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Can Design for Disassembly Principles Inform Policy for E-Textiles Waste? †

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Abstract: The adoption of circular principles by the EU and UK have led to greater focus on waste streams and the recoverability of materials and components. This has translated into regulations such as WEEE for electronic waste. Textiles and nanomaterials lag behind with no definitive waste legislation. As e-textiles are generally made up of a combination of these three components, it means e-textile products end up in electrical recycling facilities where textile components are disposed of in landfill or incinerated together with embedded nanomaterials. Consultations with recycling facilities indicate product design is key in preparing for disassembly and recycling. By embedding design for disassembly thinking into the research and development of new e-textiles, this study aims to test whether e-waste policy can be informed by design for disassembly principles. The motivation for this research is to find an anticipatory legislative solution for future e-textiles waste.

Keywords: design for disassembly; Active Disassembly; e-textiles; recycle; waste policy; landfill

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1. Introduction

The predicted monetary growth of wearable electronics by an additional USD 46 billion by 2025 [1], e-textiles waste is set to become a significant new waste stream. Planning for this eventuality is an opportunity to innovate in materials, products and recycling. To date, as the race to make flexible, wearable, functional and scalable e-textiles has intensified, little consideration has been given to the end-of-life implications of embedded electronics in our garments or medical devices. Nanomaterials are an integral part of new developments that seek to find ever more discreet ways to embed connectivity and function into e-textiles, bringing another element of complexity to an already problematic waste stream. There has been surprisingly little thought or research into how e-textiles can be disassembled, discarded or repurposed; furthermore, there has been little consideration into the use of raw materials, processing or disposal in line with European Circularity or Waste Electronic and Electrical Equipment (WEEE) directives. With Google [2] promising to embed our technology so that it "disappears" into the background, merging seamlessly into our lives and clothing in a world of "ambient computing", it appears that developments in the field are clearly well funded and moving at pace. Meanwhile, there is often a failure to mention sustainability, or end-of-life management.

2. Legislation and Regulation

The legislative landscape in relation to textiles, nanomaterials and electronics is varied. Textile waste is not officially regulated or managed with any enforceable standards globally (although the EU will bring in kerbside collection by 2025), relying on voluntary standards or regulations. Nanomaterials have no recovery or disposal policy, G20 Insights report (2017) [3] recommended member states "work together to develop efficient and unified policy efforts to regulate the field of nanotechnology, . . . (to) apply Precautionary Principle to all nanotechnology developments", also highlighting that the toxicity and chemical

reactivity of nanoparticles are concerning. This means efforts and funding should be channelled into the future management of nanowaste [4]. A total of 27 EU countries, the UK and 41 others outside of the EU have national e-waste legislation/policy or regulation in place [5]; despite this, there is an ever-growing volume of electronics going to landfill with only 17% of electronic waste being recycled globally. It appears there is still a long way to go on waste management, as UK landfill textile waste is estimated to rise by 60% to 148 million tonnes by 2030 [6]. These facts provide an opportunity to bring new e-textiles to market with a known strategy and framework for disposal and recovery, which could lead the way for future policy relating to waste across electronics, textiles and nanomaterials. Current evidence from recycling facilities suggests the biggest barrier for e-textiles recovery is that the infrastructure does not exist to manage mixed-material waste. For example, when an electronics recycling facility receives e-textiles, they are not obligated or equipped to recycle the textile part of the product and will discard to landfill once any electrical parts, e.g., batteries, recoverable metals or plastics, are removed. Smart clothing waste is beginning to arrive in electronic recycling facilities, where recoverable electronic components can be removed and processed, leaving the textile portion discarded into landfill or incinerated.

Whilst considering legislation development that encourages innovation in e-textiles, it is worth considering previous debate and research on policy. As far back as 1800, policy makers and theorists such as Bentham [7], and more recently Marciniak [8], advocate preventative legislation, agreeing that repairing damage is worse than adopting anticipatory policy principles. The arguments against preventative legislation are strong, as a potential consequence is loss of individual and societal freedoms. However, there is differentiation and debate between prevention and the so-called 'precautionary principle', highlighted by Marciniak, who acknowledges that environmental politics have led to more precautionary directives or regulation. In relation to e-textiles and their development, the waste impact is speculative, but can be based on an understanding of waste habits in related fields such as electronics and textiles. It is safe to say that preventative measures prior to e-textile waste reaching unmanageable levels are advisable and would encourage innovation in disposal and reuse. Within the EU, precautionary principles have been adopted, not without debate on effective implementation. However, retrospectively, this approach may have avoided some previous environmental issues such as asbestosis and dichlorodiphenyltrichloroethane (DDT) [9].

Legislation and regulation are closely linked, but according to Kosti et al. 2019 [10], there is little academic discourse on the subject. "Legislation and regulation increasingly impact our lives", and interplay between the two can make a difference as to how effective policy can be. Often regulation or standards are voluntary, relying on industry to comply. Policy makers have made use of voluntary standards and regulations as they are often designed by industry to bring stakeholders on board, particularly in environmental areas [11]. Records on textile and e-waste do not reflect well on the dynamic between voluntary regulation, standards and policy, though that is not to say the system cannot work in future.

3. Design for Disassembly

Dr Joseph Chiodo is the instigator of research into "Active Disassembly" [12] which was recognised by the Ellen McArthur Foundation [13] report which attracted academic and political attention. The report makes the case for a circular-based fashion system, stating that there is a need to "align clothing design and recycling processes". Both advocate the design phase as key to tackling waste by enabling circularity through reuse and disassembly. Chiodo's research in car manufacturing has influenced the industry to embed disassembly in design and manufacture, bringing economic gains in the process.

