A novel recyclability indicator for products

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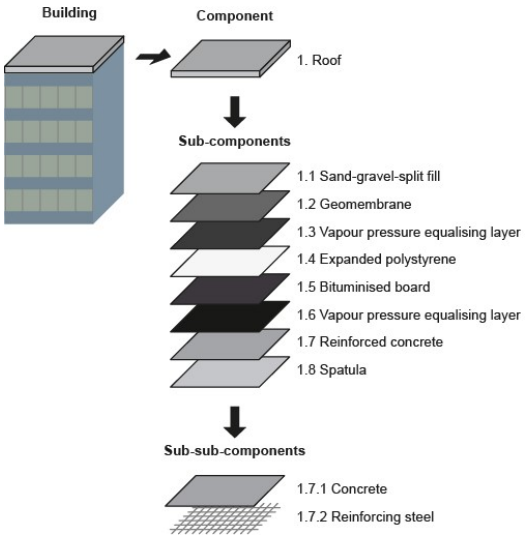
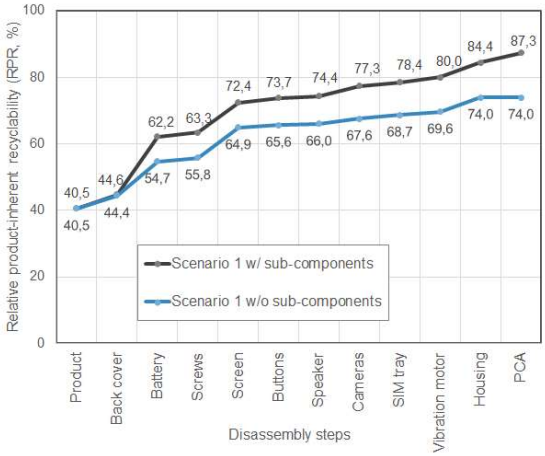
The recyclability of products depends on several factors, which can basically be assigned to three spheres. On the one hand, there is the product itself with its material composition. Another sphere is the waste management system, which determines how the product is collected and treated. And finally, there is the sphere of the national economy, which determines, among other things, whether there is a market for the recycled product. All three spheres must "work" for a product to be evaluated as recyclable as a whole. We developed a method that addresses the first and inner sphere.



A product is usually made up of various components, which in turn can be made up of several levels of subcomponents. Each component consists of at least one material or substance. Thus, the portfolio ranges from products that have a very simple or homogeneous material composition to very complex products, with many ingredients. The material distribution in a product can be quantified by means of a material balance and statistical entropy. For example, a high entropy value means that the substances are rather diluted and not separable from each other in the product. To make the entropy results more descriptive, a relative product inherent recyclability (RPR) is derived, ranging from 0 to 100%. RPR = 0% means that the substances or materials in a product are maximally mixed and not separable. RPR = 100% means that the substances or materials are in pure form and separable.

In principle, the RPR method can be applied to any product, the only prerequisite being that sufficient information about the material composition of the product is known. To demonstrate this, we applied the method to extreme cases: a smartphone (small and complex product) and the comparison of two multi-family residential buildings (high-volume products), which differ only in their construction. It is shown that the RPR increases with the hypothetical disassembly depth of the smartphone from around 40% (no disassembly possible) to just under 90% (disassembly into 32 subcomponents). The two buildings also differ in their RPR. If there is no deconstruction at all ("wrecking ball"), the concrete structure achieves a higher RPR. This changes with the deconstruction depth and thus the disassembly of the buildings into recyclable material groups or reusable components. Here, the timber construction method has a higher RPR.



The assessment of product recyclability is highly relevant in the transition towards a Circular Economy to enable successful and comprehensive implementation. Products should be designed in a way that allows extensive material recovery and easy disassembly. Among the manifold parameters impacting recyclability, material composition and product structure are among the essential determinants of the recycling path. Existing assessment methods fail to evaluate such product design characteristics in a fundamental way. The RPR method presents a new way that evaluates product-inherent recyclability based on statistical entropy. Statistical entropy represents an optimal metric to measure these essential product characteristics. The case studies show that product design weaknesses can be directly deduced from the RPR results and thus form the basis for design optimizations that increase the recyclability of products and materials, respectively. The calculation of the RPR metric is comparably simple, which enables broad stakeholder application. The method primarily addresses product designers and manufacturers, but should in the long term serve as a decision-making tool for various stakeholders (e.g. governments or consumers).