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# Technology-Driven E-Waste Management: Knowledge Mapping and Bibliometric Insights of Global Research Trends

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## Abstract

*Electronic waste (e-waste) is now among the most rapidly expanding global environmental problems, present danger to sustainable development. Between 2010 and 2022, the world produced an estimated 34 million metric tons of e-waste per year, more than doubling to 62 million metric tons/year over the 12-year period, a ratio that by all means was comparable to an alarming 82%. This work analyses the e-waste management related technology research literature using a bibliometric review of 362 publications obtained from the Scopus database for the mid-1977 to mid-2025 period. Descriptive analysis was done to examine annual publication growth, citation features, authorship patterns, and international collaboration using the Biblioshiny interface of the Bibliometrix R package. The keyword co-occurrence analysis indicated that main research frames included recycling technologies, sustainability integration, environmental impact, resources recovery, etc. By mapping out the intellectual structure and dynamic evolution of academic contributions, the research provides informative implications about the intellectual landscape of technology-driven e-waste management and topics therein that can be investigated further in future studies.*

**Keywords:** *E-Waste, Technological Advancement, Bibliometric Analysis*

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## INTRODUCTION

Electronic waste (e-waste) is growing rapidly and has become a sizeable environmental and socio-economic threat globally. Technological advances combined with increasing consumer electronics have led to shorter product life cycle and high volume of devices generation like never before (Goyal & Gupta, 2024). According to the United Nations, e-waste production more than doubled from 34 million metric tons in 2010 to 62 million metric tons in 2022, representing an 82% increase within 12 years, with a pressing need for sustainable management options (Adrian et al., 2020). If e-waste is not disposed of properly (landfilling, open burning, informal recycling), toxic substances (lead, mercury, cadmium, brominated flame retardants, etc.) can be released, which are released into the soil, water and air and can pose serious risks to the ecosystem (Zhuang, 2019; Holuszko et al., 2022) as well as to human health.

In the last few years, several technological interventions have been introduced in response to these challenges. There are promising recycling technologies due to their ability to recover valuable materials with less pollution such as mechanical recycling, hydrometallurgical recycling, and pyrometallurgical recycling (Ikhlayel, 2017). Automated disassembly systems as well as artificial intelligence (AI)-based waste sorting transform recycling efficiency, they improve material recovery rates, and they reduce contamination (Madhav et al., 2022; Liu et al., 2011). Life Cycle Assessment (LCA) tools, when these are applied, further do enable researchers to then evaluate environmental impacts across the entire recycling process since they identify hotspots and inform sustainable process design (Wu et al., 2020). These technological advancements have been complemented through the promotion of circular economy principles. These principles do stress product repairability as well as upgradeability and recyclability in order to extend product lifespans for the reduction of e-waste generation (Golsteijn & Valencia Martinez, 2017).

However, multiple barriers persist. This is more common in developing countries where it is also done informally, in unsafe and environmentally damaging ways, including acid leaching and open burning, causing environmental pollution and health problems (Robinson, 2009). Regulatory and policy loopholes, inadequate enforcement, un-standardized recycling processes, and poor public awareness also contribute to the management of e-waste being less effective (Singh & Ogunseitan, 2022). The cross-border transfer of e-waste aggravates these problems, thus shifting them to countries with unregulated facilities for safe disposal of toxic materials

(Abalansa et al., 2021). Joining forces across continents and national borders to cooperate on action at a global level, strengthen regulation and involve industry and consumers more is the only way to address them.

This work then seeks to contribute to the subject by conducting a systematic literature review of sustainable e-waste management from a technological angle using bibliometric methods. We seek to map key institutions, countries, authors, and papers through the "Biblioshiny" interface in the Bibliometrix 3.0 package in R, as well as identify core research themes using science mapping approaches like co-occurrence and co-citation analysis. The use of such research instruments helps us to perform a thorough analysis of the literature, disentangle recent developments, pinpoint gaps in the previous work and propose future lines of research.

