The model estimates the use of tin, tungsten, tantalum and gold within these products sold in 2012 to be 1%, 1%, 15% and 4% of market share respectively.

3.2.3. Mapping critical resources for Wales (MCRW): Results from an electronics perspective
C. Harris, C. Sanders, P. Harfield, Ecodesign Centre, UK

A novel approach to quantifying the criticality of materials at a national and sectoral level is described and applied to the Welsh ICT sector and the economy as a whole. Nine materials are deemed critical to the ICT sector, six of which are found to be critical to the wider economy. This highlights the importance of producing sector-specific criticality assessments upon which to base policy for mitigating resource risks and exploiting opportunities. The methodology used improves upon previous criticality studies in a number of ways, including providing a more realistic quantification of the importance of individual materials. This study acts as an ‘issue raiser’ that will help focus and prioritise research into critical materials in Wales.

C. Nafe, C. Mars, Arizona State University, US

No e-waste management system can be successful without a stable input of material, so understanding how individuals interact with collection systems is necessary for collection optimization. In this study, we present the results of a preliminary analysis of a model describing the collection system in Phoenix, Arizona. An agent-based model method is used to study outcome probabilities of a proposed e-waste recycling system for multi-family complexes and single family neighborhoods in the Phoenix area, and to compare the potential effectiveness of different variables applied to collection events (e-waste recycling education, financial incentives, and charitable donation credit) against one another. The aim of this agent-based modeling exercise is twofold: 1) to provide a model against which experimental results for the proposed system may be analyzed and 2) to serve as a decision-support tool which will be used to inform the continuing development and implementation of the City of Phoenix e-waste recycling system.

3.3. Critical materials

3.3.1. End of waste – when waste becomes a valuable resource.
S. Treichler, R. Balestra, Federchimica, IT

3.3.2. Recycling system and technologies for critical metals recycling from ELV in Japan

A practical usage of urban mine and its system formation are one of the most challenging and important issue to be progressed. According to the sustainable resource management, further progress for the special minor metals recovery may become the key issue. In the case of WEEE, however, when Cu, Au, and Ag are collected for recycling, critical metals can also be gathered with them. If critical metals are separated from ELV by proper technique and are accumulated for reservation, we can consider them as resources. Collecting system, therefore,
is very essential to achieve useful recycling of critical metals. A trial of critical metals from ELV in Japan has been done, then a possibility of further recycling is considered. New recycling techniques for critical metals from printed circuit boards in ELV have been also tried in our project. Some of them will be shown in this presentation.

3.3.3. Recycling and valorization of Nd-Fe-B permanent magnets comprised in waste of electric and electronic equipment: existing processes and new avenues

N. Maât, V. Nachbaur, J. Juraszek, R. Lardé, M. Jean, J. Le Breton, INSA Rouen, FR

Rare earths are a group of chemical elements which are currently used in a very large number of technological applications and innovations. They have been classified, since July 2010, as strategic materials for the European Union, and their supply has become a capital issue for development and industry. Exploitation of "urban mines", in this case the electrical and electronic waste, has therefore emerged as a preferred choice, motivated by the substantial use of these elements by the industrialized countries. In this context, the current research aims to enhance the magnetic metal alloys contained in electrical and electronic waste, and thus allows their reintegration into the industrial circuit. For this it is necessary to develop processes allowing the regeneration of Nd-Fe-B type magnets contained in computer hard drives. The considered processes shall permit, from used Nd-Fe-B magnets, to synthesize new magnets with sufficient magnetic properties for applications. Here we present a review of the various methods currently used, and propose new directions for retrieval of used magnets. This work is part of the project ANR-13-ECOT-0006-06 "EXTRADE".

3.3.4. Separation of shredded Rare Earth Magnets

R. Holzhauer, L. Baberg, T. Spiecker, Westfälische Hochschule, DE

Hard disk, toothbrush, water pump, wind turbine, e-mobility they all need rare earth magnets. On the side of recycling existing separation processes produce more or less clean basic materials. Sophisticated facilities exist especially for metals. With the result that rare earth magnets are driving directly into the iron melt and are lost. There are competence needs in separation technology to save these magnets. Shredding delivers complete, broken or powdered magnets clutched to the iron parts. First result from separation experiments with low frequency magnetic fields showed very good results for complete and broken magnets. It is simple and repeatable possible to divide magnets and iron parts. Comparison of simulations with COMSOL Multiphysics® and series of experiments result in good analogy and made us understand the process. This basic process can assist to set up equipment for rescuing magnets from the iron melt.

