Advancing in the digitalization of data for a better analysis of electrical and electronic equipment

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Abstract. The availability of digital tools is key for reproducible, robust, and transparent analysis. Life cycle assessment has become a well-established tool to perform environmental assessment of products and systems. However, despite the existence of diverse commercial software, data availability is still one of the major limitations. This paper introduces one database that aims to shed light in the analysis of electric and electronic equipment: the database of SEmiconductors and other components (DoSE®) and its use along with the Life Cycle Assessment database (LCADB®). DoSE® is a database that aims to provide data for a better analysis of electronics. It contains information of the material composition of semiconductors and other components, and a second section where the material composition of printed circuit boards can be modelled. Data from DoSE® are exportable to excel format to allow for a further use. It can also be exported as an activity to the LCADB® database to develop new life cycle inventories of electronics. All these functionalities are due to be further expanded and tested for the case of batteries and electronics in electric vehicles as part of the digital platform for circular economy developed in the scope of the DigiPrime project.

1 Introduction

Despite the consolidation of life cycle assessment as a robust tool to perform environmental evaluations, data availability is still one major limitation at the time of assessing the potential environmental impacts of electrical and electronic equipment (EEE). The EU ecodesign regulations on energy related products are progressively including new implementing measures about the declaration of the content of some specific materials and recycled content of materials. For example, the ecodesign regulation on enterprise servers (EC/2019/424) includes a specific requirement about an indicative weight range for cobalt in batteries, and neodymium in hard disk drives [1][2]. The draft of the new EC batteries regulation for

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batteries (EC/2020/353) imposes a progressive recycled content for cobalt, copper, lithium and nickel for batteries manufactured in 2030 and 2035 [3]. This paper presents one database to support the provision of information of EEE: the Database of SEmiconductors and other components (DoSE®) [4] and its use along with the Life Cycle Assessment database (LCADB®) [5]. Both aim at providing trusted, transparent and updated datasets of the components and materials contained in printed circuit boards (PCBs) to perform better environmental assessments and do better economic estimate recycling of electronics. Users can register and access to some exemplary datasets at http://lauratalens.eu.pythonanywhere.com

2 Database description

The database DoSE® contains datasets of the material composition of semiconductors and other electronic components contained in printed circuit board of electronics. Data of the material composition of semiconductors and other components have been harvested from the Full Material Declaration Sheet (FMD) of diverse manufacturer's websites as NXP [6], Alldatasheet [7] or similar websites. Many times, the FMDs are published following the IPC-1752A Material Declaration Management standard, developed by the 'IPC-Association Connecting Electronics Industries' (IPC) [8]. The FMD is a voluntary document, thus it is not always fully accessible from manufacturers websites. During the creation of DoSE ®, we identified more than 20 types of electronic components (i.e. capacitors, integrated circuits, coil wounds, transistors, among others), and within each of them, there were many different sub-types. At present, DoSE® has a compilation of more than 250 datasets with the full material composition of semiconductors and other components contained in PCBs. Data availability can be checked in the Semiconductor and other components' section. Figure 1 shows the material composition of one exemplary integrated circuit.

