# SMART DELIVERABLE
## Sustainability Hotspots Analysis of the Mobile Phone Lifecycle

We study the barriers and drivers for market actors' contribution to the UN Sustainable Development Goals within planetary boundaries, with the aim of achieving Policy Coherence for Development.


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# Sustainability Hotspots Analysis of the Mobile Phone Lifecycle

Interim Report of Findings in Work Package 4,
Sustainable Market Actors for Responsible Trade (SMART)

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Front photo: Mobile phone repairer in Accra, Ghana | SMART/Maja van der Velden

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## Glossary of terms

**Hotspot**: A life cycle stage, process or elementary flow, which accounts for a significant proportion of a product's impact on a planetary boundary or a dimension of the social foundation.

**Hotspots Analysis**: The rapid collection and analysis of information resources, such as LCAs, stakeholder interests, research, and expert opinions in order to identify and prioritise the most significant social and environmental sustainability impacts. The results of this qualitative process will then guide more detailed research.

**Impact**: A verified breach of defined planetary foundation or social foundation by an activity in a product's lifecycle.

**Impact category**: a class or category of actual or potential negative impact on planetary or social foundation by an activity in a product's lifecycle.

**Key informants**: Interview subjects who have an overview of activities in a particular field of activity; in this case, those with a meso-level understanding of the mobile phone lifecycle (e.g. investors, producers, but not workers or consumers).

**Planetary Boundaries**: the non-negotiable planetary preconditions that humanity needs to respect in order to avoid the risk of deleterious or even catastrophic environmental change. [1], [2]. The nine boundaries are climate change, novel entities, ozone depletion, aerosol loading, ocean acidification, biochemical flows, freshwater use, land-system change, and biosphere integrity. Between the planetary boundaries and social foundation lies an environmentally safe and socially just space in which humanity can thrive.

**Producer**: The company which produces and markets a product, in this case a mobile phone; usually the owner of the brand and owner/director of the product life cycle.

**Product lifecycle**: Based on lifecycle thinking, a product lifecycle consists of activities that need to take place in order to produce and consume a project. These activities can be described as phases: and idea and design phase, the production phase including material processing, the use and service phase, and the end of life phase.

**Regulatory Ecology**: The result of a mapping of a system of polycentric regulation; useful for understanding regulation based on a polycentric approach involving four modes of regulatory constraint (law, markets, social norms, materials/design).

**Risk**: A potential impact, that is an activity in a product's lifecycle that poses a threat of a breach of defined planetary boundaries or social dimensions.

**Salience**: A qualitative assessment of the significance of an impact or risk (identified in a particular lifecycle phase) to the planetary boundaries and social foundation.

**Social Foundation**: the minimum standards of living conditions and human rights below which people can be said to be living in deprivation The twelve dimensions of the social foundation are derived from internationally agreed minimum social standards, as identified by the world's governments in the Sustainable Development Goals in 2015. The twelve social dimensions are food, health, education, income & work, water & sanitation, energy, gender equality, social equity, housing, political voice, peace & justice, and networks. Between the social foundation and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive [3].

**Social sustainability**: Human activity that meets minimum standards of social wellbeing that protects against critical human deprivations.

**Stakeholders**: Individuals, groups, communities or organizations that have an interest or concern in a product's life cycle.

**Sustainability**: A quality of human activity, which does not conflict with the Planetary Boundaries and the Social Foundation.

**Sustainability Hot Spot Analysis**: A tool for identifying and visualising social and environmental hotspots.

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# 1. Introduction

Sustainable Market Actors for Responsible Trade (SMART) is a Horizon2020-financed research project that seeks to advance understanding on how non-development policies and regulations reinforce or undermine development policies. We study the barriers and drivers for market actors' contribution to the UN Sustainable Development Goals within planetary boundaries, with the aim of achieving Policy Coherence for Development. We analyse the regulatory complexity within which European market actors operate, both the private sector and the public sector in its many market roles with a focus especially on international supply chains of products sold in Europe. This report, *Sustainability Hotspots Analysis of the Mobile Phone Lifecycle*, is one of the deliverables in the SMART project and presents an analysis of the social and environmental externalities in the lifecycle of the mobile phone.

A Hotspots Analysis is a qualitative approach to rapidly identify and prioritize social and environmental sustainability impacts in a product lifecycle. A Hotspots Analysis should not be mistaken for an assessment of the sustainability of a product lifecycle: it doesn't replace Life Cycle Assessments (LCAs) or other evaluations of sustainability, nor does it aim to generate new data about the sustainability of a product. Rather, a Hotspots Analysis offers a method that draws on scientific research and stakeholder inputs to select particular impacts in a product lifecycle as priorities for further research. In other words, a Hotspots Analysis is true to its name: an analysis that rapidly identifies the significant manifestations of unsustainable activity in a product lifecycle.

The Hotspots Analysis of mobile phones contained in this report was conducted as part of Work Package 4 (WP4) of the Sustainable Actors for Responsible Trade (SMART) project (2016-2020)[1]. Work Package 4 is concerned with the social and environmental externalities in the product lifecycle of mobile phones, as part of the overall concern of the SMART project with EU policy coherence for social and economic development. The objectives of Work Package 4 are:

- To identify the social and environmental *hotspots* in the lifecycle of two mobile phones.

- To identify the *regulatory ecology* of a selection of the identified hotspots. Further research will investigate the legal, social, economic, material (design), and environmental constraints and opportunities for improve sustainability by high tech companies seeking to make the transition to sustainable market behaviour.

- To contribute to the SMART project's *proposals for changes* to law and policy at the EU level for improved social and environmental sustainability and, on the basis of research into the product lifecycle of mobile phones, to contribute to critical perspectives on reforms suggested by scholars in the SMART project.

This report fulfils the first objective: it identifies the social and environmental hotspots in the lifecycle (LC) of phones. To this end, the research that went into this report asked a basic question: *What are the environmental and social hotspots in the mobile phone lifecycle?*

[1] SMART: http://smart.uio.no

To answer that question, the research presented in this report proceeded in two steps (as described in the project work plan for Work Package 4 of the SMART project). The initial phase in the research involved 1) Establishing the phases in the mobile phone life cycle and identifying the corresponding environmental and social risks in each phase of the mobile phone LC; and 2) Identifying the hotspots in the LC.

On the basis of hotspots analysis in this report, and based on input from the project stakeholders[2], a selection of priority hotspots for further research will be determined by the project researchers. Under the subsequent phases of the project, the research will 3) analyse selected hotspots to better understand the regulatory ecology (see glossary) that sustains the identifies unsustainable behaviour, and 4) provide inputs to the formulation of recommendations for improving sustainability, in particular in the regulation of social and environmental impacts of the lifecycle of mobile phones. A report on the results of research in phase 3 and 4 will be published in the fall of 2019.

**In Section 2** we describe the methodology used for the identification of hotspots in the lifecycle of mobile phones. A Hotspots Analysis is a qualitative approach to rapidly identify and prioritize social and environmental impacts on sustainability in a product lifecycle. We describe the process of identifying risks in the mobile phone lifecycle and we provide the descriptions of the impact categories used in this Sustainability Hot Spots Analysis of the mobile phone lifecycle.

In this study, we define an impact as a verified breach of defined planetary boundaries or social dimensions by an activity in the mobile phone lifecycle. The Planetary Boundaries framework [1], [2], and the twelve dimensions of the Social Foundation [3], provide the benchmarks against which we formulate our impact categories. In **Annex 1** we provide the descriptions of the boundaries and dimensions as well as their indicators. **In Section 3** we associate the planetary boundaries and social dimensions with the qualitative impact categories used in our analysis. In **Section 4** we present the hotspots in the Mobile Phone Lifecycle, focusing on siox lifecycle phases: Design, Resource Extraction, Manufacturing, Transportation, Use, and End of Life. **Annex 3** provides the particular values (0 to 3) for each impact and lifecycle phase. **Annex 4** provides the bibliography of the articles, book chapters, and reports that formed the data for the analysis.

[2] First Stakeholder Report: Work Package Four – Mobile Phone Lifecyle, November 30, 2017

# 2. Methodology

The research undertaken focuses on the steps involved in making mobile phones within their real-life contexts. The objective is to produce a comprehensive understanding of environmental and social sustainability in the mobile phone lifecycle.

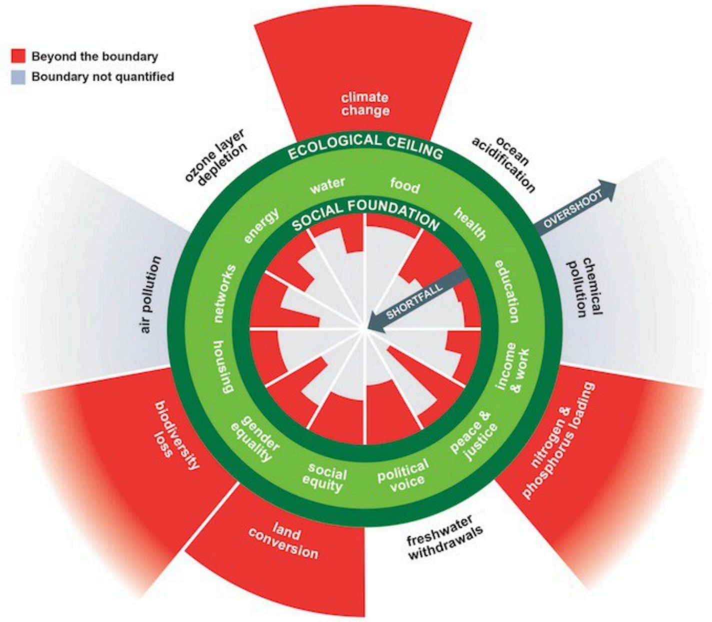


Figure 1. Planetary Boundaries and Social Foundation

The research is guided by a desire to understand the factors driving environmental and social *unsustainability* in global product lifecycles. Our working definition of sustainability and unsustainability is framed by natural and social science research into "a safe and just space for humanity" [4]. Current data indicate that human activity is the main cause for the present overshoots of the natural boundaries imposed by our planet in at least four key areas: climate change, biodiversity, land conversion and nitrogen and phosphate loading. In addition, we are failing to meet the minimum social foundations - such as access to food, water and social equity - necessary for safe and just human development. Our definition assumes that sustainable human activity lies between in between the planetary boundaries and social foundation in what Raworth has called a "environmentally safe and socially just space in which humanity can thrive."

## Case Selection

An overarching objective of the research under WP4 of the SMART project is concerned to locate the lifecycle of electronics in this larger context of sustainability. To operationalise this concern, we opted to focus on the mobile phone lifecycle as a case study into one product lifecycle out of many within the field of electronics [5], [6].

We located our research into the mobile phone lifecycle within the overall definition of sustainability outlined above, and began by asking three questions:

- What are the phases/stages and components of the mobile phone lifecycle (LC) in general?
- What are the environmental risks in the mobile phone LC?
- What are the social risks in the mobile phone LC?

These questions framed our first phase research in the mobile phone lifecycle. As anticipated, it rapidly became clear that it is often difficult to speak of a mobile phone lifecycle in the singular. The variety of companies involved in mobile phone production, each with their own value chain and with a range of suppliers stretched along global supply chains, confronts the researcher with a problem of complexity and diversity. In other words, there is not one mobile phone lifecycle but several. We took this on as a research challenge and decided to test the notion that a mobile phone lifecycle could be described in a general fashion but with enough specificity to allow for research into the regulatory ecology of sustainability (in the next phase of research).

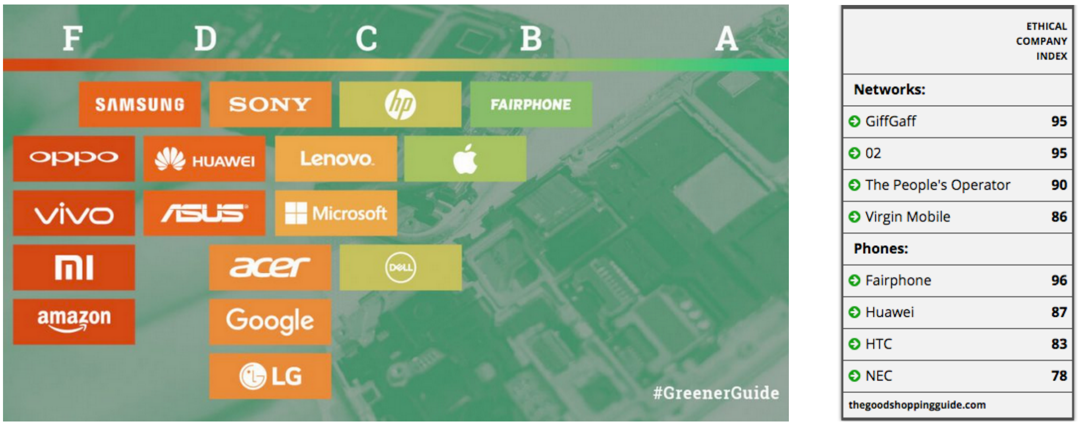


Figure 2. Ranking of mobile phones

To this end, we map the hotspots across the lifecycle of what we describe as a *composite smart phone* (CP), which draws on the extensive literature review conducted in the phase one development of the Risk Catalogue. In addition, we map the hotspots in the lifecycle of the *Fairphone 2*, developed by Fairphone B.V., a social entrepreneur in the Netherlands. Fairphone functions as our best practice company, with the Fairphone 2 has our best practice case. We selected the Fairphone 2, because the main goal of Fairphone is not to sell as many mobile phones as possible, but to create a fair and sustainable LC. The Fairphone 2 is the first modular and repair-centric mobile phone on the European market. The Fairphone 2 is ranked as the most repairable mobile phone [7]. In 2016, Bas van Abel, co-founder and then CEO of Fairphone B.V., won the prestigious German Environmental Award, of the German Federal Environmental Foundation, for being "a pioneer for more resource efficiency in the smartphone industry" [8]. In 2017, Greenpeace and The Good Shopping Guide gave Fairphone the best grade of all mobile phone producers [9] (see Figure 2).[3]

## Cataloguing Risks and Impacts

We sought answers to the questions outlined above through a systematic literature review and document analysis, as well as stakeholder consultation. For the purposes of understanding the social and environmental impacts of mobile phones, the lifecycle of a mobile phone is commonly conceived of as having six phases: design, resource extraction, manufacturing, transport, use, and end of life.

[3] There are several organisations that rank ethical products, often using different sets of criteria and different data. These two examples are provided to illustrate the ranking of Fairphone amongst its competitors.

In order to get an overview of the social and environmental impacts in the mobile phone lifecycle, a catalogue of risks and impacts was developed. The literature review covered more than 400 academic articles and reports published by international organisations (research institutes, non-governmental organisations, labour unions, etc.): 304 resources were located in a systematic review and additional resources were identified after the first review was finished. In our review, we included articles and reports focusing on mobile phones as well as articles and reports related to the electronics industry in general or to particular activities related to the mobile phone LC. Phase 1 of the research generated a comprehensive risk catalogue across all phases of the LC of mobile phones (see Annex 2).

In the systematic review, scientific and non-scientific (grey) literature was explored on the basis of a set of search strings. The result was a body of 304 resources, which were systematically coded on the lifecycle phase in which the risk took place, the country in which the risk took place, and the type of risk (risk to what and risk to whom). The result was an extensive list with risks, which we formulated as a Risk Catalogue. The Risk Catalogue is available online and, once finalised, will become a comprehensive and interactive resource for the general public (see Annex 2 and online at kumu.io/majava/). The risk map was presented and discussed during the first stakeholder meeting in Amsterdam, March 2017 and through a second round of consultations in Warsaw, in October 2017.