3.3.5. Novel LCD Separation Techniques to allow for Maximum Rare Earth Recovery

L. O’Donoghue, University Limerick, IE

From a research perspective the focus is to Europe 2020 policy: One of Europe 2020’s flagship initiatives is Resource Efficiency which promotes extraction and recycling with the aim of using waste as a resource. It recognises the strategic importance of avoiding risks to supply of resources such as rare earths which are contained within LCDs. Rare earth materials which are contained within the liquid crystal panel have been classified as Critical Raw Materials (Critical Raw materials for the EU, EC working group report, July 2010). This paper reports a novel new separation strategy for the liquid crystal panels from LCD displays. The liquid crystal panel once removed from the LCD display is a stand-alone component which contains two glass panels coated in rare earth compounds sandwiching liquid crystals. This liquid crystal panel has potential for urban mining for these critical materials which can be used in next generation display technology. The research undertaken focuses on the exploration of the indium rare earth content of the liquid crystal panel using characterisation techniques including SEM and EDX and compare and contract different LCD Television liquid crystal panel. This paper also reviews the options and methodologies for recovery of Indium.
3.4. ZeroWIN: Towards Zero Waste in Industrial Networks

3.4.2. The ZeroWIN Production Model

C. Horvath, B. Kopacek, SAT, AT; S. Arnaiz, Gaiker, ES

ZeroWIN was an EC funded collaborative project. It focused on developing and assessing new and innovative approaches, as well as effective strategies for the reduction of resource usage and waste prevention at companies, based on industrial networking and symbiosis. Traditionally separate companies and organisations from all business sectors were brought together by the industrial symbiosis, with the aim of improving cross industry resource efficiency and sustainability. This symbiosis involves the physical exchange of materials, energy, water and/or by-products, together with the shared use of assets, logistics and expertise. In order to achieve the ZeroWIN aims, the development of a Production Model based on the zero waste target, by the creation of a framework for the application of new technologies, methodologies, strategies and system tools in real industrial networks, was one of the key actions.

3.4.3. The D4R laptop computer – from prototype to market leader

J. Ospina, P. Maher, MicroPro, IE; C. Fitzpatrick, S. Hickey, University of Limerick, IE; K. Schischke, Fraunhofer IZM, DE; I. Vidorreta, J. Garatea, GAIA, ES; M. Yang, AUO Optronics, TW; G. Obersteiner, BOKU, AT; E. den Boer, Wroclaw University of Technology, PL; I. Williams, University of Southampton, UK

The iameco D4R laptop computer prototype, completed in 2013 after 4 years of development, by MicroPro (http://micropro.ie) and other Partners in the ZeroWIN Project (http://www.zerowin.eu), is the fourth market-ready prototype developed by this small company based in Dublin. MicroPro’s first prototype, the MicroPro XPC, was completed in 1999, and improved on in 2003 by the iameco v1 desktop computer (developed as part of the Project HEATSUN – LIFE ENV 2001). The iameco V1 developed the concept of “design for reuse” (D4R). MicroPro went on to develop the iameco v3 model, an integrated desktop computer that secured the European Eco-Label in 2010. From then on, MicroPro has continued development of this concept as a Partner in the ZeroWIN Project. The Partnership has allowed the D4R laptop to be developed, a laptop computer designed to reuse materials parts and components in manufacture and re-manufacture. In addition, a supply chain to provide these materials and parts has been identified, as well as service partners to provide a comprehensive after-sales service, all of which aims at achieving the “circular economy” objectives of the model.

3.4.4. Practical Demonstrator “Design for Recycling Photovoltaic System”

X. Vallve, P. Arranz, M. Anzizu , A. Pineau, TTA, ES

This paper presents the key aspects of the demonstration of the photovoltaic (PV) case study carried out within the European project “Towards Zero Waste in Industrial Networks (ZeroWIN)” in the period 2010-2014. The demonstration has consisted in three phases: the first phase concerned the development of a novel PV concept including D4R (Design for Recycling, Repair, Refurbishment and Reuse) criteria and their integration at an industrial network level; the second phase focused on the development of specific components of PV systems, and the third phase has been the demonstration in two real, complete PV systems. The achieved results include an increased projected lifetime from 20 to 25 years, an increase of the electricity output and related cut in the GHG emissions of up to a 40%, and an overall ratio of materials and components re-use and recycling of 91%.

3.4.5. Practical Demonstrator “Re-use ICT-Network”

G. Kast, UP, DE

The case study 3 of the ZeroWIN-Project proved that keeping ICT- and measurement devices in a re-use network can save up to 70% of greenhouse-gases, more than 85% of waste and up to 66% fresh-water consumption. It showed that the use of the “resource-exchange-platform” (trxp.eu), developed during the project, working as a virtual manufacturer/store-room has a potential to increase the re-use of different appliances and allows to do automatic calculations of the possible savings. For a successful use of the platform it is crucial to have manpower to look for possible appliances to be offered (“inventory walks”) as well as for possible users. Nevertheless there are still barriers like low economic incentives for SME’s, procurement practices at public organisations (Universities, Research Institutes etc) and legal problems that prevent re-use from being a real success-story. Statistics from the Federal Office of Statistics showed that in Germany in 2011 there were almost 10.000 companies of different size that worked in the repair/re-use sector of ICT- and consumer goods with about 36.000 employees and a turnover of almost 2,9 Bio Euros. There is a
chance for growing employment not only for environmental protection and resource-efficiency if ReUse-Networks become more and more established.