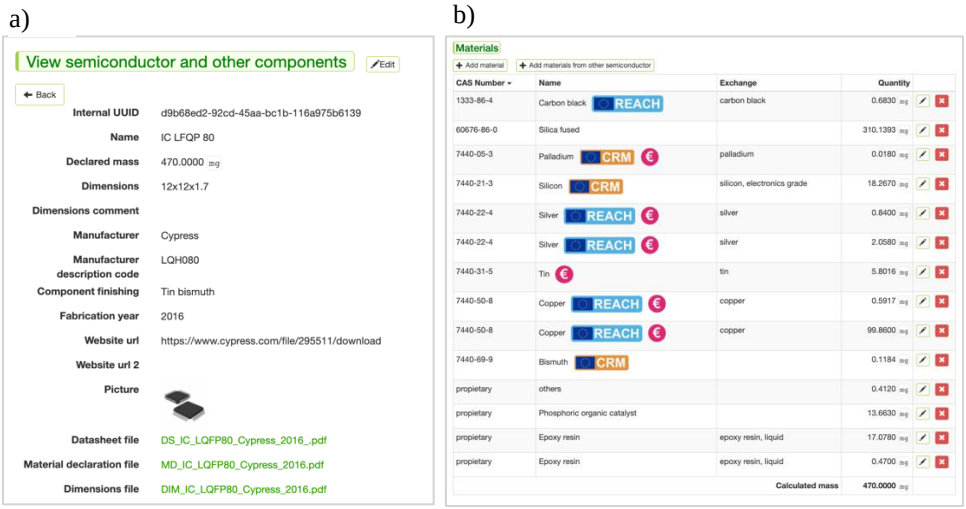

Fig. 1. Description and the material composition of the integrated circuit IC LFQP 80. a) description of the mass (mg), dimension (cm), manufacturer, manufacturer description, and fabrication year. The description also includes the links to the original manufacturer's websites, and a copy of the datasheet and the full material declaration. b) list of materials contained in the integrated circuit component and their mass.

DoSE® allows creating new datasets for components not included yet. The modelling of the PCB is done in the 'Printed Circuit Board' section. Figure 2 shows the example of the PCB of a memory stick. The general description includes the dimensions (cm), mass (g), typology, pictures of the front and the back of the PCBs, and information about the product or part where the PCB was taken among other details. Additionally, it includes a description of disassembly procedures and scheme to harvest the PCBs, and an estimate of the lifetime of the product (in months).

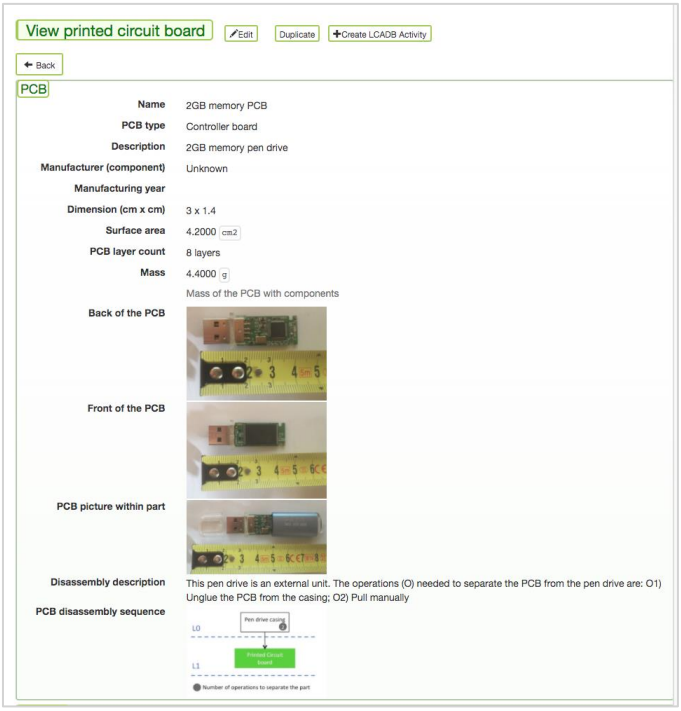

Fig. 2. General description of the PCB contained in a memory stick.

As illustrated in Figure 3a, in a later subsection, users can aggregate semiconductors using the search tool function and their number. The list includes all the semiconductors and other components included in the 'semiconductor and other component' section illustrated in Figure 1. The list of materials contained in the PCB and their quantities (in mg) is automatically generated as semiconductors and other components are included as shown in Figure 3b. Datasets are accessible to users within the same company, research group, collaborative project or research network. The nomenclature of the materials described in the 'exchange' column are those defined in the life cycle inventories of commercial LCA softwares. This is done to ensure data matching between DoSE and the commercial LCA when performing a life cycle impact assessment of an EEE.

