



**Environmental Engineering (EE);  
Circular Economy (CE) in Information  
and Communication Technology (ICT);  
Definition of approaches, concepts and metrics**

PREVIEW  
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## Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Environmental Engineering (EE).

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## Modal verbs terminology

In the present document **"should"**, **"should not"**, **"may"**, **"need not"**, **"will"**, **"will not"**, **"can"** and **"cannot"** are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

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## Introduction

In order to facilitate a shift to a more sustainable economy, Circular Economy (CE) has been proposed as one of the main ways forward. In this context, CE combined with Information and Telecommunication Technologies (ICT) could enable decoupling of economic growth and environmental impact [i.1]. Due to the seemingly scattered understanding of the topic of CE, and its main aspect Resource Efficiency (RE), it will be necessary to summarize, and then standardize, the manner in which CE and RE is quantified.

In 2015, the European Commission issued Mandate 543 (M/543), Standardization Request with regard to ecodesign requirements on material efficiency aspects for energy-related products [i.2] requesting European standardization organizations to develop needed standards. ETSI EE accepted this mandate for ICT infrastructure goods. However, the present document was initiated before the Mandate 543 and is not seen as an ETSI TC EE deliverable for Mandate 543. Nevertheless, the present document is expected to provide valuable input for the Mandate 543 work.

The present document aims to provide an overview of the most important existing aspects, parameters, indicators, metrics, results, and business models used for estimating the resource efficiency and CE characteristics of ICT infrastructure goods as input for further standardization.

The present document is intended to provide an aid for all users of CE and RE concepts within the ICT infrastructure sphere.

ITU-T SG5 (Q13/5) has made preliminary descriptions of RE for ICT goods [i.3], which have been considered in the development of the present document which focuses more broadly on CE aspects for ICT infrastructure goods. Furthermore, the Methodology for Ecodesign of Energy-related Products (MEErP) report, as used in the framework of the Ecodesign Directive (2009/125/EC) [i.2], has been used as background information for materials efficiency aspects.

# 1 Scope

The present document investigates current approaches, concepts and metrics of CE and RE and their applicability for the ICT infrastructure goods. The present document:

- 1) introduces CE and RE,
- 2) describes CE as used in the ICT industry,
- 3) describes existing CE and RE metrics and examples of their use,
- 4) proposes next steps in CE and RE standardization.

The scope of the present document includes the following aspects: upgradability, reparability, removability, durability, reusability, recyclability, recoverability, refurbishability, manufacturability. The following additional parameters, indicators and metrics are included: recycled content, use of critical raw materials, proportion of re-used parts.

The present document was developed jointly by ETSI TC EE and ITU-T Study Group 5. It is published respectively by ITU and ETSI as Supplement ITU-T L.Suppl.28 [i.72] and the present document, which are equivalent in technical content.

The present document provides a guide to CE aspects, parameters, metrics, indicators for ICT infrastructure goods.

# 2 References

## 2.1 Normative references

Normative references are not applicable in the present document.

## 2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] Ellen MacArthur Foundation (2016): "Intelligent Assets: Unlocking the circular economy potential".

NOTE: Available at [http://www3.weforum.org/docs/WEF\\_Intelligent\\_Assets\\_Unlocking\\_the\\_Circular\\_Economy.pdf](http://www3.weforum.org/docs/WEF_Intelligent_Assets_Unlocking_the_Circular_Economy.pdf).

- [i.2] European Commission Mandate M/543. Commission Implementing Decision of 17.12.2015 on a standardisation request to the European standardisation organisations as regards ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council.

NOTE: Available at <http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564>.

- [i.3] International Telecommunication Union. L Suppl. 5 (12/2014): "Life-cycle management of ICT goods".

NOTE: Available at <http://www.itu.int/ITU-T/recommendations/rec.aspx?rec=12433>.