3.5. **Environmental Assessment**

3.5.1. **Energy-efficient products for network design**  
*L. Rabinovich, D. Poon, Cisco Systems, US*

The massive deployment of computer networks in recent years has significantly enhanced our communication and productivity but also expanded resource consumption in ICT sector. Despite increased electricity consumption, usage of networking devices in more carbon-intensive sectors poses greater opportunity for emissions reductions. In this presentation we discuss importance of metrics for proper evaluation of an energy efficiency for networking devices, effect of metrics on future product design, relations between single product metric and solution efficiency. We take a detailed view on existing metrics proposed in national and international regulations and analyze their impact on networking product design and deployment. In addition, we discuss problems with product classification and as a result, application of metrics to wrong groups of products.

3.5.2. **Reducing risk by reducing hazard: Use of chemical hazard screening as the first step in the assessment process.**  
*H. Wendschlag, Hewlett-Packard, SE; C. Robertson, H. Holder, C. Wray, Hewlett-Packard, US*

Since many years, chemicals restrictions requirements beyond legislation exist in voluntary policy instruments like eco labels and customer procurement specifications. To avoid regrettable substitutions by using substances with no or poor data and instead ensure that the alternatives indeed have demonstrated better environmental properties, since 5 years we use the Green Screen™ (GS) for safer chemicals assessment methodology. Results of GS assessed and safer alternatives for halogenated flame retardants are now available and will be presented.

3.5.3. **Environmental impact of large electronic products – don’t judge a book by its cover**  
*T. Nimalasuriya, Océ Technologies, NL*

Careful examination by means of an environmental performance evaluation proves that the environmental burden of large professional imaging equipment is not as large as one might think. We evaluated the lifecycle CO2 emissions of a wide scope of professional imaging equipment. Raw materials and energy use are the main contributors to the lifecycle emissions. We analysed these contributions for a typical wide format printer. The carbon intensity of the raw materials of an Océ PlotWave 900 were found to be comparable with the carbon intensity of a bicycle. The carbon emission from the lifetime power consumption of the same printer is equivalent to eight 100 W light bulbs. It can be concluded that large electronic equipment such as a wide format printer has relatively low environmental impact due to material properties and energy efficiency.

3.5.4. **Current status, barriers, driving forces and quality of sustainability reporting in Taiwan**  
*L. Huang, A. Hu, C. Huang, National Taipei University of Technology, TW*

Corporate sustainability reporting has become a worldwide trend in the last decade. This paper investigated 100 Taiwanese companies to study their current status, the barriers they encountered, their driving force for publishing sustainability reports, and the role of third-party assurance for sustainability reporting. An evaluation framework based on the materiality and stakeholder inclusiveness of GRI G4 Guidelines was also developed to assess the quality of two “best” sustainability reports published by Taiwanese companies and to compare it with the sustainability reports published by international leading companies. Results of the study showed that the GRI Guideline was applied widely. Only 25% of the reports were compiled by multi-disciplinary team and only two-thirds of the reports were verified by a third party. The most important driving force were “tone from top.” However, “the pressure from employees” was not an important driver, which is obviously different from previous investigations. “No perceived benefit” and “sustainability reporting is not mandatory” were the main barriers that conform to previous studies. The findings indicate that corporate size is a key factor that affects the adoption of sustainability reporting of corporations. “Cost” is an important barrier for smaller companies, which may lead to their lack of knowledge about sustainability reporting. The completeness of reporting in Taiwanese companies and international
leading companies is similar. However, Taiwanese companies may need to put more emphasis on materiality, particularly on the connectivity of the material aspect with performance and material target setting.

3.5.5. Elibama (European Li-Ion Battery Advanced Manufacturing): Eco-Design, Eco-Innovation, Integrated Product Policy

L. Slotyuk, M. Gama, PE INTERNATIONAL, DE

According to the Ecodesign Directive (2009/125/EC) and the ISO 14062, the goal of integrating environmental aspects into product design and development is the reduction of adverse environmental impacts of products, which may occur at any or all stages of their life cycles. PE INTERNATIONAL successfully took part in a European research project – ELIBAMA – which had the goal of developing new, environmentally-friendlier technologies for lithium-ion batteries within the European Union. The comparison of baseline and ELIBAMA scenarios showed that the replacement of one specific material or process by another environmentally friendlier alternative led to the reduction of Global Warming Potential up to almost 50% - according to the initial results. In order to allow more flexible environmental assessments and accompany further development processes, an eco-design guide and tool were prepared. This project serves as an example for the best practices on the optimization of process chain for other companies and sectors dealing with energy using products.

3.6. e-waste around the globe


M. Schaffer, K. Wiens, iFixit, US

Service manuals and work instructions are critical tools for manufacturers and service depots, but they have suffered from a lack of innovation and standardization. There are several reasons why repair of electronics can be difficult but one of the most common is the lack of having a repair manual available. The IEEE 1874: Standard for Documentation Schema for Repair and Assembly of Electronic Devices (also called “oManual”) was developed to provide a standardized format for manuals that can be displayed on both computers and mobile devices. It provides a schema for putting together, publishing and sharing repair manuals.

