*sustainability*

MDPI

*Review*

# Material Flow Analysis in WEEE Management for Circular Economy: A Content Review on Applications, Limitations, and Future Outlook

**Dhiya Durani Sofian Azizi [1], Marlia M. Hanafiah [1,2,*] and Kok Sin Woon [3]**

[1] Department of Earth Science and Environment, Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM), Bangi 43600, Selangor, Malaysia
[2] Centre for Tropical Climate Change System, Institute of Climate Change, Universiti Kebangsaan Malaysia (UKM), Bangi 43600, Selangor, Malaysia
[3] New Energy Science and Engineering Department, School of Energy and Chemical Engineering, Xiamen University Malaysia, Sepang 43900, Selangor, Malaysia
* Correspondence: mhmarlia@ukm.edu.my

**Abstract:** Recently, the material flow analysis (MFA) of waste from electrical and electronic equipment (WEEE) has attracted much interest from researchers worldwide because of its function as a decision-making tool for moving towards a circular economy and sustainability in WEEE management. However, review studies on the development of MFA in WEEE management studies are still lacking. To fill this gap, 115 MFA studies published in various databases between 2010 and 2022 were analysed to provide a comprehensive overview of current research progress and recommendations for future studies. Three major elements from previous studies were reviewed using content analysis: (i) the trend of publishing in OECD and non-OECD countries over time; (ii) the scope and boundaries of the aspect studied, and the use of MFA in forecasting the generation, flow, and stock of WEEE; and (iii) providing a future outlook for MFA studies based on its limitations. Further analysis has revealed a considerable increase in the number of studies on MFA of WEEE in major OECD nations; however, the number of studies on concentrated areas of WEEE, particularly in non-OECD countries, remains low. Another limitation of MFA research is the scope and boundaries, with very few studies addressing the aspects of uncertainty analysis, circular economy, and life cycle analysis. Due to the increasing number of newly developed methodologies and the absence of thorough evaluation on this study topic, few studies properly utilised the static or dynamic MFA model. Thus, based on the research limitations and gaps discussed, recommendations for future studies are proposed.

**Keywords:** material flow analysis; waste electrical and electronic equipment; WEEE generation; WEEE flow; sustainable WEEE management

check for updates

**Citation:** Azizi, D.D.S.; Hanafiah, M.M.; Woon, K.S. Material Flow Analysis in WEEE Management for Circular Economy: A Content Review on Applications, Limitations, and Future Outlook. *Sustainability* **2023**, *15*, 3505. https://doi.org/10.3390/su15043505

Academic Editors: Yan Xu and Ling Zhang

Received: 4 December 2022
Revised: 31 January 2023
Accepted: 7 February 2023
Published: 14 February 2023



## 1. Introduction

Electrical and electronic equipment (EEE) consumption has increased dramatically over the last two decades because of unparalleled technological advancement and economic expansion. As a result, it has a rapidly rising waste stream known as electrical waste (e-waste) or waste from electrical and electronic equipment (WEEE). Due to the challenges of improper WEEE disposal, which may result in the release of hazardous substances into the environment, there has been considerable debate on appropriate end-of-life (EOL) processes [1–4]. In 2019, more than 54 Mt of WEEE were accumulated globally, reflecting a global average of 7.3 kg/person each year. If current trends continue, this volume might reach 75 Mt by 2030 [5–7]. WEEE recycling rates, on the other hand, do not appear to be rising in tandem with the rise in this rubbish, with Europe recycling around 42.5% of its waste, followed by Asia at 11.7%, America at 9.4%, Oceania at 8.8%, and Africa at 0.9% [8].

WEEE includes precious materials such as gold, palladium, silver, and rare earth elements. It is a viable secondary source for these since the concentration of economically essential metals found in WEEE can be several times that of natural ore [9–12]. There is also a significant environmental advantage when bulk commodities such as copper, steel, and aluminium can be recycled virtually indefinitely. In this regard, WEEE becomes a profitable source of a secondary supply of precious materials, offering significant potential and incentives for effective management and recycling. However, since WEEE contains valuable resources and may impact the environment, it cannot be discarded or recycled arbitrarily. Several researchers have stated that if these harmful compounds in e-waste are not adequately recycled, they can seriously harm human health and the environment [13–17].

