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**PERSPECTIVE**
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# Reflecting on the Disposal of Electronic Textiles in the Era of Sustainability

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## Abstract

**Purpose:** This perspective article reflects on end-of-life solutions and the disposal of electronic textiles. The article first provides a brief overview of the area to non-specialists. Publishing trends in the area are then examined with an emphasis on end-of-life, disposal, and recycling. The article then reflects on a process developed to understand the interaction between components of electronic textiles with a view to improving material selection and disassembly at end-of-life. Finally, the article presents a discussion focused on the authors' views on this topic.

**Methodology/Design:** Two distinct methods are employed in this article. First, the Scopus database has been used to identify publishing trends related to electronic textile sustainability. Second, a teardown analysis of a commercially available electronic textile hat has been carried out using an established framework from the literature. The framework has been used to understand the interaction between the components of electronic textiles with a view to improving disassembly at end-of-life.

**Findings:** This perspective article highlights that while end-of-life solutions for electronic textiles are complex, there has been increasing academic interest in this topic. It discusses the use of an established tear-down analysis framework and offers insights from the authors on employing this.

**Practical and Social Implications:** While this perspective article does not provide a solution to the ongoing challenges with the disposal of electronic textiles at the end of their lives, it discusses topics that the authors believe are important to the area and emphasises a method for improving electronic textile sustainability (designing for end-of-life). As a perspective article, this work is presented to educate, provide a point-of-discussion, and spark further debate on this important topic.

**Originality:** While interest in electronic textile sustainability and disposal has grown in recent years, the academic literature in this area is still limited. This work offers a concise overview of key factors related to end-of-life consideration for E-textiles as-of 2026.

**Keywords**
Sustainability, disposal, recycling, post-consumer waste, end-of-life, electronic textiles, e-textiles, smart textiles.

## 1 | INTRODUCTION

Environmental sustainability has been increasingly discussed in the area of electronic textiles (E-textiles; discussed in section 2), due to the complexity of the challenge, and ongoing discourse around both electronics and textiles' sustainability. Sustainability more generally describes the meeting of current needs in a way that can be maintained. Key factors of environmental sustainability include the maintenance of natural resources and the management of waste, which for a product can include production waste and post-consumer waste. Both the textiles and electronics industries generate significant post-consumer waste. Environmental sustainability considerations for E-textiles must be discussed in the context of the wider ecosystem of both academia and industry. As frequently as sentiments such as 'electronic textiles are an exciting new area' are used, the fundamental concept of combining electronics with textiles has a long history (Hughes-Riley, Dias & Cork, 2018). The electric blanket, for example, is a textile with electronic functionality that was first developed in 1912 by Sidney Irwin Russel. This led to a commercial product in 1920. The electric blanket market has expanded over the years and was worth $1.15 billion in 2024 (Grand View Research, 2019). Significant quantities of

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waste electronic textile products have therefore been generated for over one hundred years. While heated products comprise a significant market share, commercial E-textile products have expanded into other applications, including light-up garments and fitness-tracking products (such as heart-rate-monitoring bras). To address the responsible disposal of electrical waste, the Waste Electrical and Electronic Equipment (WEEE) regulations (UK Government, 2013) were developed. WEEE regulations have been adopted by a number of countries, including European Union countries and the United Kingdom. Eighty-one nations had some form of E-waste regulations in 2023 (Serpe et al., 2025). As E-textiles are a type of electronic product, the WEEE regulations cover E-textiles as long as the electronics aspect is fundamental to the product. There are, however, exceptions; the UK Government website provides a non-EEE product example as:

> 'clothing or textiles where the electrical part can be removed before cleaning, for example pillow speakers or earphones in a cap' (GOV.UK, 2025).

Due to these regulations, many E-textile products do adhere to the WEEE regulations and feature WEEE markings; for example, the Homefront Non-Woven Fitted Electric Blanket (Electric-Blankets.co.uk, n.d. -a). Some companies, such as Electric-Blankets (Electric-Blankets.co.uk, n.d. -b), offer take-back schemes, which would help facilitate consumers disposing of these E-textile products correctly. Despite this, many consumers may simply not know what to do with old, unwanted or broken E-textiles, or simply not care about their correct disposal. A study from 2022 in Brazil showed that 26 % of participants disposed of waste electricals in general waste (Prezotto et al., 2022), highlighting a lack of care of some consumers (to the knowledge of the authors, a similar study specifically investigating E-textiles has not been conducted). Even if E-textile products are disposed of in the correct waste stream, the matter of correctly processing the waste and recycling components, where possible, remains. Well-established integration methods for combining electronics and textiles can lead to products that are challenging to disassemble (Perera et al., 2024). The use of adhesives can be important to ensure durability; however, this can also make deconstructing E-textiles challenging at best, if not practically or economically impossible. Beyond this, even if an E-textile product can be disassembled correctly, many common individual components of the E-textiles are challenging to re-use or recycle. For example, synthetic fabrics such as polyester are difficult to recycle; this is further complicated when fibres are blended with other textile yarns (Dissanayake & Weerasinghe, 2021).