- [i.4] Biointelligence Service: "Material-efficiency ecodesign report and module to the methodology for the ecodesign of energy-related products (MEErP)".
- NOTE: Available at <http://ec.europa.eu/DocsRoom/documents/105/attachments/1/translations/en/renditions/pdf>.
- [i.5] ISO 22628:2002: "Road vehicles - Recyclability and recoverability - Calculation method".
- [i.6] ISO 14021:1999: "Environmental labels and declarations -- Self-declared environmental claims (Type II environmental labelling)".
- [i.7] Huysman, S.; Debaveye, S.; Schaubroeck, T. et al.: "The recyclability benefit rate of closed-loop and open-loop systems: A case study on plastic recycling in Flanders". Resources, Conservation and Recycling 2015, 101, 53-60.
- [i.8] Mueller, S.R.; Wager, P.A.; Widmer, R.; Williams, I.D.: "A geological reconnaissance of electrical and electronic waste as a source for rare earth metals" Waste Management 2015, 45, 226-234.
- NOTE: Available at <http://www.sciencedirect.com/science/article/pii/S0956053X15002329>.
- [i.9] Huysman, S.; Sala, S.; Mancini, L.; Ardente, F.; Alvarenga, R.A.; De Meester, S.; Dewulf, J.: "Toward a systematized framework for resource efficiency indicators". Resources, Conservation and Recycling 2015, 95, 68-76.
- NOTE: Available at <http://www.sciencedirect.com/science/article/pii/S0921344914002328>.
- [i.10] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: "Closing the loop - An EU action plan for the Circular Economy", COM(2015) 614 final, 2.12.2015.
- NOTE: Available at <https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-614-EN-F1-1.PDF>.
- [i.11] Smalen, L.; Galkin, T.; Volkov, T.; Karvinen, H.; Tonteri, H.; Vatanen, S.: "Life cycle methodology to assess resource efficiency of Nokia Flexi Mounting Kit".
- NOTE: Available at [http://www.mince.fi/document/esitykset\\_new/Lauri\\_Smalen\\_jaettava\\_aineisto.pdf](http://www.mince.fi/document/esitykset_new/Lauri_Smalen_jaettava_aineisto.pdf).
- [i.12] Sihvonen, S., Ritola, T.: "Conceptualizing ReX for Aggregating End-of-life Strategies in Product Development". Procedia CIRP 2015, 29, 639-644.
- NOTE: Available at [http://ac.els-cdn.com/S2212827115000293/1-s2.0-S2212827115000293-main.pdf?\\_tid=6d9b9010-321e-11e6-a718-00000aabb0f27&acdnat=1465901875\\_98cdb610cf6ae3ca776d0525bac8f390](http://ac.els-cdn.com/S2212827115000293/1-s2.0-S2212827115000293-main.pdf?_tid=6d9b9010-321e-11e6-a718-00000aabb0f27&acdnat=1465901875_98cdb610cf6ae3ca776d0525bac8f390).
- [i.13] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE).
- NOTE: Available at <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32012L0019>.
- [i.14] Larsen, A.H.; Bauer, B.; Musaeus, P.; Gylling, A.C.; Zacho, K.O.; Remmen, A.: "Forberedelse med henblik på genbrug af elektronikaffald", Miljøprojekt nr. 1739. 2015.
- NOTE: Available at [http://vbn.aau.dk/ws/files/223220188/Forberedelse\\_til\\_genbrug\\_af\\_elektronik\\_affald.pdf](http://vbn.aau.dk/ws/files/223220188/Forberedelse_til_genbrug_af_elektronik_affald.pdf).
- [i.15] BS PAS 141:2011: "Reuse of used and waste electrical and electronic equipment (UEEE and WEEE). Process management. Specification".
- NOTE: Available at <http://shop.bsigroup.com/en/ProductDetail/?pid=000000000030245346>.
- [i.16] Roos, G.: "Business model innovation to create and capture resource value in future circular material chains". Resources 2014, 3, 248-274.
- NOTE: Available at <http://www.mdpi.com/2079-9276/3/1/248>.