## DATA AND METHODOLOGY

### Data

For the current research, the Scopus database was used in order to find publication records. Even though certain limitations may exist when just a single database is used, Scopus offers wide-ranging multidisciplinary coverage of peer-reviewed literature as well as journal articles, books, conference proceedings, also review papers. Because of how it indexes with quality searches and filters in such an advanced way, and tracks citations comprehensively, it is actually a preferred choice for those bibliometric studies (Donthu et al., 2021a; Verma & Gustafsson, 2020).

Careful design for a search strategy ensured inclusion for literature directly relevant to the research objectives. For the capturing of publications, researchers applied keywords as well as Boolean operators. These publications focused upon sustainable e-waste management, as well as technology-based interventions. Additional filters were set throughout the process. These filters included publications in English only. The search resulted in what was a dataset of 362 research articles. The bibliometric analysis was based upon that dataset.

### Methodology

This study used bibliometric analysis to examine the literature systematically regarding technology-enabled e-waste management. Bibliometric analysis is a quantitative method used for identifying research trends and evaluating scientific publications to map a field's intellectual structure (Donthu et al., 2020b; Verma & Gustafsson, 2020). Researchers use it more in environmental management studies for collaboration patterns, leading contributors, thematic focus areas, and knowledge evolution because it produces those results (Donthu et al., 2021a; Khan et al., 2021). For the bibliometric analysis, Biblioshiny was used it is the web-based interface of the Bibliometrix 3.0 package in RStudio. Biblioshiny enables a variety of science mapping techniques such as these: Co-authorship analysis explores collaborative networks among authors, institutions, and countries; Co-citation analysis identifies influential studies and conceptual linkages within the literature; Keyword co-occurrence analysis reveals thematic structures and emerging research topics.

A structured search in Scopus used keyword combinations connected with sustainable development, economic development, with e-waste management, also it used Boolean operators to refine results. The dataset was limited in publications. Filters had been applied for the English-language content. The final dataset had 362 research articles published spanning 1977 to 2025.

## RESULTS

### Descriptive Analysis

The bibliometric dataset comprised 362 research articles published between 1977 and 2025 sourced from books, 331 different journals, also conference proceedings. The rate of annual growth that occurred in publications was 8.75% since it did indicate an accelerating scholarly interest within technology-driven e-waste management. Each document presented around 44.83 citations. The dataset cited a total of 40,367 references in all.

Collaboration among researchers remained prominent since there were 3.82 co-authors per document and 29.55% of publications resulted from international collaboration. In total, a sum of 2,576 authors contributed to the whole field, and yet single-authored papers numbered merely 85. This indicates that research in this domain is to a large extent team-based and multidisciplinary.

**Table 1: Descriptive Analysis of Data**

| Description | Results |
|---|---|
| Timespan | 1977–2025 |
| Sources (Journals, Books, etc.) | 331 |
| Documents | 741 |
| Annual Growth Rate (%) | 8.75 |
| Document Average Age | 6.44 |
| Average Citations per Document | 44.83 |
| References | 40,367 |
| DOCUMENT CONTENTS | |
| Keywords Plus (ID) | 5,052 |
| Author's Keywords (DE) | 2,453 |
| AUTHORS | |
| Authors | 2,576 |
| Authors of Single-authored Documents | 85 |
| AUTHORS' COLLABORATION | |
| Single-authored Documents | 87 |
| Co-authors per Document | 3.82 |
| International Co-authorship (%) | 29.55 |

Source: Data extracted from Scopus database.