The datasets of the PCBs generated in DoSE® can be exported as an excel file to allow performing further calculations as the calculation of the economic value of the PCB, and as well as an activity to the LCADB® to generate a life cycle inventory in ecospold format which allows assessing the potential environmental assessment in commercial and fee-free software. DoSE® and LCADB® have been developed to ensure the compatibility of data format and language. The names of the substances describing the material compositions in declarations are harmonized semantically with those contained in commercial databases as

Ecoinvent [9] and PE –Gabi [10], and also checked with open-source databases as European Life Cycle Database [11].

a)

PCB materials

CAS Number	Name	Calculated Mass
7440-50-8	Copper	897.1920 mg
	Flame retardant	0.0000 mg
	Glass fiber	0.0000 mg

Semiconductors and other components

+ Add semiconductors and other components | Export to .xlsx

Semiconductors and other components | Materials

Name	Manufacturer	Fabrication Year	Manufacturer Desc. Code	Amount	Calculated Mass
IC TSOP 48	Cypress	2018	ZT/TB/ZN-48L	1	502.9450 mg
IC TQFP64	Cypress	2018	AY site 1 B1 (ASET) Au wire	1	338.9487 mg
CAP MLCC	Cal Chip	2005	GMC21 - Dielectric type C0G Series (0805)	2	14.1920 mg
OSC SMD	ECS INC. INTERNATIONAL		ECS-3250SS Series SMD Oscillator	1	0.0812 mg
CON USB A	TE Connectivity	2017	TE Part#=1-292303-1	1	2040.4240 mg
			Totals	6.0	2896.5909 mg

b)

Semiconductors and other components

+ Add semiconductors and other components | Export to .xlsx

Semiconductors and other components | Materials

CAS Number	Name	Exchange	Quantity
12047-27-7	Barium Titanium trioxide REACH		13.1200 mg
1305-78-8	Calcium oxide		0.0002 mg
1308-38-9	Chromium (iii) oxide REACH		0.0021 mg
1309-48-4	Magnesium oxide	magnesium oxide	0.0002 mg
1333-86-4	Carbon black REACH	carbon black	16.8820 mg
1344-28-1	Aluminum oxide REACH €	aluminium oxide	0.0354 mg
13463-67-7	Titanium dioxide REACH	titanium dioxide	0.0002 mg
14808-60-7	Silica crystalline		16.9212 mg
26834-02-6	Phenol, polymer with 1,4-bis(methoxymethyl)benzene		8.4349 mg
461-58-5	Dicyandiamide REACH		0.0320 mg
60676-86-0	Silica fused		432.2090 mg
65997-17-3	Filament fiber glass REACH		184.2000 mg
70679-92-4	2-Naphthalenecarboxylic acid,6-(acetyl-oxyl-,polymer with 4-(acetyloxy)benzoic acid		414.4500 mg
7439-89-6	Iron REACH €	sinter, iron	1.4336 mg

Fig. 3. a) List of semiconductors and other components included in the PCB of a memory stick. b) List of the materials and their quantities (mg) contained in the PCB of a memory stick.

3 Expected impact

DoSE® is the first open-source inventory data for PCBs contained in electronics. This information provides data about the use of materials by the electronic industry and allows for a more comprehensive discussion about how technological trends in the electronics are linked to raw materials, as well as to the future e-waste flows. Advances in the information about the design for disassembly in DoSE® will help advance in the separation of printed circuit boards and drive the development of more innovative technologies to classify and recover materials. The availability of datasets to allow for accounting for the material composition and environmental footprint of electronics becomes urgent as more electronics are further regulated. The combination of DoSE®-LCADB® represents a novel digital tool to allow working in collaborative teams, either within a company or a research group, and in projects (i.e H2020 Digiprime), where users can exchange datasets to facilitate the progress towards more sustainable EEE. In terms of further work, the objective is to continue populating the database with more datasets of electronic components, especially integrated circuits, and datasets for PCB, especially those contained in the batteries of electric vehicles. Future work includes a more descriptive and user-friendly version of the disassembly sequence of the PCB, as well as more detailed estimates of the lifetime of products where the PCB are contained.

Acknowledgements. The authors would like to thank the support of the Beatriu de Pinós postdoctoral programme of the Government of Catalonia's Secretariat for Universities and Research of the Ministry of Economy (2016BP00132) and the Digital Platform for Circular Economy in Cross-sectorial Sustainable Value Networks project (https://www.digiprime.eu/). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 873111.

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