- [i.17] Accenture executive summary: "Waste to Wealth", 2015.
- NOTE: Available at [https://www.accenture.com/t20150916T215126\\_w/us-en/acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy\\_7/Accenture-Waste-Wealth-Exec-Sum-FINAL.pdf](https://www.accenture.com/t20150916T215126_w/us-en/acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Strategy_7/Accenture-Waste-Wealth-Exec-Sum-FINAL.pdf).
- [i.18] Sultan, N.: "Servitization of the IT industry: the cloud". Strategic Change 2014, 23, 375-388.
- NOTE: Available at [https://www.researchgate.net/publication/264900709\\_Servitization\\_of\\_the\\_IT\\_Industry\\_The\\_Cloud\\_Phenomenon](https://www.researchgate.net/publication/264900709_Servitization_of_the_IT_Industry_The_Cloud_Phenomenon).
- [i.19] Lasanen, M.; Aubree, M.; Cassan, C.; Conte, A.; David, J.; Elayoubi, S.-E.; Galkin, T.; Grigore, V.; Le Masson, S.; Lees, J.; Louahlia-Gualous, H.; Marquet, D.; Mokhti, Z.; Nuaymi, L.; Scheck, H.-O.; Smalen, L.: "Environmental Friendly Mobile Radio Networks: Approaches of the European OPERA-Net 2 Project".
- NOTE: Available at [http://projects.celticplus.eu/opera-net2/docs/ICT2013\\_presentation\\_OPERA\\_Net2\\_May8th2013.pdf](http://projects.celticplus.eu/opera-net2/docs/ICT2013_presentation_OPERA_Net2_May8th2013.pdf).
- [i.20] Dechenaux, E.; Smalén, L.; Junno, T. et al.: "Materials efficiency: use of LCA to analyze the impacts of the evolution of a the evolution of a radio access radio access mounting kit", ETSI 3<sup>rd</sup> Workshop on ICT Energy Efficiency and Environmental Sustainability. 3 June 2015, Sophia Antipolis, France.
- NOTE: Available at [http://docbox.etsi.org/Workshop/2015/201506\\_EEWORKSHOP/SESSION03\\_LCA/LCA\\_Use\\_AnalyseImpacts\\_RadioAccess\\_MountingKit\\_Dechenaux\\_Orange.pdf](http://docbox.etsi.org/Workshop/2015/201506_EEWORKSHOP/SESSION03_LCA/LCA_Use_AnalyseImpacts_RadioAccess_MountingKit_Dechenaux_Orange.pdf).
- [i.21] ETSI ES 203 199: " Environmental Engineering (EE); Methodology for environmental Life Cycle Assessment (LCA) of Information and Communication Technology (ICT) goods, networks and services".
- [i.22] Recommendation ITU-T L.1410. "Methodology for environmental life cycle assessments of information and communication technology goods, networks and services".
- [i.23] Ardente, F.; Mathieux, F.: "Identification and assessment of product's measures to improve resource efficiency: the case-study of an Energy using Product". Journal Cleaner Production 2014, 83, 126-141.
- NOTE: Available at <http://www.sciencedirect.com/science/article/pii/S0959652614007860>.
- [i.24] BS EN 15343:2007: "Plastics. Recycled plastics. Plastics recycling traceability and assessment of conformity and recycled content".
- NOTE: Available at <http://shop.bsigroup.com/ProductDetail/?pid=000000000030097507>.
- [i.25] Philips: "Closing the materials loop".
- NOTE: Available at <http://www.philips.com/b-dam/corporate/about-philips/sustainability/downloads/ecovision-methodologies/Closing-the-materials-loop-2016.pdf>.
- [i.26] Graedel, T.E.; Allwood, J.; Birat, J.P. Et al.: "Recycling rates of metals: a status report", 2011.
- NOTE: Available at [http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals\\_Recycling\\_Rates\\_110412-1.pdf](http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metals_Recycling_Rates_110412-1.pdf).
- [i.27] Tata Steel Europe: "Sustainable Steel", 2007.
- NOTE: Available at [http://www.tsbsnordic.lv/file\\_source/StaticFiles/SustainableSteel%20KeyMessages.pdf](http://www.tsbsnordic.lv/file_source/StaticFiles/SustainableSteel%20KeyMessages.pdf).
- [i.28] European Commission: "Critical Raw Materials".
- NOTE: Available at [https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical\\_en](https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en).