The general direction of E-textile development has been to increasingly integrate the electronics into the textile so that it is more difficult for the user to feel the embedded electronic components and consequently make the wearable more comfortable. In principle, this makes the final product more desirable to the user and may make it less likely that they will dispose of the product prematurely. While the deeper integration of electronics into the textile may improve the look and feel of the product, this deeper integration may also make it more challenging to correctly disassemble and recycle the textile at its end-of-life. There has been interest in academia to understand and address the end-of-life of E-textile products, however work has been limited (discussed in section 2). A review by Veske and Ilén in 2020 evaluated end-of-life solutions for E-textiles, only identifying 18 publications focused on this issue at the time (Veske & Ilén, 2020). A later review by Tadesse et al. in 2025 reviewed smart textile recycling literature, and highlighted that existing textile recycling techniques are often inadequate for E-textile recycling (Tadesse et al., 2025). The review also discussed design for sustainability, which is an approach that has been adopted by some to increase longevity and optimising material choices.

There has also been an increase in literature regarding smart textile materials for sustainable manufacturing, with many focusing on the use of biodegradable materials (for example, Hu et al., 2022 and Dulal et al., 2025). The adoption of a circular economy model for E-textile products would be desirable to create a closed-loop system. Shi et al. have proposed adopting the '4R concept' for E-textiles. In their concept, the four R's represent repair, recycle, replace, and reduce (Shi et al., 2023). Closed-loop recycling has also been proposed, and Dulal et al. have demonstrated the viability of the approach for graphene-based E-textiles (Dulal et al., 2024). While significant work has focused on developing novel materials to improve the sustainability of new products, this does not address the need to improve the recyclability or ease of disposal of E-textiles constructed using more established techniques. It is the view of the authors that traditional construction techniques and materials will continue to be used for many years, regardless of technological innovations and therefore believe that two key areas that must be addressed in the near future are: improving E-textile design to simplify repair, reuse, and end-of-life disposal, and to further develop recycling methods to address existing E-textile product waste at end-of-life. This article is intended to initiate debate in this important area and provide a brief introduction to

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key points in the topic for non-specialists. It also provides a current appraisal of publishing trends in this area (section 2) and a reflection on applying a tool developed for understanding the sustainability of E-textiles (section 3). As a perspective article, this work, by its nature, is subjective and is intended to express the views of the authors on this topic at this point in time (section 4).

## 2 | INCREASING ACADEMIC INTEREST

Considering that electronic textile products have been on the market for over a century, academic interest in E-textile sustainability was historically very limited. Using the Scopus database (Scopus, Elsevier B.V., Amsterdam, Netherlands) and searching within the article title, abstract, and keywords fields, the publication trends regarding E-textiles and sustainability were explored. The following search term was used: ("Smart Textile" OR "Electronic Textile" OR "E-textile" OR "Intelligent Textile") AND ("end-of-life" OR "end of life" OR "sustainability" OR "sustainable" OR "life cycle assessment" OR "disposal" OR "repair" OR "repairability" OR "reparability" OR "recycling" OR "recycle"). The search was conducted on 30th April 2026 and covered 2001 to 2026 (2001 was the earliest date allowed), with 812 documents located. The publishing trends tell a clear story, with 2016 being the first year that ten articles fitting this search criteria were published. A steady increase in publications led to 256 documents in 2025 (Figure 1a). The terms "sustainability" and "sustainable" were removed to focus the search on end-of-life solutions, and this yielded significantly fewer results (170). As shown in Figure 1b, 2021 was the first year where ten articles fitting this search criteria were published. While the above shows an increased interest in topics surrounding E-textile sustainability and disposal in recent years, it also highlights the historic lack of academic interest in the subject.

