Fairtronics: a Social Hotspot Analysis Tool for Electronics Products

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Abstract

Electronics products are not only associated with an environmental, but also a social footprint. Potential social sustainability problems can be identified along the whole life cycle of an electronics product: for example, the mining of so called "conflict minerals" that finance armed conflicts in Central Africa or cases of child labor in artisanal gold mining. Due to the complexity of electronics supply chains, the evaluation of these social risks poses a challenge. To address this, we have developed a specialized, easy to use tool for the social assessment of electronics products. The idea is to allow businesses to come to an initial idea of potential social risks in their supply chain based on the bill of materials (electronic components) of a product under consideration. Our contribution consists of four parts: First, we discuss the specific social issues in electronics supply chains as laid out above. Second, we present our method to calculate the social risks based on guidelines for Social Life Cycle Assessment (S-LCA). Specifically, we collect data on material composition of electronics components, production rates of these materials in different countries, and social indicators for these countries. The result is a social hotspot analysis based on a generic as well as component-specific assessment of social issues. Third, we further describe the current state of an open source web-based tool that implements the presented method. Finally, we discuss open challenges regarding data availability, interpretation and communication of the results and possible future extensions of the method.

1 Introduction

The production, use and disposal of electronics products is associated with a variety of social risks and potentially negative effects to human welfare. Recent reports about child labor in gold mining [1] and so called "conflict minerals" that finance armed conflicts Central Africa [2] are examples for such social risks that occur during the extraction of raw materials and are "built into" electronics products. In order to address these issues, manufacturers and other interested stakeholders, need to understand these risks. However, the complexity of electronics supply chains and the multitude of social issues pose a major challenge. To address this, we have developed Fairtronics, a web-based app that is intended to give electronics manufacturers and other stakeholders interested in the sustainability impacts of electronics products an easy entry point into social sustainability analysis. The initial version presented here was developed over the course of 6 months with funding provided by the Prototype Fund / German Federal Ministry of Education and Research.[1] Core values pursued in the development of the app are: (1) transparency, by using only free/libre open source software and providing all results under free/libre open source license. Furthermore, only publicly accessible data sources were used and all sources documented in the repository. (2) usability, the software should be usable without extensive training and provide initial results also when only limited data is available to the user.

In the following we describe the basic concepts of social sustainability analysis in section 2, and then describe their application in Fairtronics in section 3. For selected aspects, we describe the current state and lay out potential future developments. Section 4 gives a simple example for the risk calculations performed in the app and a final conclusion and outlook are given in section 5.

2 Social Life Cycle Assessment

We orient the approach of assessing social impacts in the Fairtronics app on Social Life Cycle Assessment (S-LCA) guidelines [3] and methodological sheets [4]. S-LCA itself is based on (Environmental) Life Cycle Assessment (LCA), which is a method to analyze potential environmental impacts throughout a product's

[1] https://prototypefund.de/

life cycle (from raw material extraction to final disposal). S-LCA complements LCA by addressing social and socio-economic aspects. The S-LCA guidelines and corresponding methodological sheets structure potential social impacts in five different stakeholder groups (Worker, Local community, Society, Consumer and Value Chain Actor). For each stakeholder group, several subcategories are given. In the case of the stakeholder group Worker, these are Child Labor, Fair Salary, Hours of Work, Forced Labor, Equal Opportunities / Discrimination, Health and Safety and Social Benefit / Social Security. Each of the proposed subcategories may be measured by several indicators. For conducting an S-LCA study, the guidelines distinguish the four phases (1) goal and scope definition (setting the focus of the analysis), (2) inventory analysis (collecting data), (3) impact assessment (identifying sustainability impacts) and (4) interpretation (deduct learnings).

Several S-LCA studies on electronics components and products such as integrated circuits, mobile phones, laptops and desktop pcs are available [5], [6], [7], [8], [9]. There are also studies that focus on raw material extraction [10] and recycling [11], [12]. For our implementation, we mainly drew inspiration from [9], who describe an approach to perform a hotspot assessment when only limited generic data is available.

3 Application of S-LCA in Fairtronics

In the following, we describe how the analysis is implemented in Fairtronics, the identified constraints and possible future developments along the phases of an S-LCA study.

3.1 Goal and Scope

Goal: The goal of the assessments performed in Fairtronics is to highlight hotspots in electronics products: components, materials, countries, where it is likely that negative social impacts occur. The results should motivate and direct more detailed inspections and improvement measures.