## Annual Scientific Production

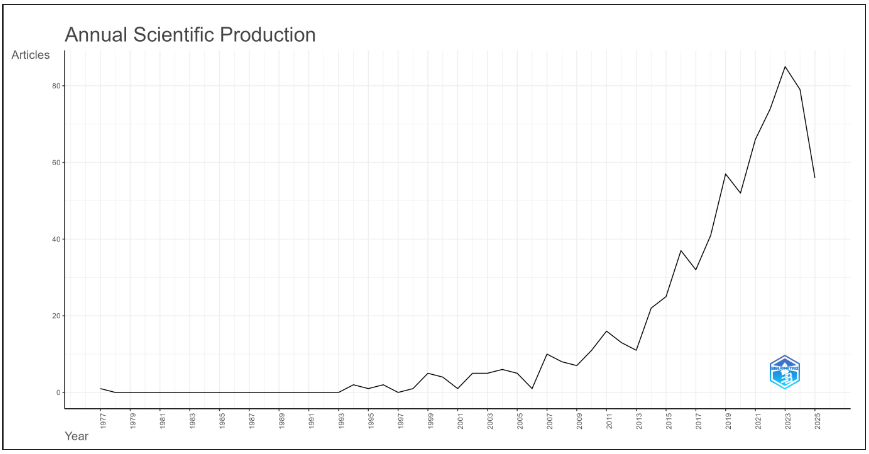


**Fig. 1: Annual Scientific Production**

Fig. 1 shows that before 2006, academics paid limited attention to the topic of e-waste management and technology. But post 2005, output gradually increases, maybe as consumer electronics rise also global awareness on e-waste hazards grows. There is a considerable and consistent increase in articles published yearly between 2006 and 2022 with a maximum of 85-90 article around 2022-2023. This could be because there has been an explosion in technology led waste management solutions (AI, IOT, Automation etc.). It is noted that there is a cut-off in production in 2025, that might be because the year is not finished yet.

## Influential Aspects of Technology Enabled E-Waste Management

### Most Influential Journals

To witness the impact of journals. Source influence and Brandford law is applied, Table 2 presents top 10 journals based on the total publication, total citations and h-index. Bornmann L, Daniel HD 2007 in their investigation wrote that h-index was considered as factual and reliable parameter to measure the scientific productivity of an individual. The global index (gindex) also appear in the table with g-index, we can have a more robust view of the global performance of a corpus where the papers are published; the g-index was created by Leo Egghe in 2006 and is similar to the h-index, but improving it.

**Table 2: Most Influential Journals**

| Sources | Articles |
|---|---|
| Resources, Conservation and Recycling | 106 |
| Journal of Cleaner Production | 104 |
| Sustainability (Switzerland) | 74 |
| Environment, Development and Sustainability | 16 |
| Journal of Industrial Ecology | 14 |
| Water (Switzerland) | 11 |
| Proceedings of the International Conference on Industrial Engineering and Operations Management | 8 |
| Ecological Economics | 6 |
| Business Strategy and the Environment | 5 |
| Environmental Impact Assessment Review | 5 |

**Table 3: Most Globally Cited Articles**

| Paper | DOI | Total Citations | TC per Year | Normalized TC |
|---|---|---|---|---|
| GHISELLINI P, 2016, J CLEAN PROD | 10.1016/j.jclepro.2015.09.007 | 4347 | 434.70 | 24.74 |
| HORBACH J, 2012, ECOL ECON | 10.1016/j.ecolecon.2012.04.005 | 1221 | 87.21 | 9.64 |
| NASCIMENTO DLM, 2019, J MANUF TECHNOL MANAGE | 10.1108/JMTM-03-2018-0071 | 725 | 103.57 | 11.39 |
| CENTOBELLI P, 2022, INF MAN-AGE | 10.1016/j.im.2021.103508 | 532 | 133.00 | 13.08 |
| NNOROM IC, 2008, RESOUR CON-SERV RECYCL | 10.1016/j.resconrec.2008.01.004 | 501 | 27.83 | 4.56 |
| DWIVEDI YK, 2022, INT J INF MANAGE | 10.1016/j.ijinfomgt.2021.102456 | 499 | 124.75 | 12.27 |
| KANG H-Y, 2005, RESOUR CON-SERV RECYCL | 10.1016/j.resconrec.2005.06.001 | 494 | 23.52 | 4.00 |
| NIŽETIĆ S, 2019, J CLEAN PROD | 10.1016/j.jclepro.2019.04.397 | 440 | 62.86 | 6.91 |
| REHFELD K-M, 2007, ECOL ECON | 10.1016/j.ecolecon.2006.02.003 | 413 | 21.74 | 5.51 |
| ISLAM A, 2020, J CLEAN PROD | 10.1016/j.jclepro.2019.118815 | 394 | 65.67 | 7.14 |