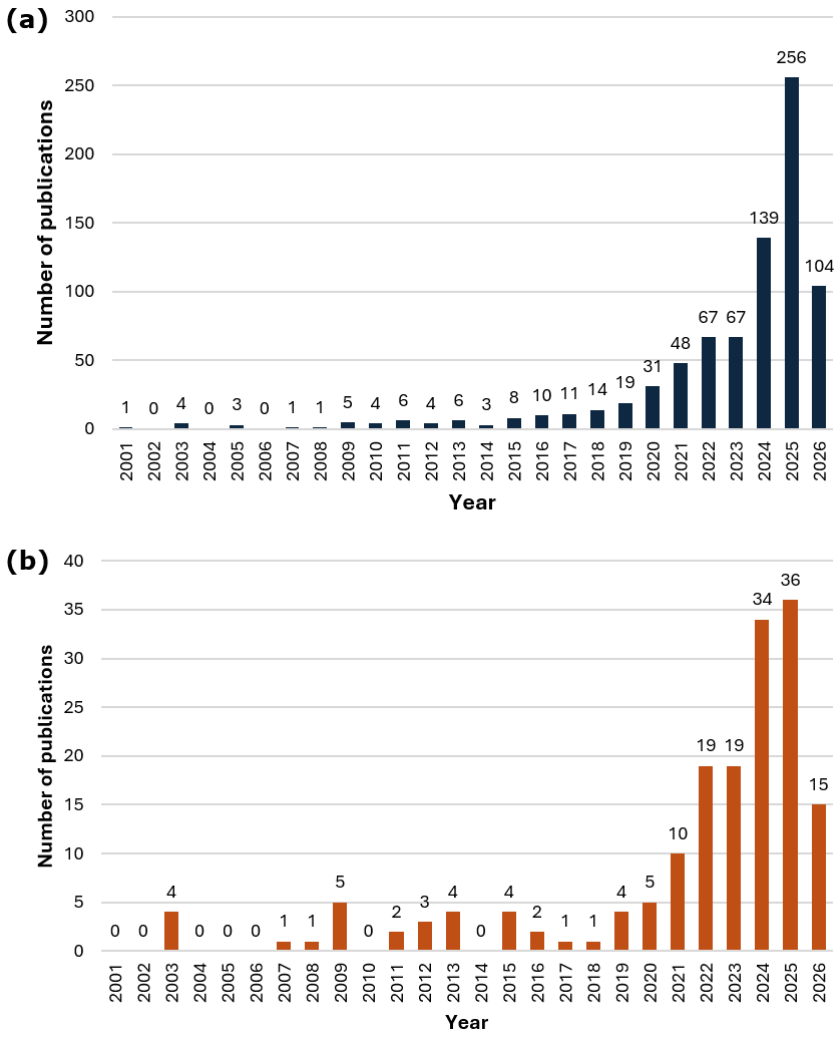



**Figure 1.** Publication trends relating to electronic textile sustainability. (a) Search terms have been chosen to capture the full spectrum of sustainability research related to electronic textiles. (b) Search terms were focused on end-of-life solutions for electronic textiles.