3.6.2. Development of E-waste Recycling Infrastructure in Africa

M. Bates, University of Northampton, UK; H. Castren, Microsoft, FI; U. Vött, Microsoft, AE; J. Cox-Kearns, Dell, IE; H. Guilcher, Hewlett Packard, FR; R. van Rensburg, Hewlett Packard, ZA; J. Perry, Dell, UK; E. Smit, Philips, NL; R. Truscott, East African Compliant Recycling, KE

The paper presents the activities of an alliance of original equipment manufacturers (e-waste solutions alliance for Africa). A sustainable solution to the electronic waste problem in Africa is discussed, including how the proposed solution works with the existing formal and informal sectors. The application of EPR (extended producer responsibility) is described, together with clear allocation of roles and responsibilities. The importance of clear definitions, standards and control mechanisms is presented together with key aspects and review of legislation required to facilitate business investment.

In the proposed solution electronic waste management is considered an opportunity to recover valuable materials, create jobs and protect the environment and human health. The plans do not solely focus on the valuable end of life products, they also consider the entire ICT e-waste stream including problematic materials and fractions (currently being burned or landfill), as well as materials and fractions with no value.

3.6.3. Life Cycle Assessment of E-Waste Recycling in the Netherlands; Data Collection and Modelling

J. Leijting, PRé Consultants, NL

The benefits of electronic waste (e-waste) recycling in the Netherlands are monitored annually since 2009. Life Cycle Assessment (LCA) is used in order to calculate avoided greenhouse gas emissions from material recycling of the collected e-waste. The avoided emission of greenhouse gases by the destruction of (H)CFC containing coolants from cooling and freezing appliances was calculated separately.
The recycling companies involved were committed to submit detailed data on the recycling processes and material streams in the registration program WF_Reptool. The data was used to create a model for calculating the benefits of e-waste recycling annually. The study shows that in the past five years (2009–2013), the release of about half a billion tonnes of CO2 equivalents were avoided due to material recycling out of e-waste. The removal and destruction of (H)CFC containing coolants led to the avoidance of 2 billion tonnes of CO2 equivalents.

3.6.4 Market Versus Regulation based Economic Instruments for start up & sustainable E-waste take back system, A Case Study of India.
A. Jain, IRG Systems South Asia, IN; A. Deshpande, 2National Green Tribunal, IN

Design and implementation of a business model for E-waste management under EPR is a major challenge in India. In India, EPR based E-waste regulation came into effect on 1st May 2012, has diverted only 5% of E-waste into formal sector resulting in 14% dismantling / recycling capacity utilization. Unviable “take back” mechanism, without “linking trigger” between “collection, transportation & recycling infrastructure” is responsible for this small flow of E-waste. Since major leakage of E-waste occurs at retailer’s “buy back” program, an assessment of “regulatory” or “market based instrument”, which could plug this leakage has been carried out. Consumer survey carried out in MMR indicates that though consumer is willing to pay “some” amount for E-waste management, it is highly averse to regulatory instruments. Further, consumer gets “residual value of E-waste at the time of purchase of new EEE in a single transaction”. Therefore, “Incentives”, in the form of “voucher” may provide solution for changing consumer behavior.

3.6.5. Developing a Town-Gown Electronic Wastes Recycling Process in Nigeria
I. Adewumi, T. Semodei, S. Adekola, E. Sapre-Obi, Niger Delta University, NG

Efforts at local recycling of discarded electrical & electronic products (DEEP) in Nigeria focused only on recovery of copper wires through burning of the cables in the e-wastes. Soil samples taken from the topsoil and 1.0 m below the surface close to the DEEP and at 1.5 m away were analyzed for leached metals from selected DEEPs in Amassoma Community. One gram from each of the homogenized samples was digested and analyzed for presence and concentration of HMs using atomic absorption spectrophotometry (AAS). Some of the HMs like Pb, Cd, Ni, Hg are present in the soil samples at concentrations far above the maximum contaminant levels. The possibility of either being washed into surface waters or leached into groundwater is of environmental concern that informs our efforts to create an avenue for recycling of DEEP backed with institutional research and knowledge sharing across Nigeria.

3.7. GreenElec

3.7.1. GreenElec: product design linked to recycling
R. Balkenende, Philips Research, NL; V. Occhionorelli, Barco, BE; W. van Meensel, IMEC, BE; J. Felix, CIT, SE; S. Stjölin, Stena, SE; M. Aerts, Philips Lighting, NL; J. Huismann, TU Delft, NL; J. Becker, TNO, NL; A. van Schaik, MARAS, NL; M. Reuter, Outotec, FI

GreenElec aims to significantly improve on the resource efficiency of electronics and electronic products. This is accomplished by close cooperation between manufacturers and recyclers. Design guidelines for improved recycling have been formulated and products (lamps and displays) have been redesigned according to these guidelines. Interestingly, design for recycling could easily be combined with value engineering. The improved recyclability has been validated in recycling runs. Further, tools are available to evaluate the choices made regarding materials and connections at various stages of the design process. As benefits are not evenly distributed over the value chain, business aspects are explicitly taken into account.