The Risk Catalogue was intended to be comprehensive and does not exclude any risks or attempt to rank them in any way. This makes the risk catalogue a vital reference point for the overall challenges to sustainability presented by mobile phones. However, and as anticipated, the comprehensiveness of the risk catalogue also makes it unwieldly for the purposes of prioritising interventions to improve sustainability in the mobile phone lifecycle. We grouped some of the risks and impacts, in particular the long lists of hazardous materials mentioned in the literature. Still, the range of risks portrayed by the catalogue is too wide for the purposes of more focused research into regulation in the subsequent phases of Work Package 4, namely regulatory research and the identification of reform proposals.

## From risks to impact categories

A key challenge in this stage of the research has been to translate the identified risks and impacts in the Risk Catalogue in ways that correlate to the Planetary Boundaries framework and the Social Foundation, which contains the benchmarks of sustainability used in the SMART project. It should be emphasised that both the planetary boundaries and the social dimensions have been defined with respect to international consensus definitions and indicators (see Annex 1. Description of Planetary Boundaries and Social Foundation). However, it was not always clear how a particular impact or risk, which arose the life cycle of a mobile phone, might translate into a salient impact or risk to a planetary boundary or social dimension. For example, we found several health risks related to working with hazardous materials in the mining, manufacturing, and informal recycling phases of the mobile phone lifecycle. However, the literature discussed particular diseases or chemicals and did not relate these to Planetary Boundaries or Social Foundation.

To achieve the translation of the identified impacts and risks into planetary boundaries and social dimensions, we adopted some of the impact categories used in Life Cycle Assessments (LCAs) of mobile phones [10]–[27]. We mapped the risks catalogued from the literature review against the impact categories commonly used in these LCAs. In doing so, we made a priority of impacts, that is, those risks to people and the planet which had occurred and for which the impact was documented in the literature. In this way, our Risk Catalogue was translated into a set of Impact Categories. The result was that a large number of risks were combined into slightly smaller number of impacts. In addition, the categorisation of these impacts was more compatible with Planetary Boundaries framework and the Social Foundation. For example, the health risks relating to working with hazardous materials in mining, manufacturing and informal recycling were re-organised as standard impact categories, such as the *Hazardous materials/Human toxicity* impact category and the *Reduced health/Reproductive health hazards* impact category. These are impacts which breach the planetary boundary called *Introduction of Novel Entities* as well as the social boundary called *Health* (see Annex 3).

In this way, were able to draw on literatures from a number of disciplines, deploying a diverse range of methods and definitions, and correlate the evidence of verified impacts described in this literature to our overall framework for sustainability. Drawing on the LCA literature also enabled us to ensure coherence with standard LCAs, which form an important source of data for sustainability in electronics production, and to avoid contributing to the proliferation of standards, which is a constant risk in the field of sustainability.

## From impact categories to hotspots

In Phase 2 of the research, we asked the question: *What are the sustainability hotspots in the mobile phone lifecycle?* For the Hotspots Analysis, we drew on the work of UNEP: "Hotspots Analysis: An overarching methodological framework and guidance for product and sector level application" [28]. UNEP defines a Hotspots Analysis as:

> The rapid assimilation and analysis of a range of information sources, including life cycle based studies, market, and scientific research, expert opinion and stakeholder concerns. The outputs from this analysis can then be used to identify and prioritise potential actions around the most significant economic, environmental and social sustainability impacts or benefits associated with a specific country, city, industry sector, organization, product portfolio, product category or individual product or service. Hotspots analysis is often used as a pre-cursor to developing more detailed or granular sustainability information.

The UNEP Hotspots Analysis defines a hotspot as "a life cycle stage, process or elementary flow[4], which accounts for a significant proportion of the impact of the functional unit". In the SMART project proposal from 2015, we defined a hotspot "as a significant risk of a breach of social or planetary boundaries in a product's life cycle, e.g. resource use that results in peak climate gas emissions or an activity that violates access to clean water". Based on the research conducted so far in this Work Package, we propose to integrate these two definitions. We propose the following definition of a hotspot in the Hotspots Analysis of Mobile Phones in the SMART project:

> A life cycle stage, process or elementary flow, that accounts for a significant proportion of the mobile phone's impact on a planetary boundary or a dimension of the social foundation.

The UNEP framework presents several particular methodologies. We have selected the "Sustainability Hot Spots Analysis" (SHSA) by the Wuppertal Institute for Climate, Environment and Energy [29]. This is qualitative approach, combining social and

[4] Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation

environmental impacts, and with a clear approach to weighing impacts in order to identify hotspots [29]–[32].

As far as we are aware, this is the first time that a Hotspots Analysis is being applied to the lifecycle of the mobile phone. This is not surprising, as Hotspots Analysis is a relatively new approach. In addition, the mobile phone lifecycle is a complex lifecycle and there is no literature available that considers the full scope of potential impacts on social and environmental sustainability in the complete mobile phone lifecycle. On the other hand, the Hotspots Analysis methodology invites research into complex lifecycles. Its systematic approach enables an understanding of the connections between similar impacts in different lifecycles as well as offers a simple process to weigh the different impacts.

The SHSA presented here builds forth on the outcome of Phase 1, namely the Risk Catalogue, in which risks to planetary boundaries and social dimensions were mapped corresponding to the phases in a generic mobile phone LC. To identify the priorities for research, we conducted a weighting of the various impacts and risks. This weighting involved ranking the identified impacts, first in relation to their prevalence or likelihood in relation to a particular phase, and, second, in relation to their salience of that phase to the sustainability of the mobile phone lifecycle overall. The weighting was based on the data and analysis found in the same database of literature from which the risk was identified. The identification of the hotspots in the mobile lifecycle of two mobile phones is explained in Section 4 and summarized in Annex 3.

Our Sustainability Hot Spots Analysis consists of five steps:

1. **Identification of the impact categories**, with each impact understood as a verified breach of a defined Planetary Boundary or Social Dimension.

2. **Specification of the significance (likelihood) of each impact** as low (1), medium (2), and high (3) or no data (0). Significance is based on a qualitative analysis (weighting) of likelihood that a particular impact will occur in a particular phase. The data used for this analysis was gathered in Step 1 and Phase 1.

3. **Ranking of the salience of the phase for the overall sustainability of the lifecycle.** The phase is ranked (weighted) as either none (0), low (1), medium (2), or high (3) based on the number of impacts in a particular phase. This determination draws on the data gathered in the Risk catalogue and Step 1 and 2 above. The salience of the phase is therefore based on its importance as a source of environment and social unsustainability. The purpose of this ranking is to identify the phase for particular attention by the analyst.

4. **Identification of the sustainability hotspots** takes place by multiplying the significance of an impact with the salience of the phase with which it is associated. We achieve this identification by multiplying the scores of step 2 and 3.

5. **Stakeholder evaluation and verification of hotspots** in stakeholder consultations (meetings, key informant interviews and online consultation) The hotspots were discussed in consultations with stakeholders in November 2017. In addition, stakeholders were asked to provide input in the form of selecting particular hotspots,

which they felt were the most pressing for the purposes of sustainability and innovation in their own sector in order to assist in the prioritisation of further research into regulating sustainability in the mobile phone life cycle.

## Triangulation

In order to increase the validity of the qualitative approach of the SHSA, we used several methods for data collection: literature review, stakeholder consultations, LCAs, and a case study (Fairphone). These were then used to specify *significance* of an impact in Step 2 and *salience* of a phase in Step 3. These values are thus based on subjective, but informed analysis. We determined hotspots by multiplying the value in Step 2 (the significance of a particular impact), and the value in Step 3 (the salience of a lifecycle phase). The multiplication is based on the recognition that some lifecycle phases have greater salience for the sustainability of the overall lifecycle, a determined by the number of impacts in a particular phase. For example, the Resource Extraction phase is weighted with a 3 because there are a large number of impacts within that phase. One result of this method is that an impact can be a hotspot in one lifecycle phase, but not in another. For example, for example, $CO_2$ emissions in the Transportation phase of the mobile phone lifecycle are significant (= 3). However, the Transportation lifecycle phase has the value 1, because the impacts in the Transport phase are few. In addition, $CO_2$ impacts constitute only one-tenth to one-fourth of the $CO_2$ emissions in the Manufacturing phase [33]–[36]. Thus, while $CO_2$ impacts are significant within the Transportation phase, they are not as significant for the overall lifecycle as the same impacts originating in other phases.

Table 1 Hotspots analysis of the $CO_2$ emissions in Manufacturing and Transportation phase.

| **Impact** | **Value** | **Phase** | **Value** | **Non-hotspot < 6** | **Hotspot ≥ 6** |
|---|---|---|---|---|---|
| $CO_2$ emissions | 3 | Manufacturing | 3 | | 9 |
| $CO_2$ emissions | 3 | Transport | 1 | 3 | |

# 3. Impact Categories

In order to identify the hotspots in the mobile phone lifecycle, we need to be in a position to weigh the identified impacts. To do that, we have first translated the risks collated in the Risk Catalogue into a set of Impact Categories. The substance of these is described below, with links to definitions. From the wide range of risks identified across the mobile phone lifecycle (Annex 2), we were able to identify one impact category corresponding to each of the nine planetary boundaries and 25 impact categories corresponding to 11 of the twelve social dimensions. The impact categories are described in relation to the planetary boundaries and social dimensions to which they correspond, as well as to the phase in which they have a major impact.

| **Planetary boundaries**[5]<br>*Impact categories* | ***Description***<br>*Impact categories as found in phases of mobile phone lifecycle* |
|---|---|
| **Ocean acidification** | |
| *Acidification* | Decrease of the ocean's pH-level as a result of uptake of $CO_2$. Acidification of water bodies is the result of mining and processing of, for example, gold, fossil fuels, and aluminium (**Resource Extraction**). Acidification threatens aquatic life (*Ecotoxicity*) and drinking water (*Drinking water pollution*) |
| **Change in biosphere integrity** | |
| *Biodiversity loss* | Biodiversity loss, the drastic reduction or even extinction of certain species in a habitat. Both artisanal and industrial mining have contributed to the destruction of local habitats (see also *Deforestation*), resulting in a decline and even extinction of species in particular countries (**Resource Extraction**). |
| **Climate change** | |
| *$CO^2$ emissions* | The emission of carbon dioxide as a result of human activity, such as the burning of fossil fuels and deforestation. $CO^2$ emissions can be found throughout the whole mobile phone lifecycle, but are especially relevant in the **Manufacturing**, **Transport**, and **Use** phases. |
| **Land-system change** | |
| *Deforestation* | Removal of a forest or stand of trees, converting land-use to non-forest. This is especially the case in forested areas with mineral deposits (**Resource Extraction**) (see also *Land use change*). |
| **Biogeochemical flows** | |
| *Eutrophication* | Increase of nutrients in a body of water, causing structural changes to an ecosystem. Eutrophication can be the result of mining activities (god, copper, cobalt, etc.) and run-offs from mining activities, such as acid mine drainage (**Resource Extraction**). Eutrophication is also found in bodies of water near sites of electronics manufacturing as a result of emissions of waste water containing toxic materials (**Manufacturing**), as well |

[5] The non-negotiable planetary preconditions that humanity needs to respect in order to avoid the risk of deleterious or even catastrophic environmental change. For descriptions of each of the Planetary Boundaries, see Annex 1.

| | |
|---|---|
| | as in bodies of water near sites where electronics are disassembled (**End of life**). |
| **Fresh water use** | |
| *Excessive water use* | Industrial water use resulting in environmental degradation and decreasing water availability for humans and wildlife. Excessive water use is found in mining (**Resource Extraction**) and in the production of mobile phones (**Manufacturing**). |
| **Introduction of Novel Entities** | |
| *Hazardous materials/Ecotoxicity* | Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds and radioactive materials affecting ecosystems. Hazardous materials are both used and produced in the mobile phone lifecycle. For example, in artisanal mining, mercury and cyanide are used to process gold from ore and uranium and cadmium are by-products of cobalt mining and cobalt processing (**Resource Extraction**). |
| **Stratospheric ozone depletion** | |
| *Ozone depletion* | Decline in the planet's ozone layer as a result of man-made chemicals. In the mobile phone LC we find halogenated organic emissions, as an effect of the manufacturing of aluminium (the average mobile phone consists of 14% aluminium) and the use of flame-retardants (**Manufacturing**). |
| **Atmospheric aerosol loading** | |
| *Particulate matter* | Solid and liquid particles in the air, organic and inorganic, mostly hazardous. Mining and smelting operations produce a large amount of particulate matter, containing a wide variety of materials, such as iron, aluminium, mercury, etc. (**Resource Extraction**). Particulate matter emissions are also high in the **Transport** phase (diesel-related). The burning of electronic waste contributes to high emissions of foe example nitrogen oxides, sulphuric acid, chlorine, and volatile organic compounds (VOCs) (**End of life**). |
| **Social Dimensions**[6]<br>*Impact categories* | **Description**<br>*Impact categories as found in the lifecycle of mobile phones* |
| **Food** | |
| *Food chain pollution* | Food, as a social dimension, refers to the percentage of the population that is undernourished. In our study, this social dimension refers the pollution of the food chain with hazardous materials, resulting in contaminated food for human consumption. Food chain pollution undermines food security and results in reduced health. Food chain pollution is found in mining areas, where grazing lands and crops are contaminated with toxic elements released into air (**Resource Extraction**) and in areas where e-waste is disassembled (**End of life**). |
| *Land-use change* | Land-use change undermines food security and can contribute to undernourishment. Land-use change is found in areas with |

[6] The minimum standards of living conditions and human rights below which people can be said to be living in deprivation. For descriptions of each of the Social Dimensions, see Annex 1.

mineral deposits, where land used for growing food for the local community is converted in to mining (**Resource Extraction**). Two main changes are found: converting agricultural land-use to non-agriculture and deforestation, which affects the livelihoods of peoples depending on the forest for food.

**Income & Work**

*Excessive overtime*

Overtime that has negative consequences for the workers is considered excessive. Excessive overtime is the result of low wages and/or production demands and is found among artisanal miners (**Resource Extraction**) and among workers in the electronics industry (**manufacturing phase**).

*Forced labour*

The ILO defines forced labour as "all work or service, which is exacted from any person under the threat of a penalty and for which the person has not offered himself or herself voluntarily." In the mobile phone LC, we find forced labour in the mining sector, in particular in areas of conflict (*Conflict*, **Resource Extraction**). In the electronics industry, forced labour is the result of human trafficking and migration.

*Low wages*

Wage labour is one of the principle means for people to escape poverty. The international poverty limit is 3.10 dollars a day, however it is common to define low wages in light of a **living wage** in a particular context. Wage levels are dependent upon factors such as the demand for labour in a particular labour market, informality and the existence or health of systems of industrial relations (e.g. of collective bargaining). An abundant supply of workers tends to lower wage levels: artisanal miners (in **Resource Extraction**) or factory workers (in the **Manufacturing** phase) tend to be particularly vulnerable to downward pressure on wage levels. Even in tight labour markets marginalisation may also affect wage disparities, for example for women versus men, or for migrant labourers.