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## 3 | UNDERSTANDING SUSTAINABLE DESIGN FOR ELECTRONIC TEXTILES

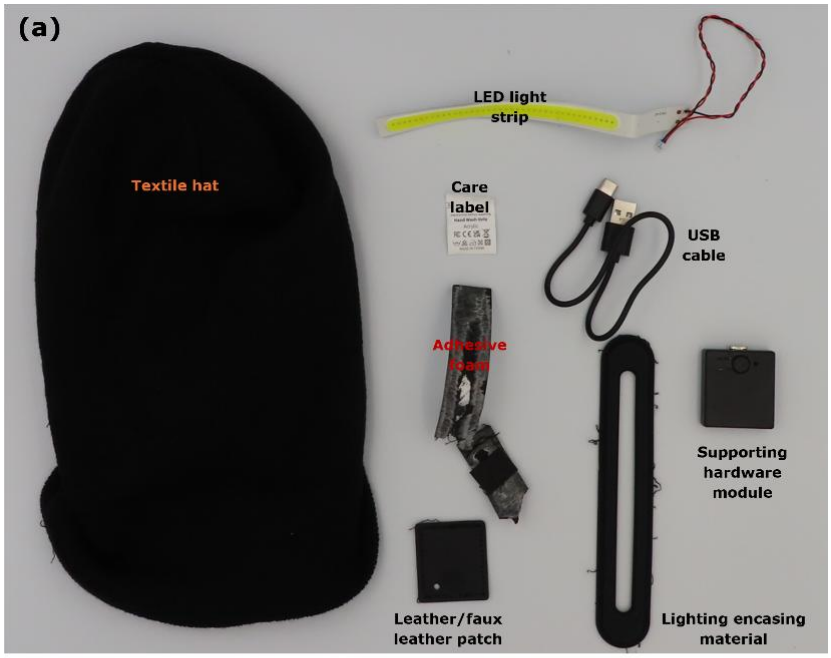
The approach adopted by the authors to understanding the sustainability of E-textiles for both commercial products and the authors' own prototypes has historically adopted a two-phase process described in detail by Perera et al. (2024) and presented at the 2nd Institute of Textiles & Fashion Professionals Ghana International Conference (Hughes-Riley, 2025). The process begins with a product disassembly built on a previously used approach in the literature (Hardy, Wickenden & McLaren, 2020). When initially developing the method, this was conducted in a workshop context, but later teardowns, such as the example in Figure 2(a), have been conducted by individuals or small groups. By disassembling the product or prototype, the interactions between the different components can be understood, and these are used to create an interaction matrix, which is based on a design matrix (see Figure 2(b)) for an example. Interaction matrices can therefore be used to identify how different components interact with each other, and colour coding can be applied to identify unsustainable materials and factors affecting the sustainability of the product. Traditionally, the material suitability has focused on the ability to recycle or re-use the material, if it is biodegradable, or if it is particularly harmful to the environment (Perera et al., 2024). Orange is used to highlight a component that is unsustainable in some way but could be replaced by a more sustainable alternative. Red highlights a critical component that affects the overall sustainability of the product. Following the development of the matrix, Kuusk's sustainability framework (Kuusk, 2016) was applied to help identify modifications that could be made to improve a product. Figure 2 shows an example of a light-up hat that was purchased from Amazon (Unisex LED Beanie Cap; Anhrnala, further company details unavailable) (Amazon.co.uk, n.d.). The hat has been disassembled, Figure 2(a), and an interaction matrix exploring how different components relate to one another has been created (Figure 2(b)).

A major issue for recycling this product, and something that the authors have observed with other products in the past, is the very limited information on the constituent materials, with only 'acrylic' stated on the label (presumably relating to the constituents of the textile hat itself). Acrylic is challenging to recycle and is not biodegradable, however this could easily be replaced with an alternative material such as wool. A lack of material details makes it difficult to further analyse the product and identify materials that are environmentally harmful to produce, are from an unsustainable source, or are difficult to recycle or dispose of. The label does include the WEEE symbol, showing consumers that this is an electronic product and should not be discarded with conventional waste. As a further positive, the product used stitching as the main means of construction, which does simplify disassembly. There was only one use of adhesive (a double-side foam tape), which could potentially be replaced. The product label states, 'hand wash only' and that the electronics must be removed before washing, with the Amazon listing further stating that the product is not waterproof. This suggests that potentially only surface cleaning is possible. The difficulty in cleaning the product may limit its service life. By not being waterproof, it is also possible that the product may fail due to use (for example, due to it raining). This analysis allows for points of improvement to be identified. In the case of the light-up hat, improving the labelling would significantly enhance the sustainable credentials of the product, as this may facilitate disassembly and correct disposal at end-of-life. It is possible that material choices could also be improved. As the hat is hand-wash only, the use of more robust materials may extend the product's lifetime; however, there may ultimately be trade-offs between the use of more robust materials and the sustainability of those materials. In many products that the authors have analysed, adhesives and glues are used to make products more robust, but this also makes them more challenging to disassemble at end-of-life. This complete framework has been applied to E-textile prototypes developed in the authors' research group (Perera et al., 2024; Ehelagasthenna et al., 2025) with the aim of improving their sustainability at an early stage. The intention is to apply the framework iteratively as the prototypes develop to ensure that sustainable practices are considered at each point in the design process.

On reflection, having now applied the framework to a variety of products and prototypes, the authors believe that the complete framework is a useful tool for analysing completed products, and through this insight, the community (both academia and industry) can learn good practices and identify things to avoid when developing new products. For prototype innovations where the constituent parts are well understood, a meaningful interaction matrix can be developed without a teardown. The Kuusk framework may also hold less relevance for early-stage innovations. For example, sustainability quality 8 'Building Relationships' may not be something being considered for a prototype, but it is much more important for a product on the market.