WEEE already contains a requirement to design for recovery. However, the main focus is on how to manage products at end of life, while the "design" part is often lost with little or no reporting, despite the added expectations of extended user responsibility (EPR) schemes. "Few or no quantitative targets or indicators on eco-design and waste

prevention have been developed within EPR schemes, as all of them are designed around main objectives on waste collection and recycling [14]". Manufacturers are required to build strategies for disassembly into the design of their products. In the past, designing products such as cars rarely involved consideration of disposal, although some companies, such as BMW, have been proactive in this respect.

Many researchers have recognized the need for design to be central to waste issues, Preston, F. (2012) [15] suggests "improving product design, (and) improving capture of products at end of life". Goldsworthy, K. and Ellams, D. (2019) [16] demonstrate that design should be considered an important part of a circular economy model by creating a "unique opportunity to develop a systematic, life cycle stakeholder approach from which to explore 'what designers need to know when designing for circularity". Bocken, N. M. P. et al. (2016) [17] echo Goldsworthy in their recommendation that circular considerations are taken into account during the early speculative design phase of product development. Bocken highlights Circular Design and Circular Economics require a combination of science, business and design to be in synergy.

Design for disassembly principles, therefore, are a key part of influencing circular aspirations and an important factor in potentially aiding waste management. Moreno, M. et al. (2016) [18] advocate that designer's should be "solution providers" rather than "object creators" and the 2016–2020 ENTeR project [19] identified missing elements in the EU Circular Economy Directive, such as specific targets for waste prevention, reuse and specifications on ecodesign. The UK Environmental Audit Committee (2019) "Fixing fashion" [20] focused on EPR as a way to influence product design for disassembly. Finally, the EEA 2019 [21] review of policy shows one of the lowest areas of policy involvement is eco-design both from a market and awareness perspective. Empowering this area of the product life cycle would enable products to have end-of-life planning built in.

4. Testing Active Disassembly in Fashion Design

To investigate the effect of design for disassembly principles on conception and development process, 700 fashion design students will be offered the opportunity to submit a Design for Disassembly Form for each new product they make, disclosing how each item should be dismantled and/or disposed of at the end of its life. The students have been given a full briefing on the context and principles. Follow-up support will be offered to aid student thinking and to discuss how they might make changes to their process, materials or final outcome, or more importantly where they are struggling to produce the desired outcome within the boundaries of design for disassembly. Once all forms are submitted and products made, some students will be invited to follow-up in focus groups where they will be asked to discuss how their overall designs, choice of materials and assembly methods changed. Early results show that alterations are being made to products in order to mitigate landfill waste. This challenge will be taken to e-textiles researchers and development teams, to see if they would make changes to materials, manufacturing methods or overall design. Results from this study will inform discussion around the development of a sustainable waste framework, underpinning policy development for e-textiles waste.

5. Conclusions and Further Study

Figure 1 shows the aspirations of this study where basing policy and legislation for e-textiles on design for disassembly principles will provide product transparency. It will then be clear at 'end of life' how a product can be disposed of and what parts are not recyclable, reusable or biodegradable. Making design for disposal and disassembly central to policy would lead to material and product and process innovation. The overarching policy would be anticipatory, in that e-textiles are a new product without an already established end-of-life story. It would contribute to new dynamic policy principles, filling the current gap in e-textiles waste legislation. If design for disassembly principles are adopted as part of policy design for waste, as a result of this study, it will be evolutionary and directly related to innovation, bringing responsibility to inventors and producers. Once the final tests have

been undertaken and analysed, a policy framework will be drafted. This will be tested further through industry focus groups, policy experts and other key stakeholders before being presented as a final policy recommendation.

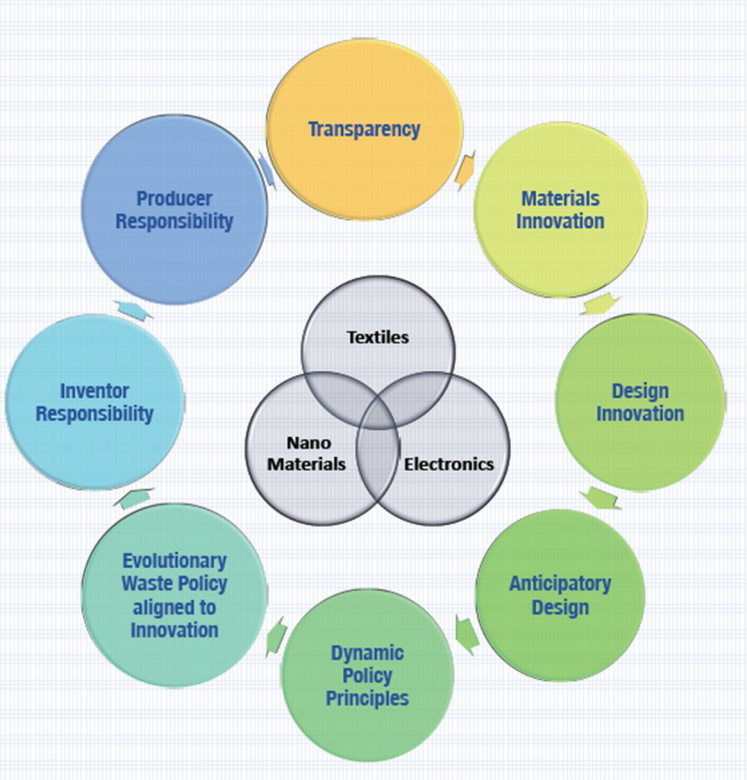

Figure 1. Aims of e-textiles waste design for disassembly waste policy.

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Institutional Review Board Statement: Ethical review and approval are being sought by the UAL ethics committee before undertaking the research that includes participants.

Informed Consent Statement: Informed consent will be obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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