*Precarious work*

Work is deemed precarious when it subjects workers to unstable or dangerous with little social or trade union protections. The term is often used in opposition to the goal of **Decent Work** and is associated with short-term contract work and outsourcing. Women, minorities and migrant workers are much more likely to end up in jobs characterised as precarious and precarious work has been found among artisanal miners (in **Resource Extraction**), factory workers (in the **Manufacturing** phase) and workers involved in e-waste disposal (**End of Life** phase) tend to be particularly vulnerable to downward pressure on wage levels. Precariousness has several dimensions: temporal (low certainty over continuity of employment); organisational (lack of worker control over working conditions, e.g. shifts, work intensity, pay, health and safety); economic (poor pay); social (few legal protections against e.g. unfair dismissal, discrimination) and social protection (e.g. health coverage, unemployment insurance). **Informal work** is work undertaken without contract or legal regulation. Informal workers may be organised but they often are

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|---|---|
| | not, leading to higher risks of non-payment of wages, compulsory overtime or extra shifts, lay-offs without notice or compensation, unsafe working conditions and the absence of social benefits such as pensions, sick pay and health insurance. Vulnerable workers such as women and migrants are often over-represented in the informal labour market. |
| *Non-union work* | Workers who are unorganised face higher risks of poorly paid, precarious, informal and unsafe work. Opposition to workers organisations by employers is common. This opposition may violate **basic rights at work,** such as the freedom of association and the right to collective bargaining. Non-union work is found among artisanal miners (in **Resource Extraction**), factory workers (in the **Manufacturing** phase) and workers involved in e-waste disposal (**End of Life** phase). |
| *Unsafe work* | Work is deemed unsafe when it exposes workers to unprotected risks to life or physical or emotional health. IN many countries, there is a generally accepted right of workers to refuse unsafe work, but the pressures on workers to work in risky situations remains. **Occupational health and safety** laws are common in many jurisdictions and often require companies to establish internal health and safety programmes. Unsafe work has been found in the workplaces of artisanal miners (in **Resource Extraction**), factory workers (in the **Manufacturing** phase) and workers involved in e-waste disposal (**End of Life** phase). |
| **Water & Sanitation** | |
| *Drinking water pollution/lack of access* | Access to clean drinking water is a **human right.** Pollution of drinking water as a result of chemical pollution is in particular found in and around mining sites (**Resource Extraction**), near electronic industries (**Manufacturing**), and near informal electronic waste disassembling sites (**End of Life**). |
| *Poor sanitation* | Access to sanitation is part of the same **human right** as the right to clean drinking water. Poor sanitation is in particular found in and around mining sites (**Resource Extraction**) and informal electronic waste disassembling sites (**End of Life**). |
| **Health** | |
| *Reduced health/Reproductive hazards* | Reproductive hazards are generally associated with workplace health and safety (*Unsafe work*), for example through the use of or exposure to hazardous materials (**Resource Extraction; Manufacturing; End of Life;** *Hazardous materials*). |
| *Hazardous materials/Human toxicity* | Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds and radioactive materials affecting humans. Miners and communities working and living around mines and processing plants have a high risk of increased levels of concentrations of toxic materials in their blood. Many of these materials can result in acute or long-term health problems (**Resource Extraction**; *Reduced health*). |

| | |
|---|---|
| | Workers in the electronics industry and communities living near these facilities have a high risk of increased levels of concentrations of toxic materials in their blood. Many of these materials can result in acute or long-term health problems (**Manufacturing**; *Reduced health*). Workers in the electronic waste, both informal and industrial, and communities living near these facilities, have a high risk of increased levels of concentrations of toxic materials in their blood. Many of these materials can result in acute or long-term health problems (**End of Life**; *Reduced health*). |
| *Lack of information about hazardous materials* | Working in mines, electronics industries, and electronic waste recycling often lack information about hazardous materials and are not able to take the necessary precautions to protect themselves from harm or they are not aware of the connection between their work and their health situation (**Resource Extraction; Manufacturing; End of Life**). |
| **Education** | |
| *Child labour* | Many children work (e.g. in the home or on family farms). Whether or not particular forms of "work" can be called "child labour" depends on the child's age, the type and hours of work performed, the conditions under which it is performed and may vary from country to country, as well as among sectors within countries. The term "child labour" is often defined as work that deprives children of their childhood, their potential and their dignity, and that is harmful to physical and mental development. It refers to work that: is mentally, physically, socially or morally dangerous and harmful to children; and interferes with their schooling by: depriving them of the opportunity to attend school; obliging them to leave school prematurely; or requiring them to attempt to combine school attendance with excessively long and heavy work. In its most extreme forms (worst forms), child labour involves children being enslaved, separated from their families, exposed to serious hazards and illnesses and/or left to fend for themselves on the streets of large cities – often at a very early age. Child labour has been found in connection with the production of minerals, in factory labour and in the informal work involved in disposal of e-waste (**Resource Extraction; Manufacturing; End of Life**). |
| *Low literacy* | Literacy represents a potential for further intellectual growth and contribution to economic-socio-cultural development of society. Literacy and illiteracy are usually measured as a proportion of the total population of a country, often broken down by age group and gender. |
| **Energy** | |
| *Lack of clean energy* | Access to electricity is a critical issue in all aspects of sustainable development. Data is scarce but the World Bank has launched efforts to map access. The cleanliness of energy is covered by the climate gas emissions categories above. |

| **Gender equality** | |
|---|---|
| *Lack of equal opportunities* | Equality of opportunity means “women and men, and girls and boys, enjoy the same rights, resources, opportunities and protections. It does not require that girls and boys, or women and men, be the same, or that they be treated exactly alike” (UNICEF). Equality of opportunity is based on the right not to be discriminated against on the basis of gender, race, religion or national origin established as a human right by the Article 2 of the UDHR. |

| **Social equity** | |
|---|---|
| *Discrimination* | Social equity is a general concept, which applies notions of justice and fairness in social policy. Migrant workers and their families are often discriminated against (**Manufacturing**; *Precarious work*). |

| **Voice** | |
|---|---|
| *Forced relocation* | Forced relocation involves the movement of people from their home. It may be the result of government policy, natural disaster of conflict. We found cases of forced relocation as a result of mining companies starting explorations and mining activities (**Resource Extraction**). |
| *Lack of representation* | In cases of forced relocation, the local communities were not part of the decision-making process or the decision was supported by local people not representative of the local community (**Resource Extraction**). |

| **Peace & Justice** | |
|---|---|
| *Conflict* | An armed conflict is a violent contestation between two or more organisations (often political organisations such as governments, insurgents), and which results in a significant damage number of casualties over a defined time period (e.g. 25 deaths per year). Armed conflict has been associated with the production of minerals (**Resource Extraction**). |
| *Corruption* | Corruption is **the abuse of entrusted power** for private gain. It can be classified as grand, petty and political, depending on the amounts of money lost and the sector where it occurs. Corruption is usually defined in relation to the bribing of public authorities but can also be found in private transactions and has been associated with the shipments of minerals (**Resource Extraction**) and monitoring of working conditions (**Manufacturing**). |
| *Illicit trade* | Illicit trade is the conducting of transactions across borders in violence of national or international law. Illicit trade has been detected in the smuggling of minerals (**Resource Extraction**) and commodities (**Manufacturing; End of Life**). |
| *Sexual violence* | **Sexual exploitation or abuse** (SEA) is the actual or threatened physical intrusion of a sexual nature, whether by force or under unequal or coercive conditions or any actual or attempted abuse of a position of vulnerability, differential power, or trust, for |

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| | sexual purposes, including, but not limited to, threatening or profiting monetarily, socially or politically from the sexual exploitation of another. Sexual exploitation or abuse involving woman underage girls has been found in association with mining (**Resource Extraction**) |
| **Housing** | |
| *Living in slums* | Housing is about urban population living in slum housing in developing countries. Large slums have been found around informal electronic waste sites, which often lack proper sanitation, access to drinking water (**End of Life**; *Water & Sanitation*) |
| **Networks** | n/a |

# 4. Hotspots Analysis


Photo credit: SMART

In this section, we present the analysis of the hotspots in the lifecycle of two mobile phones. The first one is the analysis of the *composite mobile phone* (**CP**), based on an extensive literature review and stakeholder consultations. In addition, we will present a hotspot analysis of the *Fairphone 2* (**FP2**), based on a review of the literature and initial interviews and field work with Fairphone.

In environmental Life Cycle Assessments (LCA) of mobile phones, we find a variety of ways to identify the phases in the mobile phone lifecycle. Some use the ETSI Standard, which consists of four high-level phases [37]: Raw Materials Acquisition, Production, Use, and End of Life. Proske et al., evaluating the lifecycle of the Fairphone 2, use also four high-level phases [34]: Raw Materials and Manufacturing, Use, End of Life, and Transport. Also Suckling & Lee [38] use this four-phase lifecycle. Others use five phases: Samsung [39], [40] uses Pre-Manufacturing, Manufacturing, Distribution, Use, Disposal; Möberg et al. [35] use Materials, Production, Use, Transportation, End of Life.

We identified six main phases in the lifecycle of mobile phones: Design, Resource Extraction, Manufacturing, Transportation, Use, and End of Life. Design is added as a lifecycle phase to make its central role in the sustainability visible [41], [42]. This is also recognised by the European Commission, in particular through the European Union's Ecodesign Directive, which sets EU-wide rules for the environmental performance of products [43].

Design and Transportation distinguish themselves from the other phases. They are not so much phases as well as processes that take place in or affect the other lifecycle phases. For the purpose of clarity and consistency we will use the same analysis for Design and Transportation as for the other four phases.

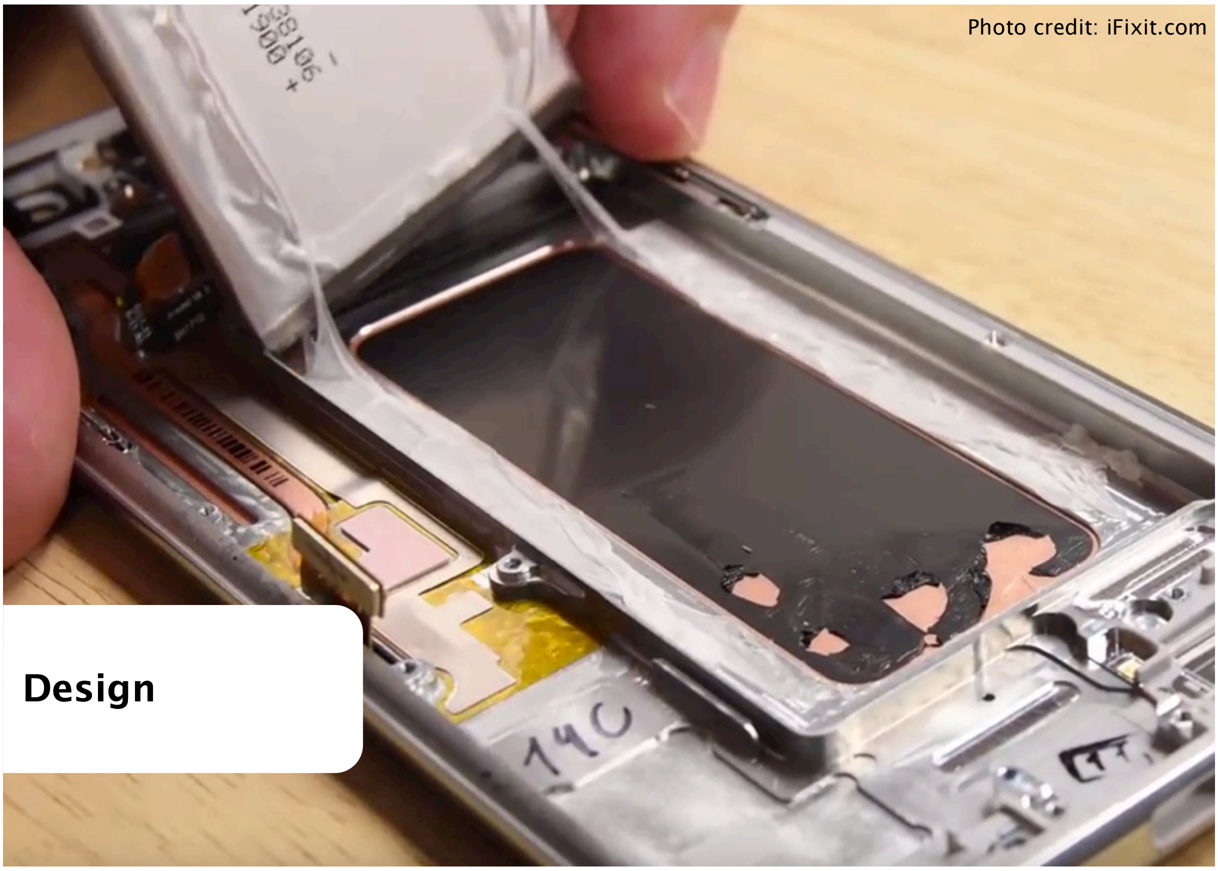


Photo credit: iFixit.com

## Design

Design is the lifecycle phase in which important decisions are made concerning the sustainability of a mobile phone. Several reports maintain that the design phase determines 80% of the environmental impact of a product [44], [45]. This number is based on research that shows that 70-80% of the features and costs are established in the design phase [46], [47].

Choices are made in terms of materials, size, weight, but also about costs and ease of repair, recycling or replacement of components, such as the battery. These choices, early in the lifecycle, affect the social and environmental sustainability in subsequent phases, such as the health and safety of the people mining and processing the materials and the workers manufacturing the components of the mobile phone.

These choices will also affect the longevity of the mobile phone as well as the possibility to repair the mobile phone to extend its life. For example, a phone designed for reparability is modular, which affects its thickness and weight. A thin phone often uses glue to keep things together, which makes it difficult to open the phone or makes the replacement of a battery by the user impossible.

The design of a mobile phone has significance for sustainability in later phases of the mobile phone lifecycle. Several of the hotspots found in the mobile phone lifecycle can be addressed through design.

**Hotspots in the Design phase:**

*Composite Phone*

Despite the importance of the design phase for the overall sustainability of mobile phones, the literature review found no reports of environmental or social impacts particular to the design phase of the CP. This is to be expected, as the effects of decisions in the design phase are expressed in impacts in other phases. For this reason, we did not identify any hotspots in the CP design phase.

Literature and research identifying the impacts in other phases in the mobile phone lifecycle point to some of the direct connections with the design of a mobile phone. For example, the risk of exploding batteries in the *Use phase* and the adverse effects of non-removable batteries in the *End of Life phase*. During fieldwork in Ghana on the repair and recycling of mobile phones, we noted that several of the latest models of known brands use glue, which makes it much more difficult to repair the mobile phone and/or to replace the battery.

*Fairphone 2*

Despite the importance of the design phase for the overall sustainability of mobile phones, the literature review found no reports of environmental or social risks particular to the design phase of the FP2. This is to be expected, as the effects of decisions in the design phase are expressed in risks in other phases. For this reason, we did not identify any hotspots in the FP2 design phase.

The Fairphone 2 is designed for repair and was the only mobile phone with a 10 out of 10 in the iFixit Reparability ranking [48]. Repairability can extend the lifespan of the FP2 to 5 years. It has a modular design, with each of the components clearly marked (identified for repair) and which can be taken out and replaced with the use of a regular screwdriver. The phone itself can be opened without the use of tools. Spare parts are available via the Fairphone website.