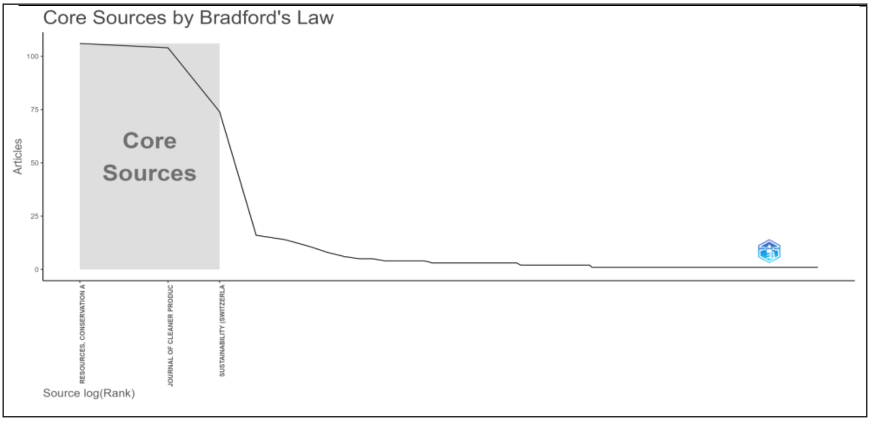


**Fig. 2**

In terms of e-waste and Technology, the top journals contributing to this subject area are Resources, Conservation and Recycling (106 documents), Journal of Cleaner Production (104 documents) and Sustainability (74 documents) is also noted. The three largest journals RCR, JCP, and Sustainability are found to account for 284 documents with the highest contribution, leading the area. This is also indicated by Bradford's Law Fig. 2. There would appear to be an increasing cross-discipline interest in this, from sustainability, via industrial ecology to economic strategy.

## Most Globally Cited Articles

As it is reflected on the Table 3, the paper by Ghissellini et al. (2016) in the J. of Cleaner Production is the most cited worldwide, having over 4347 citations. It also possesses the highest rate of annual citation (434.7/year) and the highest normalized total citations (24.74), which validates its underpinning role in the literature-presumably on circular economy or sustainable waste practices. Although Horbach (2012) is older, it has not yet become obsolete and has 87.21 citations/year and a good normalized citation index. As it is demonstrated by Nascimento (2019) and Centobelli (2022), newer publications are spreading like wildfire, especially in the management and innovation-focused journals.

## Most Influential Authors

Table 4 shows that the maximum h-index is 8 (by LIU Y), which explains why this author is the most influential in this dataset according to the number of publications cited. The m-index (range adjusting by publication years) lies between 0.167 and 1.6. LIU Y once more takes the lead with m-index = 1.6, implying swift and persistent impact as the research began publication in 2021- a good indicator of an active and influential researcher. DEWULF J has the best citations of 296 with 6 papers, but with a moderate h-index, indicates very good publications with good citations.

**Table 4: Most Influential Authors**

| Author | h_index | g_index | m_index | TC | NP | PY_start |
|---|---|---|---|---|---|---|
| LIU Y | 8 | 8 | 1.6 | 238 | 8 | 2021 |
| DEWULF J | 6 | 6 | 0.857 | 296 | 6 | 2019 |
| LI J | 6 | 7 | 0.5 | 191 | 7 | 2014 |
| LI Z | 6 | 6 | 0.5 | 224 | 6 | 2014 |
| CHEN Y | 5 | 6 | 1 | 181 | 6 | 2021 |
| LIU Z | 5 | 5 | 0.625 | 299 | 5 | 2018 |
| KLEMEŠ JJ | 4 | 4 | 0.235 | 580 | 4 | 2009 |
| LU W | 4 | 4 | 0.667 | 236 | 4 | 2020 |
| RECH-BERGER H | 4 | 4 | 0.167 | 672 | 4 | 2002 |
| WANG J | 4 | 5 | 0.333 | 119 | 5 | 2014 |


**Fig. 3**

It can be seen in the Fig. 3 that Waste Management (most noticeable), Recycling, Electronic Waste (E-waste) and Sustainable Development are the largest and most noticeable keywords. It also indicates that most of the papers have their focus on waste management and establishment of sustainable practices. Sustainable transitions have gained academic and practical attention as indicated by the use of such terms as circular economy, e-waste, and life cycle.