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(a)




(b)

| Component | Environment | Textile hat | Lighting encasing material | Leather/faux leather patch | Adhesive foam | LED light strip | USB cable | Supporting hardware module | Care label | Stiches |
|---|---|---|---|---|---|---|---|---|---|---|
| Textile hat (acrylic) | Difficult to recycle | | Stitched together | Stitched together | Weakly attached | X | X | Contained in pocket | Stitched together | Used to hold product together |
| Lighting encasing material | Potentially can be recycled however the composition is unknown | Stitched together | | X | Attached via adhesive | In contact | X | X | X | Used to hold product together |
| Leather/faux leather patch | Potentially can be recycled however the composition is unknown | Stitched together | X | | X | X | X | X | X | Used to hold product together |
| Adhesive foam | Likely needs to be disposed of in landfill | Weakly attached | Attached | X | | Attached | X | X | X | X |
| LED light strip | Can be recycled through electronics recycling routes | X | In contact | X | Attached | | X | Connected via two-pin lead | X | X |
| USB cable | Can be re-used in current state | Touching | X | X | X | X | | Inserted into (when relevant) | X | X |
| Supporting hardware module | Can be recycled through electronics recycling routes | Contained in pocket | X | X | X | Connected via two-pin lead | Inserted (when relevant) | | X | X |
| Care label | Material unknown making it difficult to recycle | Stitched onto | X | X | X | X | X | X | | X |
| Stiches (believed to be natural fibre) | Material unknown making it difficult to recycle | Used to hold product together | Used to hold product together | Used to hold product together | X | X | X | X | Used to hold product together | |

**Figure 2.** (a) An annotated photograph of the dissembled light-up hat (author's own image). (b) Interaction matrix for the product.

## 4 | DISCUSSION

This perspective article has discussed three key topics related to E-textile disposal that the authors believe are important: Legislation and compliance, academic interest, and designing for end-of-life. This is a large and complex area, and by highlighting these three topics, the authors are not stating that other considerations lack importance. Some legislation surrounding the disposal of E-textiles is in place; however, it is unclear from available information to what degree consumers adhere to this, and how E-textile products are typically processed at end-of-life. The authors have observed that multiple commercial E-textile products make significant use of adhesives, which makes disassembly for repair or recycling challenging. As shown in the example in this article, details on the constituent materials are often not forthcoming, making attempts at recycling challenging. As more methods for incorporating electronics into textiles make it to the market, material types and combinations will grow, which may make it more challenging to recycle, repair, or reuse these innovations. Conversely, the development and use of new and novel materials, such as biodegradable conductive materials, may allow for easier


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disposal in some cases; however, this will be dependent on their adoption. A solution may be to offer take-back schemes, and this is already adopted by some companies. If a product is returned to its original manufacturer, they will be best positioned to know what to do with it, and their responsibility for dealing with the waste will incentivise better design.

While academic interest has grown in this topic significantly in recent years, the historic lack of literature in the area is concerning, given that E-textile devices have been commercially available for over a century. This does raise questions about how earlier products were designed, how they were disposed of, and how many currently in-use products have been developed without the end-of-life being considered. This highlights an important need to develop new and improved recycling practices suitable for existing E-textile products. The author believes that product teardowns and analysis can be useful for understanding good practice when creating new E-textiles, and can help identify areas where improvement is needed. In the example in this article, it was identified that a lack of transparency over the materials used to create the light-up hat would make it challenging to correctly dispose of the product at its end-of-life. Adding further details to a product label would be a simple improvement that could be easily implemented. Beyond physical product tear-downs, the authors believe that a similar process (essentially a 'virtual tear-down') can be useful when developing prototypes, and that by applying this method iteratively, sustainability can be correctly considered at each stage of the development process

## 5 | CONCLUSION

This short perspective article discusses electronic textile sustainability with a focus on disposal. Ultimately, this is a complex topic, cross-cutting multiple disciplines, and the matter of designing E-textiles in a sustainable way and dealing with these products at the end of their lives is challenging and requires significant research. While there has been an increase in academic research in this topic in recent years, this has historically been very limited. The author would propose that future products need to be designed correctly to maximise service life and minimise barriers to disassembly for repair or recycling at end-of-life. An established framework for analysing existing products has been discussed and the personal reflections of the authors on using the framework have been provided. There is clear scope for further research focused on E-textile disposal. It is important that future innovations and products are correctly designed with sustainability and end-of-life considered from the start, and there are opportunities to develop new frameworks and processes to ensure that this happens. For existing products, new recycling methods should be developed to ensure that existing and future E-textile waste can be disposed of in a responsible manner.

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## DATA AVAILABILITY STATEMENT

All new data generated is presented in the article.

## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

Generative and assistive AI were not used in the writing process for this article.

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