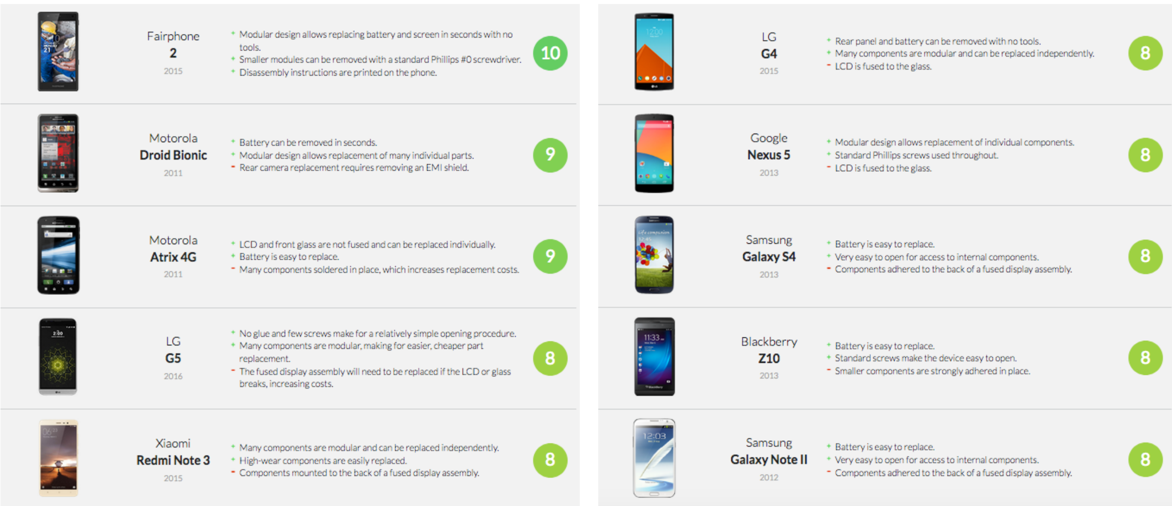



Figure 3. The top 10 mobile phones on iFixit Repairability ranking

# Resource Extraction

Resource Extraction is the phase covering activities resulting in materials that will be used in the manufacturing phase, such as the extraction and processing of oil to make plastics, the mining and processing of cobalt and lithium to make materials for the battery, and the mining and processing of tungsten to make the mobile phone vibrate. Mobile phones can contain as many as 62 different metals, including 16 of the 17 rare earth metals (see Figure 3). The most used materials in a smartphone are silicon (25%), plastic (23%), iron (20%), aluminium (14%), lead (6.3%), zinc (2.2%), tin (1%), nickel 0.85%) and barium (0.03%) [49].

The most known social impact in this phase is conflict and associated illicit trade. Some of the minerals mined for mobile phones and other electronics, gold, tin, tantalum, and tungsten, are considered conflict minerals, because their extraction is associated with armed groups that control the mining and trade of the minerals. International regulation in the USA and the EU restricts the use of conflict minerals. There are several international initiatives focusing on improving the supply chain of minerals, such as the Responsible Minerals Initiative, the Responsible Sourcing Network, and the Enough Project.

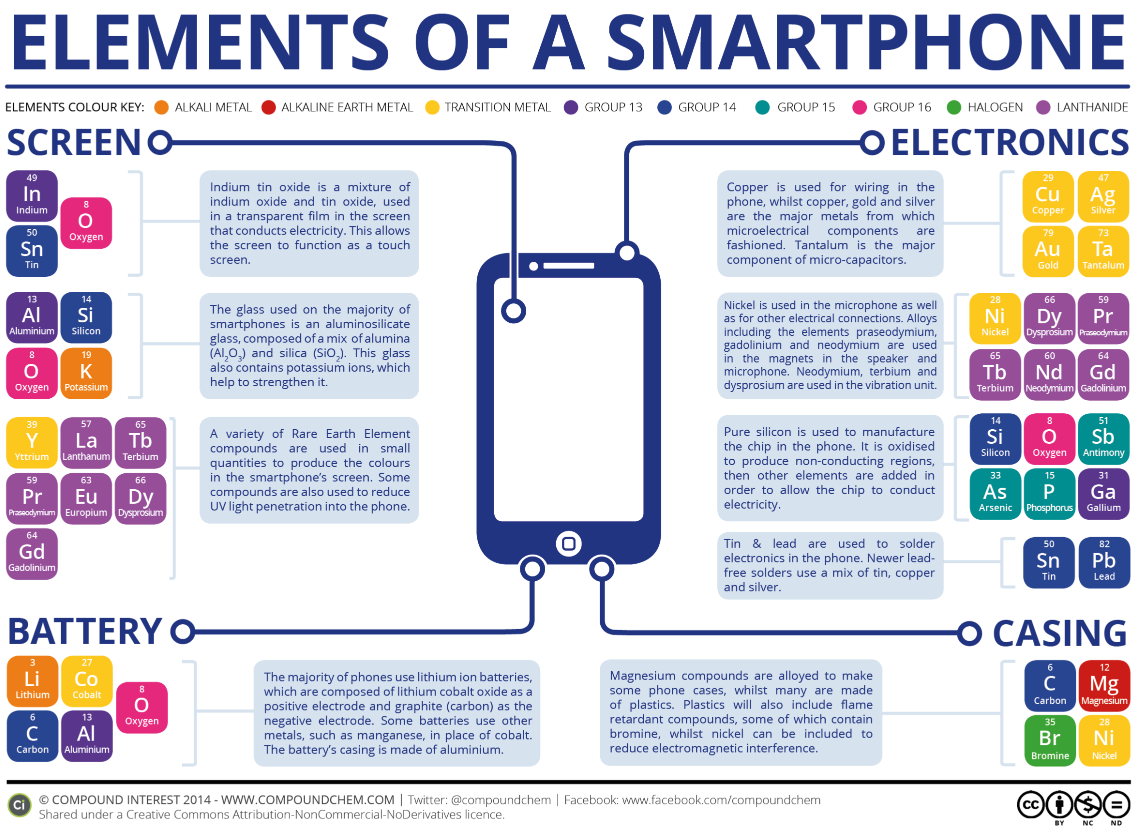



Figure 4. Elements of a mobile phone | Image: Compoundchem

## Composite Phone

A large part of the materials of the mobile phone are extracted in artisanal and small-scale mining operations (ASM) in many African countries as well as in countries in Asia and South-America. Both the industrial mining and ASM mining of minerals are associated with a variety of environmental and social impacts. Most impacts contribute to other impacts or have a knock-on effect on other impacts.

*Acidification* of water bodies is the result of the mining, processing, and production of materials such as gold, plastics, and aluminium, e.g. [13], [50]. Impacts of mining on biodiversity (*biodiversity loss*) are found in several countries. Mineral mining, both ASM and industrial, takes often place in areas with a large diversity of species, resulting in the destruction of local ecosystems/habitats as a result of *deforestation* [51], [52]. This has resulted in the drastic reduction and even extinction of species, e.g., in countries such as Bolivia [53], the Central African region [54], DR Congo [52], Nigeria [55], Mozambique [56], and Ghana [57].

*Eutrophication* is mainly associated with run-offs from mining activities and acid mine drainage from abandoned mines, e.g., [58] Eutrophication contributes to the release of *hazardous materials* in air, soil, and water (*ecotoxicity*), e.g., [59] . In mining, the release of hazardous materials in the environment can be the result of particular mining activities, such as the use of mercury, cyanide, arsenic in gold mining [58], [60], or the result of the mining activity itself, e.g., uranium from cobalt mining [50]. Mining activities are also associated with *excessive water use* [61], the release of solid particles in the air (*particulate matter*), and *ozone depletion*.

The release of hazardous materials in soli, water, and air (also eutrophication and particulate matter) results in *foodchain pollution* and *drinking water pollution*, for example as a result from copper mining and processing activities (lead, cadmium, copper) [62], [63], artisanal cobalt mining in DR Congo [64][65], and gold mining in Ghana with arsenic and mercury as the primary contaminants [66]. *Reduced health* is the result of exposure to these and other contaminants, such as uranium (radiation), heavy metals dust inhalation in artisanal cobalt mining in DR Congo [64], general health problems as a result from contact with dust and fumes, due to poor ventilation, and pneumoconiosis [black lung] and particularly silicosis occur" [67]. The *human toxicity* of some of these *hazardous materials* is high, especially for miners. For example, chronic exposure to cobalt-containing dust can result in fatal lung disease, asthma, decreased pulmonary function [68]. Mercury is widely used by artisanal miners in at least 70 countries, with 13 to 15 million artisanal miners working worldwide who risk being directly exposed to mercury; many of them are women and children [69]. Miners and local communities often *lack information about hazardous* materials [70].

The working conditions of workers in and around mines, especially in ASM, are characterized by *excessive overtime*, e.g., [50], *precarious working conditions*, e.g., [71], with some working in mines with an *anti-union policies*, e.g. [67]. Mining is associated with *unsafe work*, e.g., landslides, mine-collapses, and lack of protective gear [50], [64]. *Sexual violence* is also an issue, with under-aged girls living or working in mining areas as victims of sexual exploitation and abuse" [70], [72] [73]. In addition, *child labour* is also widespread in mining, e.g., in artisanal cobalt mining in DR Congo [64], [50] and in gold mining [74]. *Child labour* also affects the educational level of the population [70]. Research from Nigeria shows the low levels of education of workers in and around the mining areas, with 55.7% of men and 60% of women having no formal education [75]. The mining of minerals may also be associated with *conflict* through the exploitation of labour in ways already mentioned, for example *forced labour*, by state or non-state armed groups or the illegal taxation of mineral flows by groups in control of mines or transportation routes, often as part of *illicit trade* [76], [77].

Miners and their families often live in *slums* near mining areas. They lack proper *sanitation*, *lack of clean energy*, and *access to clean drinking water*. They earn low wages, which can create tension between the different groups of miners (artisanal, small-scale, and industrial) [50].

**Hotspots Analysis of the Composite Phone in the Resource Extraction phase**

1. We found a large number of environmental and social impacts in the Resource Extraction phase. Several of these impacts are evaluated as highly significant, that is, a high likelihood that this impact will take place in this phase.

2. We evaluated the Resource Extraction phase as having high salience, an highly important source for environmental and social unsustainability on the overall mobile phone life cycle.

3. In the Resource Extraction phase of the Composite Phone, we found 9 environmental impacts and 25 social impacts. The combination of the significance of impacts and

salience of the Resource Extraction phase resulted in **7 environmental hotspots** and **17 social hotspots (**hotspots in bold, see Table 2). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 2. Impacts and hotspots of the CP in the Resource Extraction phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Resource Extraction* | **1. Acidification**<br>**2. Biodiversity loss**<br>3. $CO_2$ emissions<br>**4. Deforestation**<br>**5. Eutrophication**<br>**6. Excessive water use**<br>**7. Hazardous materials/Ecotoxicity**<br>8. Ozone depletion<br>**9. Particulate matter** | **10. Food chain pollution**<br>11. Land use change<br>**12. Excessive overtime**<br>**13. Low wages**<br>14. Forced labour<br>**15. Precarious work**<br>**16. Non union work**<br>**17. Unsafe work**<br>**18. Drinking water pollution/Lack of access to drinking water**<br>19. Poor sanitation<br>**20. Reduced health/Reproductive health hazards**<br>**21. Hazardous materials/Human toxicity**<br>**22. Lack of information about hazardous materials**<br>**23. Child labour**<br>**24. Low literacy**<br>25. Lack of clean energy<br>26. Lack of equal opportunities<br>27. Discrimination<br>28. Forced relocation<br>29. Lack of representation<br>**30. Conflict**<br>**31. Corruption**<br>**32. Illicit trade**<br>**33. Sexual violence**<br>**34. Living in slums** |

## Fairphone 2

In the Resource Extraction phase of the Fairphone 2 we find the same impacts as the in Composite Phone, but Fairphone's initiatives in the Resource Extraction phase have diminished some of the environmental and social impacts. In terms of *conflict minerals*, all four minerals are considered conflict-free:

- *Tantalum*: In cooperation with the Solutions for Hope project[7], Fairphone sources conflict-free tantalum from Katanga in DR Congo. Tantalum is extracted from the ore colombite-tantalite, also often referred to as coltan.

- *Tin*: In cooperation with the Conflict-Free Tin Initiative (CFTI)[8], Fairphone sources conflict-free tin from South Kivu in DR Congo

- *Tungsten*: According to Fairphone, conflict-free tungsten is sourced from the New Bugarama Mining Company, is a semi-industrial mine located in the north of Rwanda.

[7] Solutions for Hope: http://solutions-network.org/site-solutionsforhope/
[8] Conflict-free Tin Initiative: http://solutions-network.org/site-cfti/

The mine employs between 700 and 1200 local miners (varying on demand) and is an important source of income for the community. Compared to the artisanal tin and tantalum mines in the DRC, the semi-industrial tungsten mine in Rwanda provide clear improvements in working conditions, especially in terms of *health* and *safety* [78]. The tungsten is further refined at Bergman und Hütten A.G in Germany.[9]

- *Gold*: Fairphone has a fully traceable gold supply chain (see Figure 4). Gold is sourced from Minera Sotrami S.A. (Sociedad de Trabajadores Mineros S.A.) in Peru. Minera Sotrami has 164 shareholders and employs 260 mineworkers as well as five engineers who manage the mine and processing plant. The gold mined here meets the Fairtrade Standard for Gold and Precious Metals [79], meaning that rigorous social, economic and environmental regulations are followed including *child protection policies*. In addition, the miners are guaranteed a Fairtrade Minimum Price and Premium that assists in sustainable development for the community. This way, the mine supports 500 families.

Figure 5. Child labour in the gold supply chain [80]

Fairphone mentions it is working on the sustainable sourcing of 10 materials used in the FP2, which they call their priority materials: Indium, Copper, Nickel, Gold, Gallium, Tantalum, Tin, Rare Earths, Cobalt, and Tungsten [81]. Cobalt, found in the FP2 lithium-ion batteries, is sources from mines in DR Congo. Fairphone is working with Huayou Cobalt, a cobalt refiner, to set-up a traceable supply chain from artisanal and small-scale mining communities. Fairphone will work directly with the communities to improve working conditions [82]. The copper in the Fairphone's PCB is made with recycled *copper* [83].

[9] Bergman und Htten: http://www.wolfram.at/

**Hotspots Analysis of the Fairphone 2 in the Resource Extraction phase**

1. We found a large number of environmental and social impacts in the Resource Extraction phase. Several of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the Resource Extraction phase as having high salience: a highly important source for environmental and social unsustainability on the mobile phone life cycle.