Functional unit and system boundary: The Fairtronics app allows the user to compose a to-be-assessed electronics product at runtime, so the functional unit differs for each assessment performed with Fairtronics. However, it will always be one electronics product consisting of one or multiple components. For each of the components, we collect data about its raw material composition. Ideally, the assessment should cover the full life cycle of an electronics product and all potentially affected stakeholders. However, in the initial iteration of the implementation, the scope of the data collection and calculation is restricted to the extraction of metals and potential impacts associated with the stakeholder group Worker.

Activity Variable: In the initial implementation, Fairtronics uses the relative weight of a material or component to determine the significance of social impacts. For future developments, further data collection is planned in order to use workers' hours as preferred activity variable (as suggested in the guidelines).

Data quality: We focus on the collection of country-specific data for the social indicators. For data about material extraction quantities and material composition of components, we rely on publicly available data. This allows us to be as transparent as possible for the presentation of the results.

3.2 Inventory

3.2.1 Raw material data:

General considerations: The material's world production share of different countries can be obtained from agencies such as the U.S. Geological Survey [13].

Current state: Currently, we consider the materials Bauxite, Chromium, Copper, Gold, Iron, Nickel, Palladium, Silver and Tin. Implicitly, we assume that each of the materials in a component is a mix from different origins, according to the world production share.

Possible extensions: Further (also non-metal) materials will be added in the future. Currently, the distinction between ore and smelter output is not always clear. Future iterations of Fairtronics should extend the internal system model to reflect different supply chains for materials and extend the scope of the analysis from raw material extraction.

3.2.2 Component data:

General considerations: By components we mean the parts of an electronics product. Of interest for the analysis is, what the components are "made of", which can be understood differently. In the simplest case, this means the material contents of a product after production. This level of data is especially useful for electronic waste analysis [14]. For a complete sustainability analysis, however, data about waste during production and auxiliary materials used during production is necessary. The difficulty of obtaining such data for electronics products is discussed in [15]. Primary data sources for data about the material composition of components can be provided by manufacturers or generated by analytical means (e.g. [16]). Useful secondary sources may be life cycle inventory databases or handbooks and publications of various kinds (e.g. [17]). There also exist commercial B2B platforms that provide relevant inventory data (examples are CDX or iPoint Material Compliance App). One can suppose that manufacturers know about the material composition of their products, however most do not share this information freely. There are notable exceptions, however. Publishing a full material declaration (FMD) also has advantages for manufacturers [18] and we identified several manufacturers that indeed freely provide an FMD in various data formats, and some others provide the data upon request.

Current state: Ideally, for the purposes of Fairtronics, the data should be complete, machine readable, up to date, freely accessible and freely publishable. We collect data about the material composition of electronics components (like resistors, circuit boards, cables, ...). Currently, we only consider electrical components, so screws and cases are excluded. So far, we have collected data for 31 different components from full material declarations by manufactures that are published on their websites. While we intend to extend the collection, many manufacturers do not publish full declarations for their products, and so, when configuring a product from the component list, it might be necessary to select a component that is reasonably similar to the one that is actually part of the modeled product.

Possible extensions: Our consideration of components is currently restricted to the printed circuit board (PCB) and everything that is mounted on it (solder, cable, etc.). Larger products (e.g. a desktop computer) however, consist of multiple parts (such as hard disk, motherboard, …), that themselves consist of electronic components. This modularity can not be modeled in the current state of Fairtronics. Another possible feature that may mitigate the lack of data would be to allow a scaling of example components in the database.

3.2.3 Product data:

General considerations: From our analysis of electronics design software such as LibrePCB, Autodesk Eagle and KiCad EDA, we conclude that (semi-)structured data about product composition is mostly available in PCB layout data (mostly Gerber format [19]) and component lists (bill of material or BOM). LibrePCB provides an export feature that distinguishes between fabrication data for the PCB and a BOM. Autodesk Eagle provides a PCB layout data format and a schematics format including a BOM. KiCad EDA provides a customizable BOM export. Commercial LCA software such as GaBi LCA (via DfX extension) and MiLCA apparently provide a BOM import function. Another possibly relevant data type are circuit schematics that present a graphical representation of an electrical circuit. These don't contain layout data (for PCB), however, a BOM may be compiled from them. BOMs differ in their specificity: Open Hardware projects, for example, mainly describe components by their required electrical and mechanical properties. For commercial hardware, specific supplier lists are available but rarely disclosed. Notable exceptions are Fairphone [20] and Nager IT [21]. As last resort, dismantling a device may reveal the included components.