## Co-Occurrence Analysis

The Co-occurrence analysis indicates the keywords in various papers that were co-occurring in various papers that have been used in this study. Based on the co-occurrence network diagram (Fig. 4), two large clusters can be pointed out. The middle circle is the red one, comprising the central words such as waste management, recycling, electronic waste, e-waste, sustainable development. This cluster represents studies that are interested in practical waste management experiences, sustainability and integration of policy or technology (e.g., supply chain management, innovation, information technology).

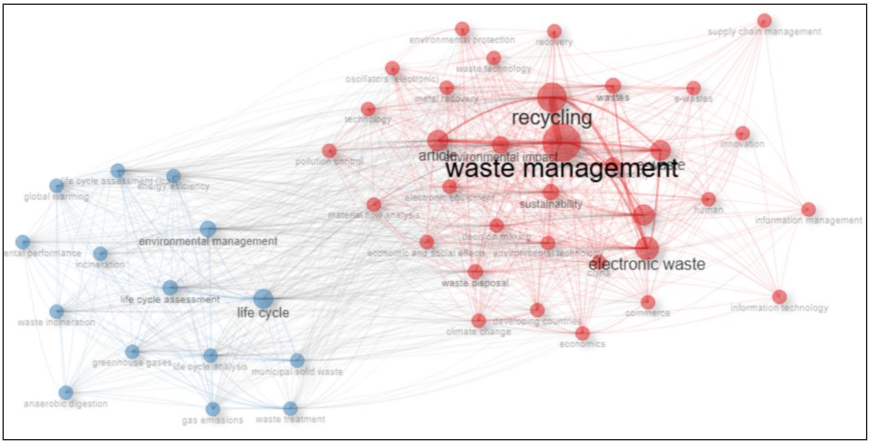


**Fig. 4**

## INTEGRATION OF INDIAN E-WASTE MANAGEMENT POLICY WITHING THE TECHNOLOGY-DRIVEN RESEARCH LANDSCAPE: POLICY GAPS AND FUTURE OPPORTUNITIES

The E-Waste (Management) Rules, which was first introduced in 2016 and since then updated twice in 2022 and most recently in 2024. The goal of primary regulatory framework for India's e-waste management system is to enhance effective implementation and diversifying its reach. This regulation has mandated Extended Producer Responsibility (EPR) which places the responsibility of collecting, recycling and disposing of electricals and electronics waste on producers.  According to the update e-waste rule, the makers, dismantlers, refurbishers and recyclers need to register themselves on centralized portal manage by the Central Pollution Control Board (CPCB). This ensures traceability and effective compliance monitoring system. This will help in formalizing the India's e-waste recycling ecosystem. According to MoEFCC, 2025 there are over 300 registered recyclers and 70 refurbishers and the annual capacity is over 22 lakh metric tons.

It is evident from the rise of scholarly publications around these advancements prompted government to take these initiatives such as expansion of approved recycling plants which is equipped with mechanical, hydrometallurgical, and pyrometallurgical methods. Despite the effort by the government, there is still a larger portion of e-waste disposal is done through informal and dangerous way like open burning, acid leaching which pose severe risk on human health and environment. (Singh & Ogunseitan, 2022). According to the bibliometric analysis, technological innovation, environmental effect assessment, and policy integration are key topic clusters necessary for sustainable e-waste management, demonstrating how Indian research is in line with global concerns.

## Comparative Policy Gaps: India vis-à-vis EU and China

There is significant policy gaps in India's e-waste policy both on regulatory and operational front as compared with European Union's waste Electrical and Electronic Equipment (WEEE) and robust e-waste governance system of China.