3. In the Resource Extraction phase of the Fairphone 2, we found 9 environmental impacts and 24 social impacts. The combination of the significance of impacts and salience of the Resource Extraction phase resulted in **7 environmental hotspots** and **11 social hotspots** **(**hotspots in bold, see Table 3). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 3. Impacts and hotspots of the FP2 in the Resource Extraction phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Resource Extraction* | **1. Acidification**<br>**2. Biodiversity loss**<br>3. $CO_2$ emissions<br>**4. Deforestation**<br>**5. Eutrophication**<br>**6. Excessive water use**<br>**7. Hazardous materials/Ecotoxicity**<br>8. Ozone depletion<br>**9. Particulate matter** | **10. Food chain pollution**<br>11. Land use change<br>**12. Excessive overtime**<br>**13. Low wages**<br>14. Forced labour<br>**15. Precarious work**<br>16. Non union work<br>17. Unsafe work<br>**18. Drinking water pollution/Lack of access to drinking water**<br>19. Poor sanitation<br>**20. Reduced health/Reproductive health hazards**<br>**21. Hazardous materials/Human toxicity**<br>**22. Lack of information about hazardous materials**<br>**23. Child labour**<br>24. Low literacy<br>25. Lack of clean energy<br>26. Lack of equal opportunities<br>27. Discrimination<br>28. Forced relocation<br>29. Lack of representation<br>**30. Corruption**<br>**31. Illicit trade**<br>32. Sexual violence<br>33. Living in slums |


Photo credit: Fairphone

# Manufacturing

Manufacturing is the phase in which the different components of the mobile phone are produced and assembled in order to become a finished product. The main components of a mobile phone are the circuit board (PCB), battery, LCD screen, antenna, microphone, speaker, camera(s), and shell. Each of these large components consists of several smaller components.

Manufacturing takes place in factories around the world, with the largest factory, in Shenzen, China, housing up to 450.000 workers. Labour costs form 2% of the factory selling price and about 0.5 % of the retail price [84].

**Composite Phone**

The manufacturing of mobile phones and other electronics is an energy-intensive activity [85]. Coal-powered electricity plants produce the majority of electricity in China [86]. Several of the environmental impacts in this phase are related to this form of electricity: *Acidification*, *$CO_2$ emissions*, and *Particulate matter*. *$CO_2$ emissions* are considered the highest in this phase [36], [87]. This phase is also characterised by *Excessive water use* and *Eutrophication*. Water consumption (including ultrapure water) in the production of ICs and PCBs is very high, because of the many cleaning and rinsing processes. *Eutrophication* is the result of the use of *Hazardous materials* in production, resulting in toxic wastewater that is not always properly treated [16]. The use of *Hazardous materials*, such as flame-retardants and halogenated organic emissions as a result of production processes, contribute to *Ozone depletion*. All emissions contribute to air pollution in the form of *Particulate matter*.

The use of *Hazardous materials* also results in high levels of *Human toxicity*, which can result in increased cancer risks, e.g., [88]. Workers are exposed to ionizing radiations, organic solvents, heavy metals like cadmium and lead, and to chemicals that damage reproductive organs, such as arsenic and phosphate. Female workers report *Reproductive health* disorders, such as spontaneous abortions [83] [84]. Workers are generally not informed about the names of the chemicals or the risks involved in their use [89], [90]. This *Lack of information about hazardous materials* contributes to *Unsafe work* [91]

In terms of working conditions, this phase is characterised by *Excessive overtime* [89], [92], which is also the effect of the *Low wages* in this sector [84]–[89], *Precarious work* [96], [90], and *No union work* [98], [89].

**Hotspots Analysis of the Composite Phone in the Manufacturing phase**

1. We found a large number of environmental and social impacts in the Manufacturing phase. Several of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the Manufacturing phase as having high salience: a highly important source for environmental and social unsustainability on the mobile phone life cycle.

3. In the Manufacturing phase of the Composite Phone, we found 7 environmental impacts and 13 social impacts. The combination of the significance of impacts and salience of the Manufacturing phase resulted in **7 environmental hotspots** and **8 social hotspots (**hotspots in bold, see Table 4). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 4. Impacts and hotspots of the CP in the Manufacturing phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Manufacturing* | **1. Acidification**<br>**2. $CO_2$ emissions**<br>**3. Eutrophication**<br>**4. Excessive water use**<br>**5. Hazardous materials/Ecotoxicity**<br>**6. Ozone depletion**<br>**7. Particulate matter** | **8. Excessive overtime**<br>**9. Low wages**<br>10. Forced labour<br>**11. Precarious work**<br>**12. No union work**<br>**13. Unsafe work**<br>14. Drinking water pollution/Lack of access<br>**15. Reduced health/Reproductive health hazards**<br>**16. Hazardous materials/Human toxicity**<br>**17. Lack of information about hazardous materials**<br>18. Child labour<br>19. Lack of equal opportunities<br>20. Discrimination |

## Fairphone 2

As mobile phone brands and models are quite similar, the Fairphone 2 has similar environmental impacts as well as similar social impacts in the Manufacturing phase. Almost

100 suppliers are involved in the manufacturing of the FP2. The Tier 1 supplier (assemblage) is Hi-P, based in Suzhou, China. Hi-P is supplier for other companies too. In contrast to some of the other mobile phone/electronics brands [99], Fairphone is transparent about its suppliers [100]. No detailed data was available about suppliers in the 2-5 Tier.[10] Fairphone has a particular programme in place with ten of their suppliers, focussing on improving the some of the environmental and social impacts [100], [102]–[104].

We evaluated the environmental impact of the Fairphone 2 similar to that of the Composite Phone. In terms of *$CO_2$ emissions*, 4.698 kWh energy is used per product at Hi-P, with all energy coming from the Chinese grid mix, which is largely coal [34]. About 12% of these emissions are the result of the parts that enable the modularity of the FP2. The modularity of the FP2 enables repairability, which can extend the lifespan of the FP2 from 3 to 5 years. This has the effect that the total lifecycle *$CO_2$ emissions* are 30% less.

In terms of *Hazardous materials*, such as lead, cadmium, chromium VI, PBDEs and PBBs, Fairphone reports that they do not surpass the thresholds set in the ROHS regulation (1000 ppm - except for cadmium with 100 ppm). The Fairphone 2 materials also comply with the RoHS Directive requirements set for Bromine Flame Retardants (BFR)s. In addition, other flameretardants, such as HBCDD and TBBPA have not been detected when tested in specific components (PCBs, filters, connectors, resistors, etc.). The Fairphone 2 is Phthalates- and PVC-free and no benzene and n-Hexane are used in the production process. Its back covers, the plastic used for the modules, and the plastic used on the back of the screen, all contain 50% post-consumer recycled polycarbonate. Energy use during the assembly process and the manufacturing of the PCBs are the main contributors to *Ecotoxicity* [34]. In terms of *Human toxicity*, the FP2 LCA mentions that human toxicity for the whole phase is 8.35 kg DCB-e [34, p. 41]. Concerning *Ozone depletion*, the Fairphone 2 is PVC and phthalates-free and halogenated flame retardants are not used at Hi-P, which reduces the ozone depletion potential. It is not clear if the Fairphone is free of materials that contribute to ozone depletion, nor if materials are used in the manufacturing process that contribute to ozone depletion.

In terms of social sustainability, Fairphone has undertaken significant steps to prevent some of the social impacts found in other mobile phone lifecycles, such as *Low wages*, *Unsafe work*, and *No union work*. In terms of *Excessive overtime*, Hi-P makes data available for the whole Hi-P facility and includes data for the FP2 production line as well as those of other customers (see Figure 5) [105]. According to Fairphone, *Excessive overtime* and lack of rest days due to Fairphone production was found in week 26 and 27. *Overtime* was the result of delays caused by problems with incoming materials from other suppliers. Fairphone reports that they are working with Hi-P to avoid *Excessive overtime* in such situations in the future, among others by ensuring timely communication and coordination whenever production issues arise [105]. According to Fairphone, lack of overtime is also a challenge as overtime constitutes an important part of employees' salary (overtime hours are paid at a higher rate than regular hours according to local law, which is 150% of the regular wage for overtime work during regular workdays, 200% for overtime work on rest days, and 300% if overtime

[10] We also note that there is no legal obligation for manufacturers to supply full material declarations. The willingness of suppliers to provide this information is often low and small companies such as Fairphone have no means to enforce that [101].

takes place on a holiday): workers may leave Hi-P when income is too low, creating a high employee turnover that costs resources (e.g. for hiring and training new employees) and can negatively affect production output and quality [102].

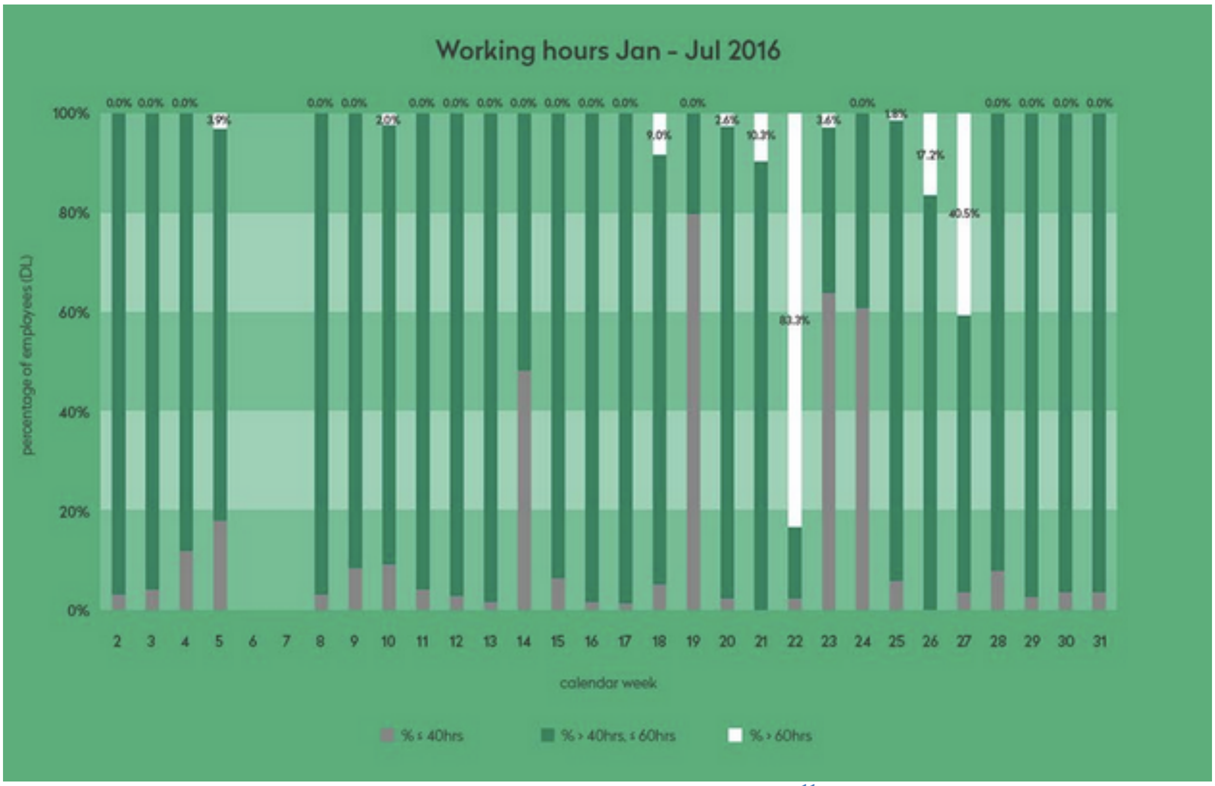



Figure 6. Working hours for whole factory[11].

Precarious work is a consistent impact in the electronics manufacturing sector. TAOS reported that in April 2016, 30% of the work force at Hi-P were agency workers, i.e., workers without a permanent contract with Hi-P. In line with the Chinese Ministry of Human Resources and Social Security, which went into effect in March 2016, Fairphone mentions it aims to limit the number of agency employees to 10% of the total workforce.[12] Temporary employees are more vulnerable in terms of exercising their rights at the workplace, for example when it comes to representation of their interests. At Hi-P, these employees are not automatically part of the factory's labour union and employee representation system. Fairphone reports that all temporary workers receive an invitation to join the Hi-P union during their job orientation [105].

**Hotspots Analysis of the Fairphone 2 in the Manufacturing phase**

1. We found a large number of environmental and social impacts in the Manufacturing phase. Several of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

[11] The factory was closed for the holidays in week 6-7.
[12] China has not ratified Convention 87 on the Freedom of Association and Protection of the Right to Organise Convention and it has not ratified Convention 98 on the Right to Organise and Collective Bargaining Convention.

2. We evaluated the Manufacturing phase as having high salience: a highly important source for environmental and social unsustainability on the mobile phone life cycle.

3. In the Manufacturing phase of the Fairphone 2, we found 7 environmental impacts and 6 social impacts. The combination of the significance of impacts and salience of the Manufacturing phase resulted in **7 environmental hotspots** and **2 social hotspots** (hotspots in bold, see Table 5). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 5. Impacts and hotspots of the FP2 in the Manufacturing phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Manufacturing* | **1. Acidification**<br>**2. $CO_2$ emissions**<br>**3. Eutrophication**<br>**4. Excessive water use**<br>**5. Hazardous materials/Ecotoxicity**<br>**6. Ozone depletion**<br>**7. Particulate matter** | 8. Excessive overtime<br>9. Low wages<br>**10. Precarious work**<br>11. No union work<br>12. Drinking water pollution/Lack of access<br>**13. Hazardous materials/Human toxicity** |

Photo credit: Fairphone

# Transportation

Transport is shorthand for a variety of activities that take place during the entire lifecycle of the mobile phone, such as distribution and transportation of raw materials, components, and finished products; the packaging of the products being transported; and the logistics or organisation and implementation of it all.

## Composite Phone

In this phase, the majority of impacts are related to energy use during the transportation of the materials, components, and the assembled mobile phones. The bulk of the transportation of mobile phones, from the site of manufacturing to the site of distribution, takes place via airfreight [33]. Local transportation involves other modes of transportation, mainly trucks. The five environmental impacts and the one social impact are the result of the use of fuel, which leads to increased levels of *$CO_2$ emissions*, *Acidification* of oceans ($CO_2$ - related), *Eutrophication*, *Hazardous materials/Ecotoxicity/Human toxicity* and *Particulate matter* (fuel-related, e.g., diesel) [35], [40].

**Hotspots Analysis of the Composite Phone in the Transportation phase**

1. We found a small number of environmental and social impacts in the Transportation phase. Some of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated this lifecycle phase as having low salience: this phase is of low importance for the environmental and social unsustainability on the mobile phone life cycle.

3. In the Transportation phase of the Composite Phone, we found 5 environmental impacts and 1 social impact. The combination of the significance of impacts and salience of the Transportation phase resulted in **0 environmental hotspots** and **0 social hotspots (**see Table 6). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 6. Impacts of the CP in the Transportation phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Transportation* | 1. Acidification<br>2. $CO_2$ emissions<br>3. Eutrophication<br>4. Hazardous materials/Ecotoxicity<br>5. Particulate matter | 6. Hazardous materials/Human toxicity |

## Fairphone 2

According to the FP2 LCA, the main modes of transportation of the FP2 are airfreight and truck [34]. Within China, the mobile phone, the battery, and the back cover are transported by truck. Also transportation from the distribution centre in the Netherlands to customers in Europe is by truck. The transportation from China to the Netherlands is by airfreight.

### Hotspots Analysis of the Fairphone 2 in the Transportation phase

1. We found a small number of environmental and social impacts in the Transportation phase. Some of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the Transportation phase as having low salience: this phase is of low importance for the environmental and social unsustainability on the mobile phone life cycle.