- [i.29] Rogers, J.; Cooper, S.; Cooper, S.; Densley Tingley, D.; Braithwaite, N.; Moreno, M.; Salvia, G.: "Product Longevity and Shared Ownership: Sustainable Routes to Satisfying the World's Growing Demand for Goods". AIMS Energy 2015, 3, 547-561.
- NOTE: Available at <http://www.aimspress.com/article/10.3934/energy.2015.4.547>.
- [i.30] Stutz, M.; O'Connell, S.; Pflueger, J.: "Carbon Footprint of a Dell Rack Server". In Proceedings of Electronics Goes Green 2012+, Berlin, Germany, 9-12 September 2012.
- NOTE: Available at <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6360427>.
- [i.31] Nokia. 2016: "Nokia Technology Vision 2020" white paper.
- NOTE: Available at <https://networks.nokia.com/innovation/technology-vision>.
- [i.32] Chan, C.A.; Gyax, A.F.; Leckie, C.; Wong, E.; Nirmalathas, A.; Hinton, K.: "Telecommunications energy and greenhouse gas emissions management for future network growth". Applied Energy 2016, 166, 174-185.
- NOTE: Available at [https://www.researchgate.net/publication/292970317\\_Telecommunications\\_energy\\_and\\_greenhouse\\_gas\\_emissions\\_management\\_for\\_future\\_network\\_growth](https://www.researchgate.net/publication/292970317_Telecommunications_energy_and_greenhouse_gas_emissions_management_for_future_network_growth).
- [i.33] Cheung, W.M.; Marsh, R.; Griffin, P.W. et al.: "Towards cleaner production: a roadmap for predicting product end-of-life costs at early design concept". Journal of Cleaner Production 2015, 87, 431-441.
- NOTE: Available at <http://www.sciencedirect.com/science/article/pii/S0959652614010750>.
- [i.34] Wang, C., Mitrouchev, P., Li, G., Lu, L.: "3D geometric removability analysis for virtual disassembly evaluation". In Proceedings 2014 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM), Besacon, France, July 8-11, 2013 (pp. 1212-17).
- NOTE: Available at <http://ieeexplore.ieee.org/document/6878247?tp=&arnumber=6878247&contentType=Conference%20Publications>.
- [i.35] Tian, G., Qiang, T., Chu, J., Xu, G., Zhou, W.: "Efficiency Optimization for Disassembly Tools via Using NN-GA Approach". Math Probl Eng 2013, Article ID 173736.
- NOTE: Available at <http://www.hindawi.com/journals/mpe/2013/173736/>.
- [i.36] IEC TR 62635:2012: "Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment".
- NOTE: Available at <https://webstore.iec.ch/publication/7292>.
- [i.37] Reuter, M. A.; Van Schaik, A.: "10 Design for recycling rules, product centric recycling & urban/landfill mining". In Proceedings 2nd International Academic Symposium on Enhance Landfill Mining, Houthalen-Helchteren, Belgium, October 14-16, 2013 (pp. 103-117).
- NOTE: Available at [http://elfm.eu/Uploads/ELFM/FILE\\_BB6D6C73-3992-4304-A5FA-154E376432F0.PDF](http://elfm.eu/Uploads/ELFM/FILE_BB6D6C73-3992-4304-A5FA-154E376432F0.PDF).
- [i.38] Mangold, J. A.: "Evaluating the end-of-life phase of consumer electronics: methods and tools to improve product design and material recovery". PhD thesis, University of California, Berkeley, 2013. ProQuest.
- NOTE: Available at <http://escholarship.org/uc/item/9tj3t93z>.
- [i.39] Balkenende, A.; Bakker, C.: "Developments and challenges in design for sustainability of electronics". In Transdisciplinary lifecycle analysis of systems: Proceedings of the 22nd ISPE Inc. International Conference on Concurrent Engineering, July 20-23, 2015 (Vol. 2, p. 3). IOS Press.
- NOTE: Available at <http://ebooks.iospress.nl/volumearticle/39947>.