*Enforcement and Monitoring:* India e-waste regulation system is decentralized and place the onus on producers for collecting, recycling and disposal of e-waste. India's policy works on command and rule model. There is incompetent monitoring on ground level whereas EUs has well established compliance processes which ensure effective implementation by mandating collection target and objectives, transparent repoting and strict auditing. India's policy despite being progressive there is lack of proper implementation at the state and municipal levels which minimises the overall effectiveness (Madkali et al., 2023).

*Formal-Informal Sector Integration:* China's methodology successfully reduces hazardous recycling processes by integrating informal recyclers into formal operations through incentives and strict regulations. Despite governmental intentions, India's informal sector continues to dominate the country's economy and lacks the financial and technical resources necessary to move into the formal sector, causing environmental damage (Liu, Tanaka & Matsui, 2006) (Fortune India, 2021).

*Technological Advancement and Adoption:* Through robust regulations and focused investments both the EU and China is changing the whole recycling ecosystem by heavily promoting and integrating Artificial Intelligence tools and robotics for sorting, disassembling and closed loop chemical recovery. In India it is still at nascent stage. There commercial adoption and government initiative around technological recycling solutions is still in their infancy.

*Regulatory Clarity and Import Controls:* According to e-waste rule 2024, India regulatory framework lacks in proper definition in this field, which increases the enforcement challenges like counterfeit and illegal import of e-waste whereas China has imposed strict ban on e-waste import with clear segmentation of second-hand goods (Abalansa et al., 2021).

*Financial Incentivization:* India works on command-and-control rule whereas EU works on eco-design criteria, deposit-refund scheme and producer financial incentives. China also provides strong financial incentives for formal recycling of their e-waste. Stakeholder desire to improve collection efficiency and invest in recycling technologies is limited by the lack of strong financial incentives (Singh & Ogunseitan, 2022).

## Consequences for Upcoming Studies and Policy Formation

To facilitate the implementation of sustainable e-waste management, the bibliometric environment highlights the importance of the combination of research, policy, and industry partnership. In the case of India, this involves the formalization of the unorganized sector based on skill development and financial support, promotion of the use of technology, and establishment of stronger enforcement processes. Moreover, it is important to enhance awareness among the population, incorporate the concepts of the circular economy in the design of products, and adjust the policy to remove regulatory uncertainty.

The advancement of the synergy between the policymakers and the scholarly research output can trigger the innovation-driven frameworks, in particular, the topics of sustainability transitions, life cycle assessment, and resource recovery technologies. International cooperation, such as transfer of technology and coherent standards, as illustrated by EU-China collaboration can enable India to overcome the traditional barriers to establish a robust e-waste management ecosystem.

## CONCLUSION AND IMPLICATIONS

This paper is an in-depth bibliometric review of academic literature on technology-based e-waste management, using 362 research articles included in Scopus database between 1977 and 2025. The results show that there has been a continuously growing research interest in the area where the growth rate is 8.75 percent annually and a significant publication boom over the last ten years. The degree of collaboration, both at the national and international levels, is associated with the fact that e-waste management research is multidisciplinary and incorporates the environmental sciences, engineering, policy research, and sustainability practices.

Results indicate that the research output is centralized in a few powerful journals including Waste Management, Journal of Cleaner Production, and Resources, Conservation and Recycling. The most frequently mentioned sources are devoted to the assessment of risks to the environment, the evaluation of the lifecycle, and technological innovations in the recycling of raw materials, especially the recovery of precious and rare metals. The analysis of keyword co-occurrence reveals that the discipline is structured around four primary thematic clusters that include technological innovations, sustainability and policy integration, environmental impact studies, and resource recovery methods.