3.7.2. Lamp redesign: shredding before selling
M. Aerts, Philips Lighting, NL; J. Huismann, Stena, NL; J. Felix, CIT, SE; R. Balkenende, Philips Research, NL

LED lamps have been redesigned taking into account design guidelines that are based on large scale recycling tests. The design guidelines focus on the materials used, but especially on the way in which materials and parts are connected with as key aim the ability to enable separation of the electronics at end of life. A MR16 halogen replacement LED spot has been chosen as the carrier. Different design approaches have been followed and validated by a small scale recycling test. The
design guidelines have also successfully been applied to a bulb replacement LED lamp.

3.7.3. Material Identification in Electronics
W. van Meensel, G. Willems, M. de Cauwe, IMEC, BE

If an electronic designer wants to make an electronic module more recyclable, a way to quantify the impact of the design changes on the recyclability of the module is needed. One of the most important aspects to quantify the impact of design changes is information about the materials that are used in the electronic module. This paper will explain how the material composition of electronic components or an electronic module can be described. It will also give an overview of the dedicated models that are developed to estimate the material content of electronic components, in case the material composition of these components is unknown.

3.7.4. Product Centric Design for Recycling: Predicting Recyclingrates an Example on LED Lamp Recycling
A. van Schaik, MARAS, NL; M. Reuter, Outotec, FI

This paper will illustrate how a Product Centric approach to recycling, building on the extensive expertise, knowhow and tools of classical minerals and metallurgical processing, is core to Design for Recycling & Resource Efficiency underpinned by rigorous recycling rate calculations. It will be discussed how physics based recycling process simulation tools are applied by the authors in the commercial HSC Sim software to quantify critical DfR rules for a particular product as well as to quantify recycling rates of all materials and elements in a product. Ten DfR rules will be presented, developed by the authors in a study performed for NVMP/Wecycle (The Netherlands). The digitalization tools will be illustrated by HSC Sim process simulation models for the pre-processing of LED lamps. The results produced include recycling and recovery rates, as well as recyclate qualities and quantities, losses and emissions of materials during recycling. Metallurgical recovery is also discussed showing that in many cases element recoveries reduce to zero. Simulation models are linked to environmental assessment, revealing how this rigorous, full mass balance simulation basis, provides the detail to define and improve environmental assessment at the same time revealing the weaknesses of LCA databases and their results.

3.7.5. Data driven recycling of end-of-life electronics
H. Melin, Refind, SE

As a part of the GreenElec project Refind Technologies has developed a technology that enables decisions for recycling and reuse to be taken based on real-time information about the processed material. Fully used the technology could have a positive impact not only on recovery yield but also contribute to the decrease in illegal trade and generate growth opportunities for the European recycling and refurbishment industry.

3.8. ZeroWIN: Towards Zero Waste in Industrial Networks

3.8.1. Demolition and New Buildings in Germany, Portugal and the United Kingdom
I. Williams, University of Southampton, UK; E. den Boer, Wroclaw University of Technology, PL; V. Durão, J. Caixinhas, S. Osório-Peters, CEIFA ambiente, PT; G. Obersteiner, A. Pertl, BOKU, AT; A. Tischer, Fachgebiet Massivbau, DE; A. Kent, Remade South-East, UK; P. Wilding, Wilding-Butler, UK

The construction and demolition industry is a major contributor towards individual nations’ economies but also has relatively high environmental impacts. In this paper, demonstration case studies are provided for construction activities in England, construction logistics in Germany, and demolition activities in Portugal. The results clearly show that the approach taken by the ZeroWIN consortium lead to the successful development of industrial networks around each site; significant reductions in greenhouse gas emissions and fresh water use; and increases in reuse and recycling of materials.

3.8.2. Assessing sustainability in industrial networks. Based on the experience from ZeroWIN project.
A. Saraev, PE International, DE; G. Obersteiner, BOKU, AT

The ZeroWIN Project (Towards Zero Waste in Industrial Networks), funded by the EU 7th framework program, focuses on waste prevention approaches through industrial networks. The paper presents results for the selected case studies from high-tech, photovoltaic, construction
and demolition sectors on environmental, economic and social impacts. Also it shows measures, for example through industrial symbiosis, that were implemented in order to reach the project targets: decrease of greenhouse gas emissions and of fresh water utilization, as well as increase of re-use and recycling of waste.

Measures related to industrial networks cover e.g. use of highly durable, wooden chassis that is sourced from by-products of the furniture industry, application of remanufactured LCD panels for the high-tech case study; use of second hand or off-spec PV modules for the photovoltaic case study; or separate collection on-site to improve the recycling rates for the construction case study.