3. In the Transportation phase of the FP2, we found 5 environmental impacts and 1 social impact. The combination of the significance of impacts and salience of the Transportation phase resulted in **0 environmental hotspots** and **0 social hotspots (**see Table 7). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 7. Impacts and hotspots of the FP2 in the Transportation phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Transportation* | 1. Acidification<br>2. $CO_2$ emissions<br>3. Eutrophication<br>4. Hazardous materials/Ecotoxicity<br>5. Particulate matter | 6. Hazardous materials/Human toxicity |

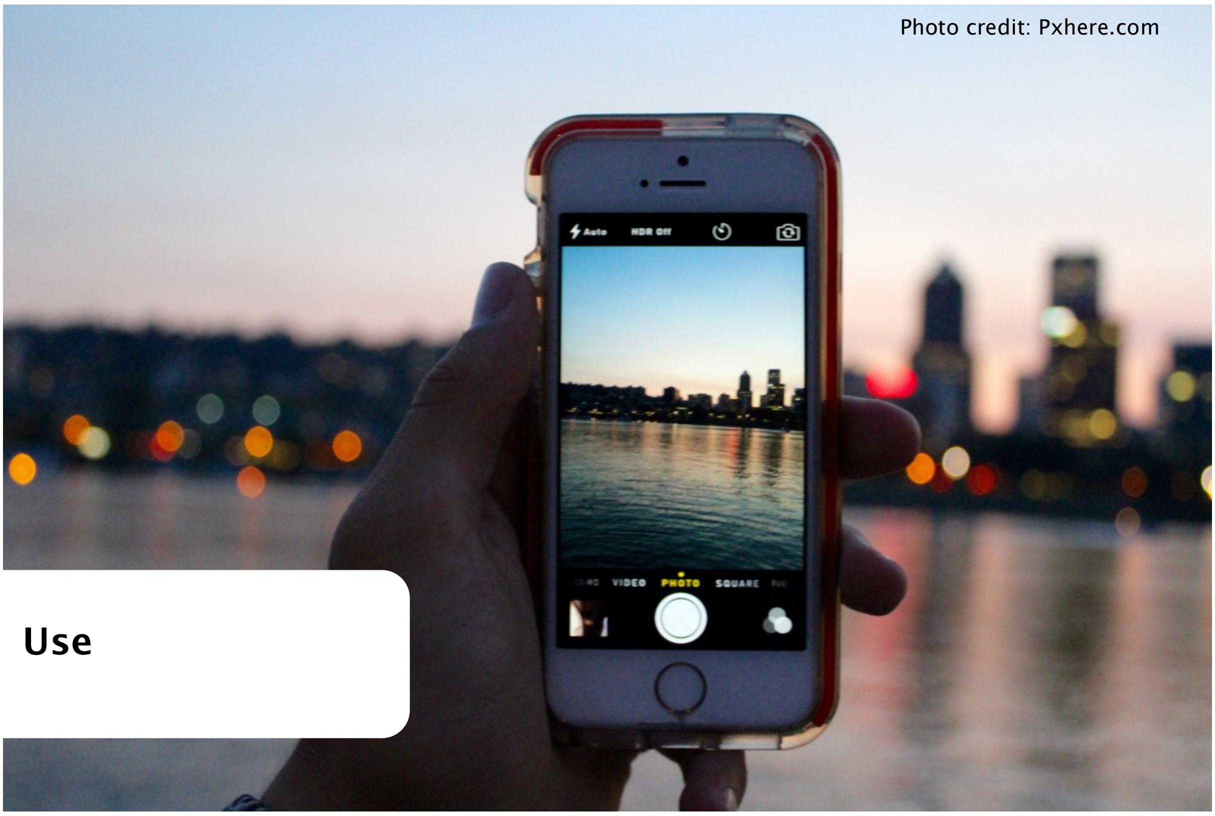


Photo credit: Pxhere.com

## Use

Use refers to the phase in which the mobile phone is used for information and communication activities by a mobile phone user. It is estimated that there are 4.43 billion mobile phone users worldwide, that is 60% of the total population of our planet [106]. The widespread use of mobile phones for access to the Internet has resulted in a significant environmental risk in the form of $CO_2$ emissions from the servers necessary to Internet use.

With respect to social risks, the centrality of the mobile phone in our lives has generated a vast and expanding range of uses, which interact with equally diverse ecosystems of regulation. There are a range of actual or potential impacts of mobile phones on such issues as privacy, property rights, attention economics, surveillance, online harassment, and criminality of various sorts. It is also the case that access to mobile phones has generated significant benefits to people in the form of access to information about markets, health issues, housing, and political processes. The legal, market and social actors and processes involved in the regulation of mobile phone use extend well beyond the product life cycle of the phone as a product, to include mobile telephone service providers, internet service providers, state regulators, as well as a vast and growing number of consumers. In other words, the widespread use of mobile phones and the increasing centrality of the smart phone in many aspects of contemporary life make any study of mobile phone regulation an undertaking that would extend well beyond the lifecycle approach adopted by this project.

**Composite Phone**

In the Use phase we found one major impact category, namely *$CO_2$ emissions*, as a result of charging the battery. If we include energy use as a result of the connections between the mobile phone and networks and servers, the $CO_2$ emissions in this phase would be the same or higher as the $CO_2$ emissions in the Resource Extraction phase and Manufacturing phase combined [107]. The *$CO_2$ emissions* introduce other environmental and social impacts, similarly to the Transportation phase: *Acidification* of oceans ($CO_2$ - related), *Eutrophication*, *Hazardous materials/Ecotoxicity/Human toxicity* and *Particulate matter* (coal-powered electricity plants).

**Hotspots Analysis of the Composite Phone in the Use phase**

1. We found a small number of environmental and social impacts in the Use phase. Some of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the Use phase as having low salience: this phase is of low importance for the environmental and social unsustainability on the mobile phone life cycle.

3. In the Use phase of the Composite Phone, we found 5 environmental impacts and 1 social impacts. The combination of the significance of impacts and salience of the Use phase resulted in **0 environmental hotspots** and **0 social hotspots (**see Table 8). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 8. Impacts and hotspots of the CP in the Use phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Use* | Acidification<br>$CO_2$ emissions<br>Eutrophication<br>Hazardous materials/Ecotoxicity<br>Particulate matter | Hazardous materials/Human toxicity |

## Fairphone 2

The description of the Use phase of the FP2 is similar to that of the CP. In the Use phase we found one major impact category, namely *$CO_2$ emissions* as a result of charging the battery. If we include energy use as a result of the connections between the mobile phone and networks and servers, the $CO_2$ emissions in this phase would be the same or higher as the $CO_2$ emissions in the Resource Extraction phase and Manufacturing phase combined [107]. The *$CO_2$ emissions* introduce other environmental and social impacts, similarly to the Transportation phase: *Acidification* of oceans ($CO_2$ - related), *Eutrophication*, *Hazardous materials/Ecotoxicity/Human toxicity* and *Particulate matter* (coal-powered electricity plants).

**Hotspots Analysis of the Fairphone in the Use phase**

1. We found a small number of environmental and social impacts in the Use phase. Some of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the Use phase as having low salience: this phase is of low importance for the environmental and social unsustainability on the mobile phone life cycle.

3. In the Use phase of the Fairphone, we found 5 environmental impacts and 1 social impacts. The combination of the significance of impacts and salience of the Use phase resulted in **0 environmental hotspots** and **0 social hotspots (**see Table 9). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 9. Impacts and hotspots of the FP2 in the Use phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *Use* | Acidification<br>$CO_2$ emissions<br>Eutrophication<br>Hazardous materials/Ecotoxicity<br>Particulate matter | Hazardous materials/Human toxicity |


# End of Life

End of Life is the phase in which the mobile phone is no longer in use as the result of planned, functional or perceived obsolescence. These mobile phones disappear in dusty drawers, get sold for spare parts, disappear in the garbage or are partly or fully recycled. In countries with a sustainable electronic waste management system, mobile phones are collected for recycling at industrial recycling facilities, enabling the recovering of valuable metals. About 80% of the mobile phone can be effectively recycled [108].

The literature on the impact of the recycling of mobile phone and other small electronics focuses in particular on informal and small enterprise recycling in countries without a sustainable electronic waste management system.

## Composite Phone

In many countries in the world, the recycling of e-waste is an informal activity[13], taking place in urban environments. E-waste is disassembled and burned under circumstances in which workers lack measures and tools that prevent harm to themselves (*Unsafe work*) [110], as well as to their local communities and to the environment (*Foodchain pollution*, *Drinking water pollution*), e.g., [111]–[113]. Sometimes only valuable materials are taken out for recycling, such as the motherboard (PCB), and the rest is burned or discarded, resulting in the release of

[13] We understand informal economic activity markets as economic exchange in the absence of formal regulation or a lack of effective enforcement of existing regulation This definition reflects what has been called the “legalistic” approach to the study of informal economies. For a summary of approaches and issues concerning informal economies see [109]

*Hazardous materials* in water, soil, and air (*Ecotoxocity*) [114] as well as harm to the workers and the local community (*Reduced health*, *Human toxicity*), e.g., [115], [116]

The work of workers in the informal recycling sector is *Precarious work*, characterised by *Low wages* [117]. They often lack *Information about hazardous materials* [110]. Many workers and their families live in slums around the e-waste site [118], [119]. Land issues and evictions can result in *Conflict* [120].

**Hotspots Analysis of the Composite Phone in the End of Life phase**

1. We found a large number of environmental and social impacts in the End of Life phase. Several of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the End of Life phase as having high salience: a highly important source for environmental and social unsustainability on the mobile phone life cycle.

3. In the End of Life phase of the Composite Phone, we found 3 environmental impacts and 16 social impacts. The combination of the significance of impacts and salience of the End of Life phase resulted in **2 environmental hotspots** and **13 social hotspots (**hotspots in bold, see Table 10). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 10. Impacts and hotspots of the CP in the End of Life phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *End of Life* | 1. $CO_2$ emissions<br>**2. Hazardous materials/Ecotoxicity**<br>**3. Particulate matter** | **4. Food chain pollution**<br>**5. Low wages**<br>**6. Precarious work**<br>**7. Unsafe work**<br>**8. Drinking water pollution/Lack of access to drinking water**<br>9. Poor sanitation<br>**10. Reduced health/Reproductive health hazards**<br>**11. Hazardous materials/Human toxicity**<br>**12. Lack of information about hazardous materials**<br>**13. Child labour**<br>**14. Low literacy**<br>15. Lack of clean energy<br>16. Conflict<br>**17. Corruption**<br>**18. Illicit trade**<br>**19. Living in slums** |

## Fairphone 2

The Fairphone 2 is only available for the European market. Industrial recycling facilities are available in all these countries. Fairphone also has a take-back system for old Fairphones, offering free shipping labels through its website. In addition, in order to offset the environmental and social impacts in the End of Life phase of mobile phones in general, Fairphone is implementing a recycling programme: for each kilo of Fairphones put in the market, Fairphone aims to buy a kilo of condemned mobile phones in countries without a sustainable e-waste recycling system. This take-back system is implemented in Ghana, Uganda, and Rwanda, in cooperation with partner organisations, such as ReCell Ghana and Closing the Loop. Condemned mobile phones are shipped to SIMS, the Netherlands, and Umicore, Belgium, where the mobile phones are dissembled, recycled, and valuable materials are recovered for use in new mobile phones and other products [121].

Fairphone provides the following numbers concerning their take-back programme [121]:

| Year | Electronics sold (Kg) | Electronics Taken Back (Kg) |
|---|---|---|
| 2013 | 4250 | 2782 |
| 2014 | 5950 | 93 |
| 2015 | 5270 | 3100 |
| 2016 | 6120 | 0 |
| Expected 2017 | 6460 | 10571 |

Figure 7. Fairphone take-back programme in numbers

Fairphone's take-back programme is able to off-set a large part of the environmental and social impacts in the End of Life phase of the FP2.

**Hotspots Analysis of the Fairphone 2 in the End of Life phase**

1. We found a large number of environmental and social impacts in the End of Life phase. Several of these impacts are evaluated as high significance: a high likelihood that this impact will take place in this phase.

2. We evaluated the End of Life phase as having high salience: a highly important source for environmental and social unsustainability on the mobile phone life cycle.

3. In the End of Life phase of the Fairphone 2, we found 3 environmental impacts and 1 social impacts. The combination of the significance of impacts and salience of the End of Life phase resulted in **2 environmental hotspots** and **1 social hotspot (**hotspots in bold, see Table 11). Annex 3 gives an overview of the evaluation of impacts and lifecycle phases and the identification of hotspots.

Table 11. Impacts and hotspots of the FP2 in the End of Life phase

| **Lifecycle phase** | *Environmental impacts* | *Social impacts* |
|---|---|---|
| *End of Life* | 1. $CO_2$ emissions<br>**2. Hazardous materials/Ecotoxicity**<br>**3. Particulate matter** | **4. Hazardous materials/Human toxicity** |

# Annex 1. Description of Planetary Boundaries and Social Foundation

*Planetary Boundaries* [1]

| Earth-system pressure | Control Variable | Planetary boundary | Current value and trend | Current value as % of the planetary boundary |
|---|---|---|---|---|
| **Climate change** | Atmospheric carbon dioxide concentration, parts per million | At most 350ppm | 400ppm and rising (worsening) | 169% |
| **Ocean acidification** | Average saturation of aragonite (calcium carbonate) at the ocean surface, as a percentage of pre-industrial levels | at least 80% of pre-industrial saturation levels | ~84% (worsening) | 78% |
| **Chemical pollution** | No global control variable yet defined | - | - | - |
| **Nitrogen & phosphorus loading** | Phosphorus applied to land as fertilizer, millions of tons per year | at most 6.2 million tons per year | ~14 million tons per year and rising (worsening) | 229% |
| | Reactive nitrogen applied to land as fertilizer, millions of tons per year | at most 62 million tons per year | ~150 million tons per year and rising (worsening) | 217% |
| **Freshwater withdrawals** | Blue water consumption, cubic kilometres per year | at most 4000 $km^3$ per year | ~2600 $km^3$ per year (intensifying) | 61% |
| **Land conversion** | Area of forested land as a proportion of forest-covered land prior to human alteration | at least 75% | 62% and shrinking (worsening) | 152% |
| **Biodiversity loss** | Rate of species extinction per million species per year | at most 10 | Around 100-1000 and rising (worsening) | 1,000% |
| **Air pollution** | No global control variable yet defined | - | - | - |
| **Ozone layer depletion** | Concentration of ozone in the stratosphere, in Dobson Units | at least 275 DU | 283 DU and rising (improving) | 47% |

Source: Steffen W, Richardson K, Rockström J, *et al.* 2015. All percentages are rounded to the nearest decimal

**Figure 8. The Planetary Boundaries in their current state**

**Ocean acidification**

Around a quarter of the $CO_2$ that humanity emits into the atmosphere is ultimately dissolved in the oceans. Here it forms carbonic acid, altering ocean chemistry and decreasing the pH of the surface water. This increased acidity reduces the amount of available carbonate ions, an essential 'building block' used by many marine species for shell and skeleton formation. Beyond a threshold concentration, this rising acidity makes it hard for organisms such as corals and some shellfish and plankton species to grow and survive. Losses of these species would change the structure and dynamics of ocean ecosystems and could potentially lead to drastic reductions in fish stocks. Compared to pre-industrial times, surface ocean acidity has already increased by 30 per cent. Unlike most other human impacts on the marine environment, which are often local in scale, the ocean acidification boundary has ramifications for the whole planet. It is also an example of how tightly interconnected the boundaries are, since atmospheric $CO_2$ concentration is the underlying controlling variable for both the climate and the ocean acidification boundaries, although they are defined in terms of different Earth system thresholds.

