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Some pervasive challenges to sustainability by design of electronic products – a conceptual discussion

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A B S T R A C T

Sustainability should encompass responsibility for unintended environmental consequences of modern developments. This study examined some pervasive challenges to sustainability by design of electronic products, namely: (i) product and consumption redundancies; (i) embodied environmental and social impacts occurring distant in time and space from the point of consumption; and (iii) production and consumption dynamics. This analysis identified essential developments in certain areas that can assist design practice in preventing unintended environmental consequences. These were: (1) complementing life cycle assessment studies with analyses of unintended environmental consequences; and (2) exploiting the vital role of product design in fostering a circular economy. Indicators that provide information about (a) the increasing spatial and decreasing temporal separation of production, consumption and waste management, (b) constraints in raw materials supply and (c) marginal changes in money and time spent should be available to product designers and consumers. Furthermore, information technology, namely computer-aided design (CAD) tools, should be refined to assist product designers in designing for effective circularity and end-of-waste and limiting hibernation of resources in the use phase.

1. Introduction

Much of the increased human well-being that modern society is experiencing is the result of scientific and technological developments. However, these developments have also had severe environmental consequences. In an attempt to respond to this dilemma, the concept of sustainability has emerged.

According to Swilling and Annecke (2012), there are three main schools of thought within the domain of sustainability: (1) 'Doom and gloom' environmentalism; (2) 'ecological modernisation'; and (3) acknowledgement of unintended environmental consequences. Within the 'doom and gloom' school, environmentalists have basically given up on technological development, blaming it for the 'mess' in which they perceive society to be engulfed. They claim that Earth has already passed its tipping point in terms of the environment's carrying capacity and resilience and that future efforts should be devoted to adapting society to the negative consequences to come (Lovelock, 2009).

The other extreme is the 'ecological modernisation' school of thought. It believes that technological fixes can mitigate environmental improvements through economic growth (OECD, 2010). Within this paradigm, product designers and engineers have been directing their product innovation efforts towards massively reducing the purchase cost per unit of functionality (Bovea and Pérez-Belis, 2012). From an industrial perspective, great progress has been made in achieving environmental gains that yield parallel economic benefits, e.g. refrigerators, washing machines, cars, computers, mobile phones and other industrial appliances now consume much less material and energy during their life cycle than previous generations.

However, rather less attention has been paid to the unintended consequences (e.g. rebound effects) of incremental improvements, which occur separated in time and geographical location from the point of consumption. Thus incremental improvements may be acting in a counterproductive manner from a long-term sustainability perspective, posing many challenges to design practice.

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The third school of thought within the domain of sustainability involves acknowledgement that with modern developments comes responsibility for unintended environmental consequences. Most of these unintended consequences are defined during the product design phase by design specifications. Therefore, the aim of this study was to identify some pervasive challenges to design for sustainability, with the focus on electronic products. The sustainability challenges to design practices examined were:

i) Product and consumption redundancies.
ii) Embodied environmental and social impacts occurring distant in time and space from the point of consumption.
iii) Production and consumption dynamics.

Based on examination of these challenges, attempts were made to highlight directions for further developments in the field.

2. General concepts

2.1. Unintended environmental consequences

Although the term unintended consequences may seem self-explanatory, the setting in which this term is used requires further explanation. In the first place, unintended consequences are not direct outcomes of purposive action, since the intended and anticipated outcomes of purposive action are always relatively desirable from the perspective of the actor of the action (Merton, 1936). However, those intended and anticipated outcomes may later cause negative and undesirable effects from the perspective of an outside observer. These later effects not addressed by the actor of the purposive action are treated in this paper as unintended consequences.

Examples of pervasive unintended environmental consequences occurring at different times and geographical locations are:

- Increasing use of scarce minerals in smart phones, tablets, laptops, hybrid cars, LED light bulbs, etc., which have contributed to resource wars in developing countries (Christopher, 2012; Kumah, 2006; Prior et al., 2012; Stamp et al., 2012; Whitmore, 2006).
- Rapid technological advances in consumer goods, which have contributed to shortening the life span of products and increasingly rapid replacement of product generations (Laurenti et al., 2015).
- Growing amounts of discarded electronic products not accompanied by growing installed capacity for properly managing this large waste stream, which have led to illegal exports of electronic waste (e-waste) to low-income countries for poor informal e-waste recycling (recovery of some precious metals present in electronic products) in those countries (Dwivedy and Mittal, 2012; Nnorom and Osibanjo, 2008; Ongondo et al., 2011; Widmer et al., 2005).
- The crude processes of informal e-waste recycling in low-income countries, which add toxins to the environment and negatively affect the health of workers (Ekener-Petersen and Finnveden, 2012; Umair et al., 2013).
- Population growth, improved standard of living and the associated increasing demand for material goods, which have been rapidly depleting the stocks of high-grade resources for producing consumer goods (Hall et al., 2014; Jowsey, 2009; Northey et al., 2014). Consequently, raw materials have become more difficult to extract and production of goods more expensive (Prior et al., 2012; Yellishetty and Mudd, 2014).

2.2. Sustainability

Sustainability is both a vague and politicised term (Lant, 2004). It has different meanings for different people (Graedel and Klee, 2002), ranging from short- to long-term visions, from individual to community perspectives and from technological innovations to changes in people's attitudes, behaviours and preferences (Partidario et al., 2010). It has been estimated that some three hundred definitions of 'sustainability' exist within the domain of environmental management and associated disciplines linked directly or indirectly to that domain (Johnston et al., 2007). Due to this lack of objectiveness, sustainability can be defined sufficiently narrowly or broadly to suit particular interests.

Like other fields, Industrial Ecology has struggled with practical application of the concept of sustainability. Ehrenfeld (2007) states that sustainability is not merely the opposite face of unsustainability and that "*[…] reducing unsustainability, the objective that is the driving force behind dematerialization, efficiency improvements, and other strategies associated with sustainable development, will not automatically produce sustainability […]*". Similarly, Swilling and Annecke (2012) suggest that sustainability will not result from causing less damage over time, but rather by finding ways of living that restore those ecosystems upon which we depend. This is the meaning of sustainability adopted in the present study.

2.3. Product design

Product design involves conceiving and giving form to artefacts that solve problems (Ulrich and Eppinger, 2008). In this sense, design is part of an overall problem-solving process beginning with perception of a gap in user experience, leading to a plan for a new artefact and resulting in the production of that artefact. In addition, product design determines most of the environmental impacts that a product will potentially have during its life cycle. Design choices such as type of materials and manufacturing processes strongly influence the rate of material or energy input per unit of the service offered by the product (see Fig. 1).

3. Unintended environmental consequences of design

3.1. Technological obsolescence and redundancy by design

Capitalist economies work by a combined strategy comprising a continuous innovation process which brings new product models that render previous products more or less obsolete; and a complex social logic leading to consumption redundancy. This combined strategy involves a self-perpetuating cycle of innovation, production, consumption, innovation, marketing of quality enhancement in emerging product models, a perpetual desire for novelty and redundancy in consumption. The health of all modern economies depends on this cycle (Jackson, 2009; Partidario et al., 2010). However, it is important to stress that the process of growth in terms of profits is also partly achieved by increased labour and capital productivity. If there is no net economic growth, then any productivity increase will result in fewer people being employed.

Consumers replace their products for the latest launched on the market, rather than because of technical failure in their existing product, for a variety of reasons, including (Khetriwal and First, 2012):

- Style preferences
- Product feature and technology advances
- Marketing campaigns with emphasis on price decreases and sales promotions
- Changed family circumstances