3.8.3. Towards IPR for B2C WEEE – Can RFID Step up the Challenge?
C. Fitzpatrick, C. Ryan, E. Berkery, K. Hayes, University Limerick, IE

As 100% read rates are not achievable from RFID tags in a mixed WEEE environment it is essential to understand if product position influences the probability of achieving a read. In this paper, 50 small appliances were tagged with RFID tags and placed into a WEEE cage at random where their read rates recorded. This experiment was repeated 50 times with different random configurations of product placement. The results were examined using a logistical regression to interrogate if the position of the product with the cage influenced its read rate. The results have demonstrated that product position within the cage has no statistically significant impact on the ability to achieve a read.

3.8.4. Industrial Networking in Practice – What Needs to be done to make it happen
C. Luepschen, R. Kuehr, United Nations University, DE; E. den Boer, Wrocław University of Technology, PL; W. Gornikowski, WAMECO, DE; M. Charter, University for the Creative Arts, UK; B. Kopacek, SAT, AT; C. O'Connor, BIO by Deloitte, FR; M. Yang, AU Optronics, TW

The ZeroWIN project has developed effective strategies for waste prevention through industrial networks. ZeroWIN's Work Package on policy implications investigates barriers and overlaps of relevant legislation while integrating the outcomes of the ten ZeroWIN industrial case studies at a policy level. Discussions with the ZeroWIN case studies as well as feedback from the stakeholder consultations have shown that there are a couple of key constitutive factors determining the applicability and implementation of industrial networks. These comprise: economic benefits, material quality and standardization, access to information and material, by-product recognition and the facilitation of industrial networks. Additional barriers were identified specifically during the implementation of the pilot applications. Policy instruments are proposed to address such barriers. This paper summarizes the main results.

3.9. LCA to go

3.9.1. LCA to GO for PV systems: analysis tool for optimized PV design and green marketing
P. Arranz, M. Anzizu, X. Vallvè, TTA, ES; K. Schischke, M. Helmy, Fraunhofer IZM, DE; J. Alonso, J. Rodrigo, Simpple, ES

The EC FP7 project “Life Cycle Assessment to go (LCA to go)” has developed an open access, user-friendly web based tool to facilitate LCA characterisation and its incorporation into the PV system value chain. The results obtained from the tool are used to compare and evaluate different types of installations showing the choices’ impacts on relevant Key Environmental Performance Indicators (KEPIs) for the PV sector. Within this paper the tool is presented and a real case study is assessed.

3.9.2. Life Cycle Assessment as a practical tool in the eco-design and promotion of eco-innovative electronics - the Case of the iameco computers.
J. Ospina, P. Maher, MicroPro, IE; K. Schischke, Fraunhofer IZM, DE

MicroPro Computers has been working since 1999 on the development of green computers. It has to date designed, manufactured and marketed four such models. In doing so it has applied Life Cycle Assessment as an eco-design tool, to select materials and components and guide design decisions. This has usually been externally contracted and funded by European and national supports. This accumulated experience is being used by the LCA to Go Project (FP7) for the development of a simplified Life Cycle Assessment tool for electronics that aims to simply decisions making for SME’s in sustainable eco-design.
3.9.3. **Translating Product Specifications into Environmental Evidence – Carbon Footprint Models Explained on the Example of a Netbook, a Consumer Laptop and an Ultrabook**

K. Schischke, N. Nissen, Fraunhofer IZM, DE; K. Lang, Fraunhofer IZM / TU Berlin, DE

In a complex industry such as the electronics sector Life Cycle Assessments are still challenging. This holds true in particular for small and medium-sized enterprises with rarely any knowledge in LCA and limited resources to undertake comprehensive LCA studies. This paper describes the approach of the FP7 funded project LCA to go, which developed simplified online tools for SMEs to assess products from a selection of sectors on their own. The webtools build on embedded LCA data models and a translation of environmental impacts (Key Environmental Performance Indicators) into the technical terms found typically in the specification of computer products. As this spec has to be defined by a computer assembler anyway, he is aware of almost all the required entry data. This approach is demonstrated by establishing 3 benchmark laptop products, which can be used by SMEs to compare own designs with conventional laptops. Chosen benchmarks are a netbook, a consumer laptop 15.6" and a business ultrabook 14". The paper outlines the methodology and shows quantified results for these 3 benchmark products. Some remaining challenges will be discussed, such as product lifetime and modelling end-of-life. This approach is not intended to replace a detailed LCA or carbon footprint study compliant with ISO 14040 or 14067, but has to be understood as an entry-level for SMEs to Life Cycle Assessments.

3.9.4. **Carbon Footprint Analysis of PCBs Using “LCA to go” e-Tool as the Instrument for Environmental Performance Improvement of Electronics Products at Design Stage**

J. Sitek, M. Koscielski, A. Girulska, Tele and Radio Research Institute, PL

The article shows the issue of environmental performance of products and the problems of life cycle analysis (LCA) on the example of printed circuit board sector. It was presented the possibility of simplified LCA analyzes using the online tool “LCA to go”. The tool indicated in which areas connected with life cycle of PCBs we can look for improvements of the environmental performance of printed circuit boards. In the article the case studies results from carbon footprint analysis of different types of PCBs were presented. They showed that a designer of electronics products has possibility to decrease carbon footprint of electronics product at the design stage and in this way he can decrease negative influence of product on environment.