The lessons of this research arouse the need to make technological innovation and policy frameworks more integrated in order to overcome the increasing global e-waste problem. Advanced recycling technologies (AI-assisted sorting, robotics-based dismantling, and efficient chemical recovery) can be used to help policymakers make waste processing more efficient and minimize environmental damage. Stakeholders in the industry especially in the electronics manufacturing can embrace the concepts of the circular economy to make future products more repairable and recyclable so that the volume of waste produced at the origin reduces. The fact that the rate of international research cooperation was high in this paper also points to the possibility of cross-border joint ventures sharing best practices, standardizing recycling procedures and addressing informal recycling procedures that are common in developing economies. Technology-led e-waste management can emerge as a pillar of sustainable development and resource preservation by converging research, policy and industry action.

## REFERENCES

Abalansa, S., El Mahrad, B., Icely, J., & Newton, A. (2021). Electronic waste, an environmental problem exported to developing countries: The GOOD, the BAD and the UGLY. *Sustainability, 13*(9), 5302. doi:https://doi.org/10.3390/su13095302

Adrian, M., D'Amato, A., & Mazzocchi, P. (2020). E-waste management and the circular economy: A case study of policy and practice. *Journal of Cleaner Production, 276,* 123378. doi:https://doi.org/10.1016/j.jclepro.2020.123378

Donthu, N., Kumar, S., Pattnaik, D., & Lim, W. M. (2021a). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133,* 285–296. doi:https://doi.org/10.1016/j.jbusres.2021.04.070

Golsteijn, L., & Valencia Martínez, E. (2017). A circular economy approach to e-waste management. *Waste Management & Research, 35*(6), 565–568. doi:https://doi.org/10.1177/0734242X17707077

Goyal, P., & Gupta, S. (2024). Advances in e-waste recycling technologies: Opportunities and challenges. *Journal of Environmental Management, 352,* 119601. doi:https://doi.org/10.1016/j.jenvman.2023.119601

Holuszko, M., Kumar, A., & Espinosa, D. C. R. (2022). *Electronic waste: Recycling and reprocessing for a sustainable future.* Wiley-VCH. doi:https://doi.org/10.1002/9783527816392

Ikhlayel, M. (2017). An integrated approach to establish e-waste management systems for developing countries. *Journal of Cleaner Production, 153,* 215–230. doi:https://doi.org/10.1016/j.jclepro.2017.03.158

Khan, G. F., Park, H. W., & Park, D. (2021). A scientometric review of research on sustainable development goals. *Sustainability, 13*(2), 746. doi:https://doi.org/10.3390/su13020746

Liu, X., Tanaka, M., & Matsui, Y. (2011). Electrical and electronic waste management in China: Progress and the barriers to overcome. *Waste Management & Research, 29*(5), 549–558. doi:https://doi.org/10.1177/0734242X10379496

Madhav, A., Kumar, S., & Bharti, S. (2022). Artificial intelligence in waste management: A comprehensive review. *Resources, Conservation & Recycling Advances, 14,* 200074. doi:https://doi.org/10.1016/j.rcradv.2022.200074

Robinson, B. H. (2009). E-waste: An assessment of global production and environmental impacts. *Science of the Total Environment, 408*(2), 183–191. doi:https://doi.org/10.1016/j.scitotenv.2009.09.044

Singh, N., & Ogunseitan, O. A. (2022). E-waste: A global hazard and product stewardship perspectives for sustainable recycling. *Journal of Hazardous Materials, 423,* 127203. doi:https://doi.org/10.1016/j.jhazmat.2021.127203

Verma, S., & Gustafsson, A. (2020). Investigating the emerging COVID-19 research trends in the field of business and management: A bibliometric analysis approach. *Journal of Business Research, 118,* 253–261. doi:https://doi.org/10.1016/j.jbusres.2020.06.057

Wu, H., Zhang, S., & Xu, J. (2020). Environmental impacts of e-waste recycling: A life cycle assessment perspective. *Journal of Cleaner Production,* 276, 124180. doi:https://doi.org/10.1016/j.jclepro.2020.124180

Zhuang, X. (2019). The environmental and human health burdens of electronic waste recycling in China. *Environmental Science & Technology, 53*(7), 4009–4019. doi:https://doi.org/10.1021/acs.est.8b06417