Modular Smartphones:
Design Strategies Driven by Life Cycle Assessment Evidence

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Introduction

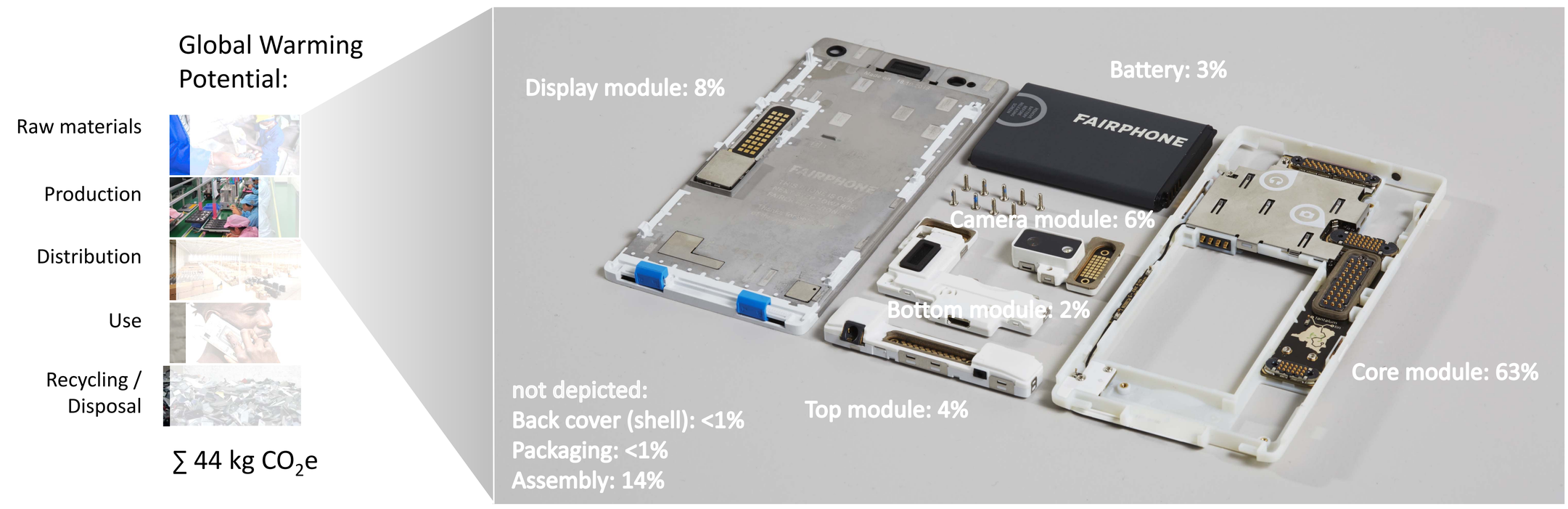
Smartphones are extremely complex products and approaches for making them more sustainable face major trade-offs between optimizing the product for one use scenario, but at the expense of potentially higher environmental impacts for another use case. An example are embedded batteries, which help to reduce the form factor of the device along with a reduction of the overall amount of material used for e.g. housing of the battery and the device. An embedded battery however is difficult to replace and can limit the use lifetime of any mobile IT device. One example of a product, which has been designed with environmental aspects in mind, such as do-it-yourself repairability for extended product lifetime, is the Fairphone 2.

Life Cycle Assessment

The major environmental hot spots of a smartphone are the semiconductor components, printed circuit boards, followed by display unit and battery. Even proper recycling can only recover a minor share of the once invested high environmental footprint of such high-tech products. Consequently, a broken screen or a drained battery should not limit the lifetime of those components, which have a much higher environmental footprint and a longer technical lifetime. Modularity is the key enabler for an optimized product life cycle.

Modularization of a smartphone means a radical redesign of the internal layout of such a device. The Life Cycle Assessment, including impact categories climate change, abiotic resource depletion and human toxicity, unveils the share of environmental impacts, which are attributable to modularization. Additional internal module housings, gold as coating of the connectors (which dominates the impacts on abiotic resource depletion), and the additional printed circuit board area needed for the connectors all contribute to the higher initial impact of a modular phone.

Figure: Fairphone 2 Life Cycle Assessment results (GWP) over full life cycle and per module



Circular Design

Modularization is a key enabler for several design strategies (see table below). However, there is an additional environmental footprint related to modular design. As long as such modularity is embraced by the consumer and components with a rather low environmental impact are replaced when needed and the rest of the phone thus is kept running, then additional impacts are easily outweighed.

Changed user behavior, such as successful do-it-yourself repairs and parts replacement, is essential for extending the use lifetime of the overall phone. The results of the Life Cycle Assessment help to set priorities for further improvements in product design, module strategies, but also for the overall business model.

Table: Circular Design Strategies and related evidence from Fairphone 2 Life Cycle Assessment

Circular Design Strategy (see Bakker et al., 2014)	Fairphone 2 Design Features	Fairphone 2 Life Cycle Assessment Findings
Attachment & Trust	▪ **Modularity** as unique, visible feature ▪ Selection of **shell colours** ▪ **Transparency** about fair and conflict-free sourcing of selected materials and further sustainability measures	▪ Plastic shells have a **very minor contribution to overall environmental impact**, exchange is acceptable for the sake of long-term user attachment to the product
Durability	▪ **Protective shell** being part of the housing ▪ Reliability of **non-permanent connectors**	▪ **Longer lifetime** is the single most important aspect to reduce overall environmental impact
Standardization and Compatibility	▪ No compatibility with non-FP modules (except power supply unit and other standard accessories)	▪ Continued use of **power supply slightly reduces environmental impact**
Ease of Maintenance & Repair	▪ Display replacement **without tools** ▪ **Modular internal design**, modules clearly identifiable, screws marked ▪ Availability of **spare parts** and **repair instructions**	▪ Longer lifetime is essential to **compensate production efforts for modularity**: module housings, gold-coated connectors and additional board area **increase environmental impact by approx. 10%** ▪ Field data indicates successful lifetime extension: modularity yields demonstrated **high rate of successful DIY repairs** by owners ▪ Lifetime extension from 3 to 5 years (through replacement of defect parts) reduces **carbon footprint per year of use by 30%**
Upgradability & Adaptability	▪ **Dual-SIM** (business and private use) ▪ Introduction of enhanced camera module	▪ Dual-SIM replaces potentially a **second phone** ▪ Upgradability of low-impact modules could significantly extend use lifetime of high-impact modules
Dis- & Reassembly	▪ Extremely **easy** down to the module level	▪ Longer lifetime is essential to **compensate production efforts for modularity**

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