3.9.5. **Tablet PCs through the lens of environment – design trends and impacts on the environmental performance**

G. Dimitrova, K. Schischke, N. Nissen, L. Stobbe, Fraunhofer IZM, DE; K. Lang, Fraunhofer IZM / TU Berlin, DE

The mobile IT market is seeing a significant growth in the tablet PC shipments. The high sales numbers combined with potential short use and complex design lead to concerns about tablets’ environmental relevance. In this respect, it is of specific interest to assess the environmental performance of tablets, comprising the evaluation of the design solutions with regard to repair and recycling as well as the identification of the environmentally relevant life cycle phases. 21 tablet models have been disassembled and compared in terms of non-destructive opening for repair purposes and partly destructive dismantling for end-of-life scenarios. Furthermore, an assessment of the environmental impacts associated with tablets in comparison with netbooks has been carried out. The modelling is performed using the LCA to go tool. In addition, using X-Ray Fluorescence spectrometry, the paper examines the content of critical raw materials in selected components. Quantified results from the assessments are presented.
3.10. **Solving the e-waste problem**

The increasing volumes of e-waste in newly industrialized countries bear some challenges as well as great opportunities for the concerned countries. The Solving the e-waste problem (Step) Initiative with its members supports countries to establish the technological and institutional capacity to grasp the opportunity rather than suffer with the challenges. A well-established system to collect and treat used or obsolete electrical and electronic equipment on national level leads to an improved economic situation through the creation of green jobs and a decreasing impact on the environment and on human health. It also supports increased resource efficiency by substantially reusing material and not losing it through improper treatment by primitive recycling practices.

The paper gives an overview of how international organizations work together to support developing countries and transition countries to establish a sustainable e-waste management system and to eliminate the e-waste problem on a global scale.

3.11. **Recycling**

3.11.1. **A Challenge for Electronics Recycling – Critical Metals Recovery: A Call for Action**


This extended abstract is a call to action for the electronics recycling industry to improve recovery of the technology metals, including precious metals, rare earth metals and some others. It analyzes the barriers that are preventing high recovery rates currently, and proposes a course of action to overcome these barriers. This extended abstract is a work in progress and is intended to spur discussion on this important topic.

3.11.2. **Performance of new electrical and electronic products at their end-of-life management chain: A case of Robotic Vacuum Cleaners**

*K. Parajuly, H. Wenzel, Univ. of Southern Denmark, DK*

Achieving new recycling targets still remains a challenge despite the trend of increasing collection of electronic waste in Europe. It becomes more pertinent in case of new products with more complex design that behave varyingly in the end-of-life management chain. This paper tries to illustrate how robotic vacuum cleaners perform in the existing setup for post-consumer electronics management in Denmark. A total of 349 kg end-of-life robotic vacuum cleaner was treated at a pre-processing facility for electronic waste. The setup consisted of chain shredder, size sorting, magnetic and eddy-current separators and manual sorting. Mapping of the selected resource-flows across the system was done using material flow analysis. These findings were used to interpret performance of the case product at the conventional pre-processing steps in terms of material recovery and its implications in the overall recycling chain.

3.11.3. **Multi-body Granular Flow Simulation for the Design and Operation of Mechanical Separation Processes for Recycling**

*M. Colledani, I. Critelli, A. Degiorgi, Politecnico di Milano, IT; A. Tasora, Università degli Studi di Parma, IT*

Products and material mixtures found in E-waste are highly inhomogeneous and in continuous evolutions. In spite of this variability, state-of-the-art mechanical recycling systems are extremely rigid, both in their design and parameter settings. This is mainly due to the lack of knowledge-based engineering models and tools to support the design and operation of separation processes able to capture, with an acceptable level of confidence, all the major phenomena affecting the quality of the output, including particle-particle interactions and impacts. In this paper, multi-body granular flow simulation is proposed as a modeling and analysis tool able to capture the physics of mechanical separation processes and to support process parameter design, operation and control in industrial settings. The proposed models are validated at pilot plant level. The major improvements towards state-of-the-art modeling approaches are discussed.
3.11.4. HyperSpectral Imaging for the on-line characterization of fine mixtures in WEEE mechanical recycling systems.

N. Picone, ITIA-CNR, IT; G. Candiani, M. Pepe, IREA-CNR, IT; M. Colledani, Politecnico di Milano / ITIA-CNR, IT

HyperSpectral imaging (HSI) is a promising technique that could support on-line characterization of multi-material mixtures in recycling. However, this technology currently shows limitations when analyzing metallic mixtures at relatively low particle sizes. In this paper, the set-up of a fast and flexible vision system for the characterization of waste from electric and electronic equipment (WEEE) at fine fractions is presented. The paper deals with technical and chemometric challenges related to: i) the integration of this approach in an on-line de-manufacturing plant; ii) the development of an innovative procedures, based on the analysis of NIR spectral features, for the on-line mixture characterization to perform both sorting of metal and non-metal fractions and the quality control of End Of Life (EOL) products and the different flow streams inside the recycling plant; iii) the application of this technique to very fine products (<2mm). The experimental analyses have been performed on shredded copper and PVC wires from E-waste samples. The achieved results are very promising, especially and specifically with reference to WEEE recycling sector.