- [i.40] International Telecommunication Union: "Connect 2020 Agenda".
- NOTE: Available at <http://www.itu.int/en/connect2020/Pages/default.aspx>.
- [i.41] Liebmann, A.: "ICT waste handling: regional and global end-of-life treatment scenarios for ICT equipment". KTH:s Publikationsdatabas DiVA. 2015.
- NOTE: Available at <http://www.diva-portal.org/smash/record.jsf?pid=diva2:839633>.
- [i.42] Dretsch, G. 2015: "End-of-Life of ICT Equipment".
- NOTE: Available at [https://docbox.etsi.org/Workshop/2015/201506\\_EEWORKSHOP/SESSION04\\_Environm\\_Sustain\\_Aspects/Managmt\\_EndOfLife\\_ICT\\_equipment\\_WEEE\\_Dretsch\\_Orange.pdf](https://docbox.etsi.org/Workshop/2015/201506_EEWORKSHOP/SESSION04_Environm_Sustain_Aspects/Managmt_EndOfLife_ICT_equipment_WEEE_Dretsch_Orange.pdf).
- [i.43] O'Connell, S.; Shrivastava, P.; Moriarty, T.; Schafer, S.: "Going Green, CARE INNOVATION 2014", November 17 - 20, 2014, Schoenbrunn Palace Conference Centre, Vienna (Austria).
- NOTE: Available at <http://www.4980.timewarp.at/CARE/CI2014/PDFs/Abstract%20Book%20final.pdf>.
- [i.44] Bakas, I., Herczeg, M., Vea, E. B., Frâne, A., Youhanan, L., & Baxter, J. (2016). Critical metals in discarded electronics: Mapping recycling potentials from selected waste electronics in the Nordic region.
- [i.45] World Steel Association: "World steel figures in 2012".
- NOTE: Available at <http://www.worldsteel.org/media-centre/press-releases/2012/wsif.html>.
- [i.46] World Steel Association: "Steel Statistical Yearbook 2014".
- NOTE: Available at <https://www.worldsteel.org/statistics/statistics-archive/yearbook-archive.html>.
- [i.47] IEC 62430:2009: "Environmentally conscious design for electrical and electronic products".
- NOTE: Available at <https://webstore.iec.ch/publication/7005>.
- [i.48] Andrae, A.S.G.; Xia, M.; Zhang, J.; Tang, X.: "Practical Eco-Design and Eco-Innovation of Consumer Electronics - The Case of Mobile Phones". Challenges 2016, 7, 3.
- NOTE: Available at <http://www.mdpi.com/2078-1547/7/1/3>.
- [i.49] Ritthoff, M.; Rohn, H.; Liedtke, C.: "Calculating MIPS: Resource productivity of products and services" (No. 27e). Wuppertal Spezial, Wuppertal Institut für Klima, Umwelt und Energie. 2002.
- NOTE: Available at <http://www.econstor.eu/bitstream/10419/59294/1/485276682.pdf>.
- [i.50] McKinsey article: "Are you ready for the resource revolution?" March 2014.
- NOTE: Available at [http://www.mckinsey.com/insights/sustainability/are\\_you\\_ready\\_for\\_the\\_resource\\_revolution](http://www.mckinsey.com/insights/sustainability/are_you_ready_for_the_resource_revolution).
- [i.51] European Commission Staff Working Document: "Analysis of an EU target for resource productivity". 2014.
- NOTE: Available at <http://ec.europa.eu/environment/circular-economy/pdf/AnalysisEUtarget.pdf>.
- [i.52] The Green Grid®: "Electronic Disposal Efficiency (EDE): An IT Recycling Metric for Enterprises and Data Centers". 2012.
- NOTE: Available at <http://www.datacenterdynamics.com/content-tracks/servers-storage/the-green-grid-brings-in-new-metric-for-equipment-use/74439.article>.
- [i.53] McDonough, W.; Braungart, M.: "Cradle to cradle: Remaking the way we make things". 1<sup>st</sup> ed.; McDonough, W. Braungart, M., Eds.; North Point Press: New York, NY, USA, 2002; pp. 3-193.
- NOTE: Available at <http://www.mcdonough.com/speaking-writing/cradle-to-cradle/>.