**Loss of biosphere integrity (biodiversity loss and extinctions)**
The Millennium Ecosystem Assessment of 2005 concluded that changes to ecosystems due to human activities were more rapid in the past 50 years than at any time in human history, increasing the risks of abrupt and irreversible changes. The main drivers of change are the demand for food, water, and natural resources, causing severe biodiversity loss and leading to changes in ecosystem services. These drivers are either steady, showing no evidence of declining over time, or are increasing in intensity. The current high rates of ecosystem damage and extinction can be slowed by efforts to protect the integrity of living systems (the biosphere), enhancing habitat, and improving connectivity between ecosystems while maintaining the high agricultural productivity that humanity needs. Further research is underway to improve the availability of reliable data for use as the 'control variables' for this boundary.

**Climate Change**
Recent evidence suggests that the Earth, now passing 400 ppmv $CO_2$ in the atmosphere, has already transgressed the planetary boundary and is approaching several Earth system thresholds. We have reached a point at which the loss of summer polar sea-ice is almost certainly irreversible. This is one example of a well-defined threshold above which rapid physical feedback mechanisms can drive the Earth system into a much warmer state with sea levels metres higher than present. The weakening or reversal of terrestrial carbon sinks, for example through the on-going destruction of the world's rainforests, is another potential tipping point, where climate-carbon cycle feedbacks accelerate Earth's warming and intensify the climate impacts. A major question is how long we can remain over this boundary before large, irreversible changes become unavoidable.

**Land system change**
Land is converted to human use all over the planet. Forests, grasslands, wetlands and other vegetation types have primarily been converted to agricultural land. This land-use change is one driving force behind the serious reductions in biodiversity, and it has impacts on water flows and on the biogeochemical cycling of carbon, nitrogen and phosphorus and other important elements. While each incident of land cover change occurs on a local scale, the aggregated impacts can have consequences for Earth system processes on a global scale. A boundary for human changes to land systems needs to reflect not just the absolute quantity of land, but also its function, quality and spatial distribution. Forests play a particularly important role in controlling the linked dynamics of land use and climate, and is the focus of the boundary for land system change.

**Nitrogen and phosphorus flows to the biosphere and oceans**
The biogeochemical cycles of nitrogen and phosphorus have been radically changed by humans as a result of many industrial and agricultural processes. Nitrogen and phosphorus are both essential for plant growth, so fertilizer production and application is the main concern. Human activities now convert more atmospheric nitrogen into reactive forms than all of the Earth's terrestrial processes combined. Much of this new reactive nitrogen is emitted to the atmosphere in various forms rather than taken up by crops. When it is rained out, it pollutes waterways and coastal zones or accumulates in the terrestrial biosphere. Similarly, a relatively small proportion of phosphorus fertilizers applied to food production systems is taken up by plants; much of the phosphorus mobilized by humans also ends up in aquatic systems. These can become oxygen-starved as bacteria consume the blooms of algae that grow in response to the high nutrient supply. A significant fraction of the applied nitrogen and phosphorus makes its way to the sea, and can push marine and aquatic systems across ecological thresholds of their own. One regional-scale example of this effect is the decline in the shrimp catch in the Gulf of Mexico's 'dead zone' caused by fertilizer transported in rivers from the US Midwest.

**Freshwater consumption and the global hydrological cycle**
The freshwater cycle is strongly affected by climate change and its boundary is closely linked to the climate boundary, yet human pressure is now the dominant driving force determining the functioning and distribution of global freshwater systems. The consequences of human modification of water

bodies include both global-scale river flow changes and shifts in vapour flows arising from land use change. These shifts in the hydrological system can be abrupt and irreversible. Water is becoming increasingly scarce - by 2050 about half a billion people are likely to be subject to water-stress, increasing the pressure to intervene in water systems. A water boundary related to consumptive freshwater use and environmental flow requirements has been proposed to maintain the overall resilience of the Earth system and to avoid the risk of 'cascading' local and regional thresholds.

**Introduction of novel entities (previously called Chemical pollution)**

Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds and radioactive materials represent some of the key human-driven changes to the planetary environment. These compounds can have potentially irreversible effects on living organisms and on the physical environment (by affecting atmospheric processes and climate). Even when the uptake and bioaccumulation of chemical pollution is at sub-lethal levels for organisms, the effects of reduced fertility and the potential of permanent genetic damage can have severe effects on ecosystems far removed from the source of the pollution. For example, persistent organic compounds have caused dramatic reductions in bird populations and impaired reproduction and development in marine mammals. There are many examples of additive and synergic effects from these compounds, but these are still poorly understood scientifically. At present, we are unable to quantify a single chemical pollution boundary, although the risk of crossing Earth system thresholds is considered sufficiently well-defined for it to be included in the list as a priority for precautionary action and for further research.

**Stratospheric ozone depletion**

The stratospheric ozone layer in the atmosphere filters out ultraviolet (UV) radiation from the sun. If this layer decreases, increasing amounts of UV radiation will reach ground level. This can cause a higher incidence of skin cancer in humans as well as damage to terrestrial and marine biological systems. The appearance of the Antarctic ozone hole was proof that increased concentrations of anthropogenic ozone-depleting chemical substances, interacting with polar stratospheric clouds, had passed a threshold and moved the Antarctic stratosphere into a new regime. Fortunately, because of the actions taken as a result of the Montreal Protocol, we appear to be on the path that will allow us to stay within this boundary.

**Atmospheric aerosol loading**

An atmospheric aerosol planetary boundary was proposed primarily because of the influence of aerosols on Earth's climate system. Through their interaction with water vapour, aerosols play a critically important role in the hydrological cycle affecting cloud formation and global-scale and regional patterns of atmospheric circulation, such as the monsoon systems in tropical regions. They also have a direct effect on climate, by changing how much solar radiation is reflected or absorbed in the atmosphere. Humans change the aerosol loading by emitting atmospheric pollution (many pollutant gases condense into droplets and particles), and also through land-use change that increases the release of dust and smoke into the air. Shifts in climate regimes and monsoon systems have already been seen in highly polluted environments, giving a quantifiable regional measure for an aerosol boundary. A further reason for an aerosol boundary is that aerosols have adverse effects on many living organisms. Inhaling highly polluted air causes roughly 800,000 people to die prematurely each year. The toxicological and ecological effects of aerosols may thus relate to other Earth system thresholds. However, the behaviour of aerosols in the atmosphere is extremely complex, depending on their chemical composition and their geographical location and height in the atmosphere. While many relationships between aerosols, climate and ecosystems are well established, many causal links are yet to be determined.

*Social Dimensions and their indicators* [101]

Table 12. The social foundation and its indicators of shortfall [3, p. 255]

| Dimension | Illustrative Indicators (% of global population unless otherwise stated) | % | Year | Source |
|---|---|---|---|---|
| **Food** | Population undernourished | 11 | 2014-2016 | FAO |
| **Health** | Population living in countries with under-five mortality rate exceeding 25 per 1,000 live births | 46 | 2015 | World Bank |
| | Population living in countries with a life expectancy at birth of less than 70 years | 39 | 2013 | World Bank |
| **Education** | Adult population (aged +15) who are illiterate | 15 | 2013 | UNESCO |
| | Children aged 12-15 out of school | 17 | 2013 | UNESCO |
| **Income & Work** | Population living on less that the international poverty limit of $3.10 a day | 29 | 2012 | World Bank |
| | Proportion of young people /aged 15-24) seeking but not able to find work | 13 | 2014 | ILO |
| **Water & Sanitation** | Population without access to improved drinking water | 9 | 2015 | WHO/UNICEF |
| | Population without access to improved sanitation | 32 | 2015 | WHO/UNICEF |
| **Energy** | Population lacking access to electricity | 17 | 2013 | OECD/IEA |
| | Population lacking access to clean cooking facilities | 38 | 2013 | OECD/IEA |
| **Networks** | Population stating that they are without someone to count on for help in times of trouble | 24 | 2015 | Gallup |
| | Population without access to the Internet | 57 | 2015 | ITU |
| **Housing** | Global urban population living in slum housing in developing countries | 24 | 2012 | UN |
| **Gender equality** | Representation gap between women and men in national parliaments | 56 | 2014 | World Bank |
| | Worldwide earnings gap between women and men | 23 | 2009 | ILO |
| **Social equity** | Population living in countries with a Palma ratio of 2 or more (ratio of the income share of the top 10% of people to that of the bottom 40%) | 39 | 1995-2012 | World Bank |
| **Political voice** | Population living in countries scoring 0.5 or less out of 1.0 in the Voice and Accountability Index | 52 | 2013 | World Bank |
| **Peace & Justice** | Population living in countries scoring 50 or less out of 100 in the Corruption Perceptions Index | 85 | 2014 | Transparency International |
| | Population living in countries with a homicide rate of 10 or more per 10,000 | 13 | 2008-2013 | UNODC |

## Food

Ending hunger and achieving food security is the focus of SDG Goal 2. Here undernourishment is assessed in terms of inadequate caloric intake. The indicator used, as defined by the UN FAO, is the probability that a randomly selected individual from the population consumes below the minimum dietary energy requirement, which varies by gender and age, and for different levels of physical activity. Data are given as a three-year average for 2014-16 (FAO 2015a). These data would ideally be accompanied by an indicator of malnourishment to reflect the lack of nutrient balance in many people's diets. An internationally comparable indicator of women's dietary diversity is currently under development but data are not yet available globally (FAO 2015b). In the future it will provide a highly valuable complementary measure.

**Health**
Ensuring healthy lives and promoting wellbeing for all is the focus of SDG Goal 3. Two indicators are used here to assess shortfalls in access to health care: under-five child mortality and life expectancy at birth, both selected for being recognised proxies for wider health outcomes. The under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, based on age-specific mortality rates of the specified year. Data are given for 2015 (World Bank 2015b). The benchmark is the international target for all countries to reduce under-five mortality to at least as low as 25 per 1,000 live births by 2030 (WHO 2015). Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. Data are given for 2013 (World Bank 2015b). No equivalent international benchmark has been established. A life expectancy at birth of 70 years is selected here as a benchmark, being an outcome typically achieved by countries classified under medium human development according to UNDP's Human Development Index (UNDP 2015).

**Education**
Ensuring quality education and lifelong learning opportunities for all is the focus of SDG Goal 4. Here, two indicators for educational deprivations are used so as to reflect achievements and outcomes across diverse population age groups. For the school-aged population, the proportion of adolescents not enrolled in lower secondary school (typically ages 12 to 15 years) is used. Data are given for 2013 (UNESCO 2015a). For the adult population, the chosen indicator is the rate of adult illiteracy, defined as adults aged over 15 years who are unable to read and write a simple sentence . Data are given for 2013 (UNESCO 2015b).

**Income and Work**
Ending poverty, including income poverty, is the focus of SDG 1 and promoting decent work is among the commitments of SDG 8. Deprivation in terms of income is assessed with the internationally established poverty line of $3.10 per person per day, calculated by the World Bank on the basis of purchasing power parity at 2011 prices. Data are given for 2012 (World Bank 2015a). This indicator is used instead of the often-cited extreme poverty line of $1.90 per person per day (popularly known as the 'dollar a day' measure) because the cut-off point for extreme poverty does not constitute a social foundation of income for a life of dignity and opportunity. Given the importance of paid work as a means to income, and its centrality in many people's lives, it would be highly desirable to include a composite indicator of decent work, defined as 'the opportunity of women and men to obtain decent and productive work in conditions of freedom, equity, security and human dignity' (ILO 1999). However such a composite indicator is not yet available. As a proxy indicator for assessing the availability of work, youth unemployment is used instead, measuring the proportion of young people (aged 15-24) who are seeking but unable to find work (ILO 2015). It is likely, however, to undercount those youth who, through force of poverty and circumstance, must accept any work, no matter how poorly paid or exploitative.

**Water & sanitation**
Ensuring safe water and adequate sanitation for all is the focus of SDG 6. Deprivations in access to water and sanitation services are assessed here on the basis of two widely used indicators. Inadequate access to water is given by the proportion of people who do not have access to an improved drinking water source, such as piped household water, public taps, protected wells and springs, or collected rainwater. Inadequate access to sanitation is given by the proportion of people who do not have access to improved sanitation facilities such as flush toilets, ventilated improved pit latrines, or composting toilets. For both indicators, data are given for 2015 (WHO/UNICEF 2015).

**Energy**
Ensuring access to energy for all is the focus of SDG 7. Deprivations in access to energy assessed here include both electricity and the quality of cooking facilities. Inadequate access to electricity is assessed

as the proportion of people who do not enjoy a household electricity supply accompanied by aminimum level of electricity consumption. In rural areas the specified minimum per household is 250 kWh per year, which provides, for example, for the use of a floor fan, a mobile phone, and two compact fluorescent light bulbs for about five hours per day. In urban areas, the specified minimum per household is 500 kWh per year, for which consumption might additionally include an efficient refrigerator, a second mobile telephone, and another appliance such as a computer or small television. Inadequate cooking facilities are assessed as the proportion of people who do not have access to electricity and who rely on the traditional use of solid biomass (such as fuelwood, charcoal, tree leaves, crop residues and animal dung) for cooking. For both indicators, data are given for 2013 (OECD/IEA 2015).

**Networks**
Digital communications networks and person-to-person social support networks are both important means of generating opportunity, building community and increasing resilience, and they tend to be mutually supportive. In the context of the SDGs, Target 9.c promotes 'universal and affordable access to the Internet' and Target 1.5 commits to 'build the resilience of the poor and those in vulnerable situations'. Here, deprivation in terms of access to digital communications networks is assessed as the proportion of people not using the Internet, and estimated global data are given for 2015 (ITU 2015). These estimates are derived from data on the percentage of households with Internet access at home, and so overestimate the shortfall. Future international data will preferably also take account of users of public Internet access, such as through libraries, post offices, community centres, Internet cafes, and schools (ITU 2014). Deprivation in terms of lacking a network of social support is assessed here on the basis of self-reported data through the Gallup World Poll survey. Conducted in 140 countries, the urvey asks the question, 'If you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?' Data are given for 2015 (Gallup World Poll).

**Housing**
Ensuring safe and affordable housing and upgrading slums is central to SDG 11. Internationally comparable data on housing conditions are currently limited to the proportion of the urban population in developing countries who are living in slums. Such slum housing is defined as having at least one of the following four characteristics: lack of access to improved drinking water; lack of access to improved sanitation; overcrowding (more than three persons per room); and dwellings made of non-durable material. Given this definition, there will be some overlap with indicators assessing deprivations in access to improved water and sanitation. Here the data are expressed as the proportion of the global urban population that is living in slum conditions in developing countries. Data are given for 2012 (UN 2014). Given that just under half of the global population lives in rural areas, a highly desirable complementary indicator for assessing housing deprivation would address the conditions of rural housing but such an indicator has not yet been developed. Data on the percentage of people living in inadequate housing conditions, both urban and rural, in high-income countries would also be desirable to include.