3.11.5. Recovery of valuable metals from mixture of end-of-life electronic products - a hydrometallurgy path

Z. Sun, Y. Yanga, J. Sietsma, TU Delft, NL; Y. Xiao, Tata Steel, NL; H. Agterhuis, G. Visser, Van Gansewinkel, NL

In recent years, recovery of metals from electronic waste within EU has been increasingly important due to potential strategic raw material supply risk and environmental concerns. Electronic waste, especially a mixture of end-of-life electronic products from a variety of sources, is inherently with high complexity in composition, phase and physiochemical properties. In this research a hydrometallurgical process was developed to recover valuable metals, i.e. copper and precious metals, from an industrially processed information and communication technology (ICT) waste. By combining a range of technologies of multi-step leaching and physical separations, valuable metals were effectively recovered with high recovery efficiency and selectivity. With the concentrate of precious metals and a solution with high copper and zinc as the products, this new recycling route is a close-loop process, which paves a way for a sustainable future.

3.12. Circular Economy


V. Fennemann, European Commission

3.12.2. Integration of Circular Economy Business

M. Laubscher, T. Marinelli, Philips, NL

Circular Economy has gained attention in society and industry in the past years, since the world is faced by the challenge of balancing the economic growth with the use and availability of natural resources. Royal Philips embraced the Circular Economy concept and started its journey to integrate this new business model in its business processes. Six key areas for integration were identified including the sales model, product design & material composition, IT & data Management, supply loops, strategic sourcing for own operations and HR & incentives. There is a call on the European policy makers to create the right conditions for the Circular Economy. When implementing a new business model the company is interested to measure the success; the paper will conclude with suggestions of value drivers.

3.12.3. Green Engineering and Supply Chain for B2B

D. Poon, Cisco, US

Green engineering and sustainable supply chain are the top priorities of many companies in the electronic industry today. There have been many presentations and papers on how to design greener products and how to implement a more sustainable supply chain on consumer electronics. However, for companies whose majority of the sales is B2B, the implementation approach needs to be adjusted. In this paper, I like to share some ideas and experience on how to use business data, customer feedback, collaboration technology to reduce information and telecommunication
technology equipment’s life cycle footprint. First, we’ll take at a case where collaboration between Sales, Engineering and Supply Chain lead to the implementation of dynamic packaging of products as a mean to reduce the volume of protective packaging. Then, we’ll look at how software defined radio transceiver and dynamic product label printing help reduced the number of wireless product models while meeting customers’ needs and the relevant regulatory compliance requirements. Finally, we will look at how the product trade-in program help extended the product life and promoted B2B electronics recycling.

3.12.4. Moving beyond the circular economy
M. Moreno, N. Braithwaite, T. Cooper, Nottingham Trent University, UK

The production model, which currently underpins our material prosperity, remains highly resource-intensive, and the volume of minerals, ores and fossil fuels consumed annually is set to triple by 2050 unless economic growth is decoupled from resource consumption. One response that has been attracting significant attention is the idea of a circular economy (or close loop economy), in which waste is transformed into value rather than disposed of to landfill. While acknowledging potential benefits to businesses of a circular economy, this paper critically reviews the model and proposes an approach that addresses concerns that even recycling processes have energy impacts through transportation, reprocessing and subsequent manufacturing, and that in practice it is impossible to have a complete circular system in which there is no use of virgin materials and no final waste. It presents an overarching framework that responds to such concerns, built by studying different circular models in a macro-level perspective and then tailoring tactics for different sectors in a micro-level perspective. The paper explains how the framework was built and how it is applied to the large household appliance (LHA) sector, through developing two emerging models based on product-service systems (PSS). The paper presents findings from a workshop in which the two models were presented to industry representatives, revealing their responses regarding the opportunities and challenges to implement the proposed models to go beyond the circular economy.

3.12.5. More disposable than ever: Do non-removeable batteries support premature disposal of mobile devices?
C. Bakker, Delft University of Technology, NL; L. Kuijer, University of Sheffield, UK

Mobile devices like smart phones, tablet computers and ultraportable laptops are experiencing rapid worldwide market growth and have relatively short lifespans. Recently, embedded (non-removable) batteries were introduced that cannot be replaced by consumers. This study traces the environmental and social consequences of the introduction of embedded batteries throughout the value chain: from the original equipment manufacturers, to the users of mobile devices, to the repair, refurbishment and end-of-life recycling companies. It shows that the introduction of embedded batteries was mainly technology and design-driven, that original owners are hardly aware of embedded batteries (unless they seek to prolong the life of their phones), that embedded batteries have contributed to a thriving but mostly unauthorized repair and refurbishment market and finally that recyclers have difficulties removing the batteries. From a social and environmental sustainability perspective, reintroducing removable batteries is preferable, but the study shows this may not be feasible and examines alternative options.
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