- [i.54] International Electronics Manufacturing Initiative: "iNEMI project on repair and recycling metrics". 2015.
- NOTE: Available at [http://thor.inemi.org/webdownload/projects/ese/Repair-Recycling/Repair-Recycling\\_Metrics\\_call091913.pdf](http://thor.inemi.org/webdownload/projects/ese/Repair-Recycling/Repair-Recycling_Metrics_call091913.pdf).
- [i.55] Ellen MacArthur Foundation: "Circularity indicators - an approach to measuring circularity in product development". 2015.
- NOTE: Available at [http://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators\\_Methodology\\_May2015.pdf](http://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_Methodology_May2015.pdf).
- [i.56] Pereira, A.; Fredriksson, C.: "Teaching circularity using CES EduPack". 43rd Annual SEFI Conference June 29 - July 2, 2015 Orléans, France.
- NOTE: Available at <http://www.sefi.be/conference-2015/CHAP%2025.%20Poster%20Session/56147.%20A.PEREIRA.pdf>.
- [i.57] Ellen MacArthur Foundation: "Circularity Indicators: Detailed Calculation Methodology for a Material Circularity Indicator and Guidance on its Use and Outline Descriptions of Associated Complementary Risk and Impact Indicators", Version 2.0.
- NOTE: Available at <http://www.ellenmacarthurfoundation.org/circularity-indicators>.
- [i.58] Vakhitova, T.; Fredriksson, C.: "Practical competences as Learning Outcomes using CES EduPack". J. Ass. Eng. Ed. Russia 2013, 13, 16-23.
- NOTE: Available at [http://aeer.ru/filesen/io/m13/art\\_3.pdf](http://aeer.ru/filesen/io/m13/art_3.pdf).
- [i.59] Williander, M.; Nyström, T.; Linder, T.; Sarasini, S.; Van Loon, P.; Mellquist, C.: "Cirkulär ekonomi bör kunna mätas". (in Swedish).
- NOTE: Available at <http://www.svd.se/cirkular-ekonomi-behover-kunna-matas>.
- [i.60] Global e-Sustainability Initiative (GeSI): "Sustainability Assessment Standard Framework (SASF)". 2015.
- NOTE: Available at <http://gesi.org/portfolio/project/81>.
- [i.61] Güvendik, M.: "From smartphone to futurephone: assessing the environmental impacts of different circular economy scenarios of a smartphone using LCA" (Doctoral dissertation, TU Delft, Delft University of Technology). 2014.
- NOTE: Available at <http://repository.tudelft.nl/view/ir/uuid%3A13c85c95-cf75-43d2-bb61-ee8cf0acf4ff/>.
- [i.62] den Uijl, R. L.: "Going Full Circle: The Developments in Life Cycle Assessments to Deal with Circular Economy Problems". 2016.
- NOTE: Available at <http://dspace.library.uu.nl/handle/1874/337171>.
- [i.63] Van Eygen, E.; De Meester, S.; Tran, H.P.; Dewulf, J.: "Resource savings by urban mining: The case of desktop and laptop computers in Belgium". Resources Conservation and Recycling 2016, 107, 53-64.
- NOTE: Available at <http://www.sciencedirect.com/science/article/pii/S0921344915301269>.
- [i.64] Baxter, J.; Lyng, K.A.; Askham, C.; Hanssen, O.J.: "High-quality collection and disposal of WEEE: Environmental impacts and resultant issues". Waste Management 2016.
- NOTE: Available at <http://www.sciencedirect.com/science/article/pii/S0956053X16300538>.
- [i.65] Sundin, E.; Lee, H.M.: "In what way is remanufacturing good for the environment?" Proceedings of EcoDesign 2011 International Symposium. p. 551-556.
- NOTE: Available at [https://www.researchgate.net/publication/237073726\\_In\\_what\\_way\\_is\\_remanufacturing\\_good\\_for\\_the\\_environment](https://www.researchgate.net/publication/237073726_In_what_way_is_remanufacturing_good_for_the_environment).