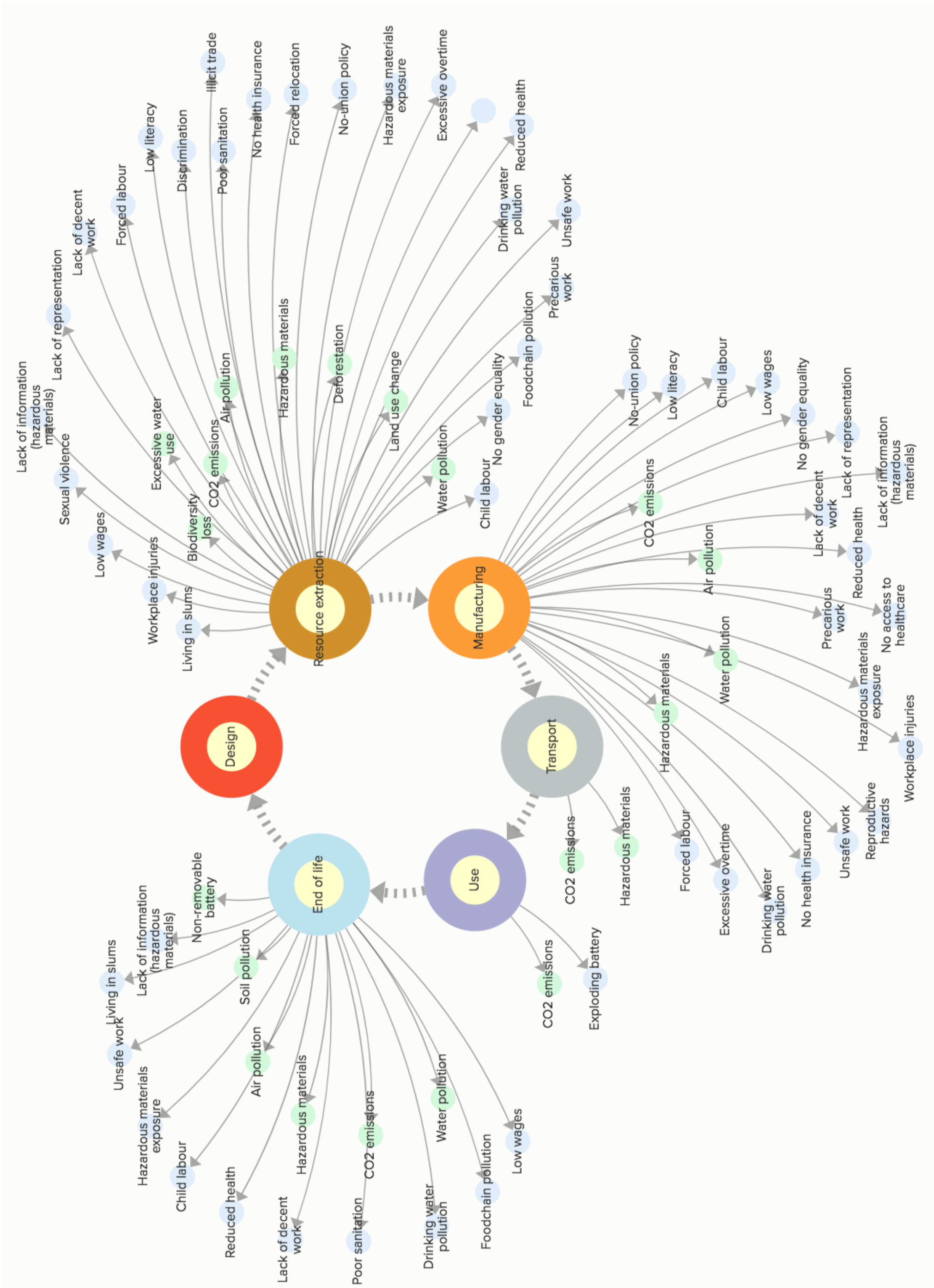
**Social equity**
Reducing inequality within and among countries is the focus of SDG 10. Here the shortfall in social equity is measured on the basis of national income inequalities. The indicator used is the Palma ratio, which is the ratio of the income of the top 10% to that of the bottom 40% within a nation. The Palma ratio is chosen here over the Gini coefficient because it is more sensitive to inequalities of income at the extremes of wealth and poverty (Cobham, Schlogl and Sumner 2015). A benchmark is set at a Palma ratio of 2, which occurs when the richest10% in a country have double the annual income of the poorest 40%, and is equivalent to a Gini coefficient of approximately 0.35 (Cobham and Sumner, 2013). Hence the indicator gives the proportion of the global population that lives in countries in which the Palma ratio is 2 or greater. Data are given for the most recent available year, 1995-2012 (World Bank 2015b).

**Gender equality**
Achieving gender equality and empowering all women and girls is the focus of SDG 5. It would be ideal to assess the extent of gender inequality in each of the social foundation's dimensions but as proxy measures, two indicators are chosen which are indicative of inequalities in women and men's roles and status in political and economic life. For assessing inequalities in the political realm, the indicator is derived from the proportion of seats held by women in national parliaments. Data are given for 2014 (World Bank 2015b). The indicator value is calculated such that if women held no parliamentary seats globally, the deprivation would be 100%, whereas if women held exactly half of all parliamentary seats, the deprivation would be 0%.For assessing inequalities in the economic realm, the gender pay gap is used, which is based on survey data from a diverse sample of 48countries. Data are given for 2008-09. The indicator is the percentage gap between women and men's pay, based on international estimates of women's earnings as a proportion of men's (ILO 2011).Gender inequalities and income inequalities are of course just two among many dimensions of social inequality. Internationally comparable indicators of inequalities based on other social differences, such as ethnicity, age, religion, disability, language, sexual orientation, and location, would also be desirable for inclusion.

**Political voice**
Ensuring 'responsive, inclusive, participatory and representative decision-making at all levels' is the focus of SDG Target 16.7. The indicator used here as a proxy for the shortfall of political voice is the Voice and Accountability Index, which is a component of the World Bank's Worldwide Governance Indicators. The Index is scored on a scale of 0 (very poor performance) to 1 (very high performance) and includes measures of democracy, vested interests, accountability of public officials, human rights, and freedom of association. It is created through expert assessment by over 500 correspondents and is reviewed for consistency by a panel of regional experts. Data are given for 2013 (World Bank 2015c). Here, a benchmark is set at 0.5, hence the social foundation indicator denotes the proportion of the global population living in countries with a score of 0.5 or less on the Voice and Accountability Index.

**Peace & justice**
Promoting peaceful and inclusive societies and providing access to central to SDG 16. Two indicators are used here in order to assess shortfalls in peace and in justice respectively. The indicator used as a proxy for the shortfall in peace is the rate of intentional homicide, which is unlawful death purposefully inflicted on a person by another person. It does not include killings in war or conflicts, however an indicator that did also take account of these would be preferable. A benchmark is set at 10 or more homicide deaths per 100,000 population per year and data are given for the most recent year, 2008-2013 (UNODC 2015). The indicator used as a proxy for shortfall in justice is Transparency International's Corruption Perceptions Index, which scores countries according to how corrupt their public sector is perceived to be, on a scale of 0 (highly corrupt) to 100 (very clean). National scores are compiled using data sources from independent institutions specialising in governance and business climate analysis. Data are given for 2014 (Transparency International 2014). Here, a benchmark is set at a score of 50 or below, hence the social foundation indicator denotes the proportion of the world's population living in countries that score 50 or less in the Corruption Perceptions Index.

# Annex 2. Risks in the lifecycle of mobile phones



# Annex 3. Hotspots Analysis (Summary)

**Step 2, 3, and 4 in the Sustainability Hot Spots Analysis**

Step 2: Assessing defined aspects within each lifecycle
Step 3: Assessing defined aspects between the different life cycle phases
Step 4: Identification of environmental and social hotspots (hotspot = yellow)

Literature and stakeholders consultations inform the ranking from 0 to 3:

0 = no data found
1 = low significance or salience
2 = moderate significance or salience
3 = high significance or salience

In **Step 2**, the significance of each impact is specified.

| **Step 2. Assessing defined aspects within each lifecycle phase** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Planetary boundaries** | ***Impact categories*** | *Lifecycle phases* | | | | | | | | | |
| | | *Resource Extraction* | | *Manufacturing* | | *Transport* | | *Use* | | *End of Life* | |
| | | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* |
| Ocean acidification | *Acidification* | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 |
| Change in biosphere integrity | *Biodiversity loss* | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Climate change | *$CO^{2}$ emissions* | 1 | 1 | 3 | 2 | 3 | 3 | 3 | 3 | 1 | 1 |
| Land-system change | *Deforestation* | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Biogeochemical flows | *Eutrophication* | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 |
| Fresh water use | *Excessive water use* | 2 | 2 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Introduction of novel entities | *Hazardous materials:<br>- Ecotoxicity* | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 2 |
| Stratospheric ozone depletion | *Ozone depletion* | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Atmospheric aerosol loading | *Particulate matter* | 2 | 2 | 3 | 3 | 3 | 3 | 1 | 1 | 3 | 2 |
| **Social dimensions** | ***Impact categories*** | *Lifecycle phase* | | | | | | | | | |
| | | *Resource Extraction* | | *Manufacturing* | | *Transport* | | *Use* | | *End of Life* | |
| | | *CP* | *FP2* | *CP* | *FP2*[14] | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2*[15] |

[14] Fairphone has almost 100 suppliers for the manufactoring of the Fairphone 2 [100]. Ten of the suppliers participate in suppliers engagement initatives to improve the supply chain, e.g. [102]. For the analysis of hotspots in the Manufacturing phase, we focuses on the FP2 Tier 1 supplier **Hi-P Suzhou EMS** from Suzhou, China. Hi-P participates in a supplier engagement initiative. The company is audited by the independent organisation TAOS (taosnetwork.org) [105].

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | *Foodchain pollution* | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | *Land use change* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Income & Work | *Excessive overtime* | 3 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Low wages* | 3 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 3 | 0 |
| | *Forced labour* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Precarious work* | 3 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 3 | 0 |
| | *Non-union work* | 2 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Unsafe work* | 3 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Water & Sanitation | *Drinking water pollution/lack of access* | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 0 |
| | *Poor sanitation* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Health | *Reduced health/reproductive hazards* | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| | *Hazardous materials/ Human toxicity* | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 2 |
| | *Lack of information about hazardous materials* | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Education | *Child labour* | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | *Low literacy* | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Energy | *Lack of clean energy* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Gender equality | *Lack of equal opportunities* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Social equity | *Discrimination* | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Voice | *Forced relocation* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Lack of representation (local community)* | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peace & Justice | *Conflict* | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| | *Corruption* | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | *Illicit trade* | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| | *Sexual violence* | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Housing | *Living in slums* | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Networks | *P2P network* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Households with Internet* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Step 3** of the Hotspots Analysis is an assessment of the salience of each lifecycle phase for the whole mobile phone lifecycle. The assessment is based on the number of impacts in a certain phase.

| **Step 3. Assessing defined aspects between the different life cycle phases** | | | | | |
|---|---|---|---|---|---|
| **Aspects** | *Lifecycle phase* | | | | |
| | *Resource Extraction* | *Manufacturing* | *Transport* | *Use* | *End of Life* |
| Environmental aspects | 3 | 3 | 1 | 1 | 3 |
| Social aspects | 3 | 3 | 1 | 1 | 3 |

[15] Fairphone has a take-back system in place, offering free shipping of condemned Fairphones to Amsterdam. In addition, Fairphone buys up condemned phones in Ghana, Kenya, and Rwanda (one kilo condemned phones for each kilo of Fairphones sold) for recycling in the Netherlands and Belgium.

**Step 4** of the Hotspots Analysis, the identification of hotspots, is based on the multiplication of the significance of an impact with the salience of the phase with which it is associated. The scores of Step 2 are multiplied with the values of Step 3.

| **Step 4. Identification of environmental and social hotspots** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Planetary boundaries** | **Impact categories** | *Lifecycle phase* | | | | | | | | | |
| | | *Resource Extraction* | | *Manufacturing* | | *Transport* | | *Use* | | *End of Life* | |
| | | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* |
| Ocean acidification | *Acidification* | 6 | 6 | 6 | 6 | 2 | 2 | 2 | 2 | 0 | 0 |
| Change in biosphere integrity | *Biodiversity loss* | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Climate change | *$CO^2$ emissions* | 3 | 3 | 9 | 6 | 3 | 3 | 3 | 3 | 3 | 3 |
| Land-system change | *Deforestation* | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Biogeochemical flows | *Eutrophication* | 6 | 6 | 9 | 9 | 3 | 3 | 3 | 3 | 0 | 0 |
| Fresh water use | *Excessive water use* | 6 | 6 | 9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| Introduction of novel entities | *Hazardous materials/ Ecotoxicity* | 9 | 6 | 9 | 6 | 1 | 1 | 1 | 1 | 9 | 6 |
| Stratospheric ozone depletion | *Ozone depletion* | 3 | 3 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Atmospheric aerosol loading | *Particulate matter* | 6 | 6 | 9 | 9 | 3 | 3 | 3 | 3 | 9 | 6 |
| **Social dimensions** | **Life cycle phase** | *Lifecycle phase* | | | | | | | | | |
| | | *Resource Extraction* | | *Manufacturing* | | *Transport* | | *Use* | | *End of Life* | |
| | | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* | *CP* | *FP2* |
| Food | *Foodchain pollution* | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| | *Land use change* | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Income & Work | *Excessive overtime* | 9 | 6 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Low wages* | 9 | 6 | 9 | 3 | 0 | 0 | 0 | 0 | 9 | 0 |
| | *Forced labour* | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Precarious work* | 9 | 6 | 9 | 6 | 0 | 0 | 0 | 0 | 9 | 0 |
| | *No union work* | 6 | 3 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Unsafe work* | 9 | 3 | 9 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| Water & Sanitation | *Drinking water pollution/lack of access* | 9 | 6 | 3 | 3 | 0 | 0 | 0 | 0 | 9 | 0 |
| | *Poor sanitation* | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Health | *Reduced health/reproductive hazards* | 9 | 6 | 9 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| | *Hazardous materials/* | 9 | 6 | 9 | 6 | 3 | 3 | 3 | 3 | 9 | 6 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Human toxicity* | | | | | | | | | | |
| | *Lack of information about hazardous materials* | 9 | 6 | 9 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| Education | *Child labour* | 9 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| | *Low literacy* | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| Energy | *Lack of clean energy* | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Gender equality | *Lack of equal opportunities* | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Social equity | *Discrimination* | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Voice | *Forced relocation* | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Lack of representation (local community)* | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Peace & Justice | *Conflict* | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| | *Corruption* | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| | *Illicit trade* | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| | *Sexual violence* | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Housing | *Living in slums* | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 |
| Networks | *P2P network* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | *Households with Internet* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# Annex 4. Literature Review

The literature review **Environmental and Social Risks and Hotspots in the Mobile Phone Lifecycle** consists of a systematic literature review of scientific resources and a systematic literature of grey literature. This resulted in a database of 304 articles and reports. These resources were coded and resulted in an initial set of risks. While developing the risks catalogue and implementing the hotspots analysis, additional resources were identified in order to provide more recent data or to confirm initial findings. This Literature Review does not present a comprehensive review of all relevant literature. The final count for this report is as follows:

- Scientific literature: 298 resources
- Lifecycle assessments of mobile phones: 21
- Grey literature: 88 resources
- Fairphone: 52 resources

**Scientific literature (peer-reviewed)**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# SMART DELIVERABLE No. D4.1

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