Current state: We have collected data about the composition of the Nager IT computer mouse, Arduino Uno and MNT reform v2 laptop. The user interface allows to specify the list of components and their quantity from a predefined list of components we have collected so far.

Possible extensions: In the future, it may be possible to streamline the process for the user, e.g. by providing import functionality for BOMs and Gerber files. We also intend to collect further product data, especially from Open Hardware projects.

3.2.4 Social indicators:

General considerations: Global institutions like the International Labor Organization or Unicef provide reports and estimates for human rights conditions in different countries. While one singular supplier might perform better (or worse) than the country average, we assume that these estimates provide an indication how likely it is that human rights were violated during the production of materials in this country.

Current state: for each of the subcategory for workers described in the S-LCA methodological sheets (Child Labor, Freedom of Association, Fair Salary, Hours of Work, Social Protection, Discrimination and Health), we have selected one relevant indicator from the Ilostat database provided by the International Labor Organization.

Possible extensions: The currently selected indicators may not be sufficient to measure the full scope of an impact category (see [22]). Future iterations may add more indicators per subcategory and cover further stakeholder groups. Providing sector-specific data and data on a higher regional resolution would also improve the quality of the analysis.

3.3 Impact Assessment

Activity value: Based on our basic concepts and assumptions explained in section 3.1, we calculate an activity value (share of total product weight) that can be associated to each involved component, material and country. The activity value is dependent on the corresponding relative weight. Activity values

- for materials express the share of this material in total product weight (across all involved components).[2]
- for components express the share of the component's weight to the total product weight.
- for countries express the share of the materials produced in this country to total product weight.

An activity value above 10% is interpreted as "High Activity", and below 1% as "Low Activity". Anything in between is interpreted as "Medium Activity".

Risk value: For each social indicator, the values are sorted and the highest 25% of values are interpreted as "High Risk", the lowest 25% of values as "Low Risk", and everything in between as "Medium Risk" (depending on the indicator interpretation, this may also be inverted, with lowest values as "High Risk", and highest values as "Low Risk"). Via our assumed distribution of material production across countries and the material composition of countries, these risk values are associated with countries, materials and components (for a detailed description see the example calculation in section 4). When an indicator does not provide a value for an involved country, this is denoted as "Unknown Risk".

Hotspot identification: Hotspots are those countries, components and materials that show the highest activity and highest risks. For each component, we highlight the two components that show high risk and have the highest activity as hotspots. If no components show High Risk, we highlight the two Medium Risk components with highest activity etc. The same procedure applies for material and country hotspots. Finally, a table gives a complete overview of shares and risk ratings.

3.4 Interpretation

In the app, users are guided through a process, where they configure an electronics product from a library of components (see figure 1). Afterwards they can obtain a report that presents the results of the impact assessment.

[2] Since we restrict the scope of the analysis currently to metals, it is more specifically the "total weight of metals in the product".

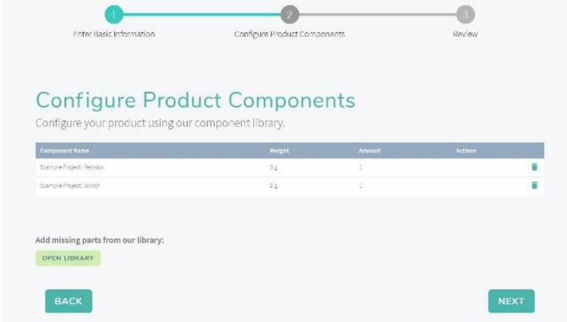

Figure 1: Product configuration in Fairtronics.

To support the interpretation of the results, we break down the results separately for each of the dimensions (materials, components and countries). For each dimension, we first present an explorable tree map with the activity (weight) share (see figure 2), and then highlight the corresponding hotspots.

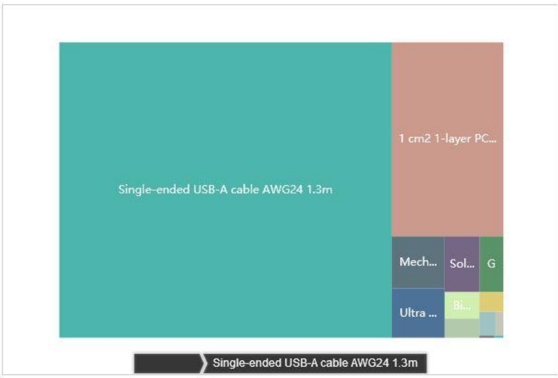

Figure 2: Example for a tree map showing the shares in weight for different components of a product.

To visualize the risk levels, we provide a traffic light visualization for High, Medium, Low and Unknown Risk (see figure 3).

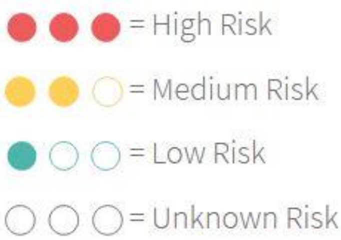

Figure 3: Traffic light visualization of risk levels.

4 Example Calculation

In order to exemplify the calculations that are performed in the app, we give a brief, simplified example with 2 components (C1 and C2), 2 materials (M1 and M2), 2 indicators (I1 and I2) and 2 involved countries (L1 and L2). The first type of data we collect is the share of different materials in components. Table 1 shows an example, where component C1 consists of 7g material M1 and 13g M2. Component C2 consists of 6g M1 and 4g M2. We then want to find out, where these materials are produced. In the example given in table 2, we can see that 60% of the world production of M1 stems from country L1 and 40% from country L2. For M2, the distribution is 20% from L1 and 80% from L2. In order to assess the social risks, the indicators I1 and I2 are given. The indicators may have different scales, in the example, we assume that possible values for I1 range from 1 to 5 and for I2 from 0 to 100.

	C1	C2
M1	7g	6g
M2	13g	4g

Table 1: Material share for different component.

	L1	L2
M1	60%	40%
M2	20%	80%

Table 2: Material production shares for different countries.

	I1	I2
L1	2	80
L2	5	100

Table 3: Indicator values for different countries.

Based on this data, the total product weight is 30g. The activity values are calculated as follows:

- C1: 66,66% (2/3 of total product weight)
- C2: 33,33% (1/3 of total product weight)
- M1: 43,33% ((7g + 6g) / 30g)
- M2: 56,66% ((13g + 4 g) / 30g)
- L1: 37,33 (60% * 43,33% + 20% * 56,66%)
- L2: 62,66% (40% * 43,33% + 80% * 56,66%)

In the next step, the indicator values for materials and components are scaled, according to their contribution.

- $I1_{M1}$: 3,2 (2 * 60% + 5 * 40%)
- $I2_{M1}$: 88 (80 * 60% + 100 * 40%)
- $I1_{M2}$: 4,4 (2 * 20% + 5 * 80%)
- $I2_{M2}$: 96 (80 * 20% + 100 * 80% = 96)
- $I1_{C1}$: 3,98 (35% * 3,2 + 65 % + 4,4)
- $I2_{C1}$: 93,2 (35% * 88 + 65% * 96)
- $I1_{C2}$: 3,68 (0,6 * 3,2 + 0,4 * 4,4)
- $I2_{C2}$: 91,2 (0,6 * 88 + 0,4 * 96)

In order to keep this example simple, we further assume the thresholds for Medium and High Risk as given, with an I1 indicator value of 3 as threshold for Medium Risk and 4 for High Risk. For I2 we assume 50 as threshold for Medium Risk and 90 as threshold for High Risk. As described in section 3.3, these values would normally be calculated from the highest and lowest 25% of values.

Based on the given threshold we can categorize for indicator I1:

- Low Risk for L1
- Medium Risk for M1, C1 and C2
- High Risk for L2 and M2

And for indicator I2:

- Medium Risk for L1 and M1
- High Risk for L2, M2, C1 and C2

In terms of hotspots, C1 would be ranked higher than C2, as it has a higher weight contribution to the product. M2 would be highlighted as material hotspot, as it shows High Risks and has the higher activity value. L2 shows High Risks and higher activity values as well.

For a more detailed example with real data, we provide the analysis of a computer mouse as an exemplary application of Fairtronics under https://fairtronics.org/browse/. The analysis covers 13 components, 9 materials and 40 countries.

5 Conclusion

In this paper, we have described the concept and implementation of a social analysis tool for electronics products. It is intended as a simple to use “entry point” to social sustainability analysis. In the future, we plan to extend the data base, internal model and calculation to cover further materials, life cycle stages and sustainability aspects.

6 Acknowledgments

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7 Literature

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