Waste streams endanger the environment and human health and add to economic risk. WEEE must be handled effectively and properly to reduce environmental and human health implications [18–22]. WEEE has the potential to be a sustainable and profitable resource recovery option, replacing raw material manufacturing. Effective WEEE management should include all aspects of waste management, such as formal or informal recycling, collecting and sorting, repairing and reusing at the same time, treatment wherever feasible, EOL processing to eliminate harmful chemicals, recovering valuable materials, as well as disposal of toxic parts and non-recyclable wastes in a safe or environmentally sound manner (ESM) [23,24].

Another significant barrier in WEEE management is the lack of comprehensive data and statistics on the quantity of WEEE generated [12,25,26]. Measuring and monitoring WEEE quantities at the national and global level is crucial for addressing the WEEE problem. Proper measurements and accurate data help track trends, determine the best policy and regulatory implementation practices, prevent unlawful actions and improper handling, boost recycling, and strengthen the reuse and recycling businesses [23]. The available statistics on WEEE are somewhat scarce in most countries, but only in most European countries that information is transparent and standardised and is currently open and accessible [27,28]. However, developed and developing nations continue to have major disparities in national-level e-waste stocks and movements.

With WEEE's complex material structure and multiple reverse supply chain players, identifying the material flows as well as known and unknown flows in the overall waste-management scenario are critical under the holistic concept of a circular economy (CE), closed-loop supply chain, and sustainable development. Since WEEE has a complicated material structure and necessitates the participation of several partners in the reverse supply chain, analytical tools such as material flow analysis (MFA) are required [17,26]. Due to the rigorous approach utilised by developed nations to address various waste streams, MFA is recognised as an appealing decision support tool, particularly in resource management and waste management. In general, four primary steps are covered in MFA: (i) identification of the key MFA concerns, (ii) system analysis to determine the relevant matter process, indicator elements, and system limits, (iii) qualification of mass flows of matter and indicator compounds, and (iv) identification of weak points in the entire MFA system. This procedure is followed by a schematic depiction and interpretation of the MFA flowchart to analyse the entire process. Figure 1 shows an example of a WEEE MFA.

The approach is low-cost and may be used to estimate product inventories for WEEE generation, transportation, and disposal, as well as the chemicals it releases [22,29]. MFA is a robust mechanism developed countries use to handle various waste sources with an input-output analysis model. This tool may identify problems and gaps in the value chain and devise relevant management solutions. It is beneficial for waste streams that are complicated and different, such as WEEE, which contains both valuable and harmful components. Furthermore, MFA is defined as "a concept utilised in analysing the flow of matter (compounds, chemical components, materials, or commodities) that is helped by material equilibrium, which follows the material conservation law" [30].

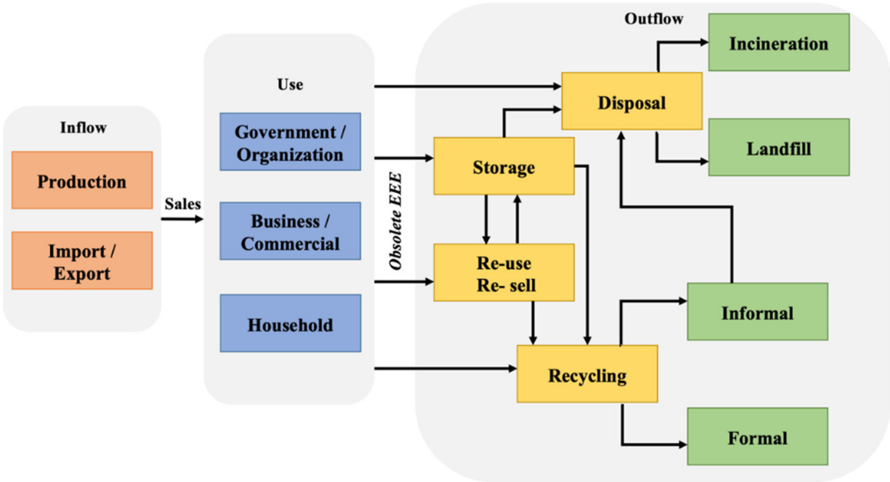



**Figure 1.** Material flow analysis of WEEE.

In the majority of MFAs, the system approach and mass balance are two key components. The system approach is concerned with defining a system or model. An MFA system is made up of precise processes, a system boundary, and explicit definitions of each product, substance, and material, allowing for more control over the research parameters and focused evaluation. Meanwhile, mass balance is concerned with measuring specific components of processes than with economic accounting. Developing a laser-focused approach is crucial for adopting industrial engineering solutions and maintaining optimal operations while reducing waste.

The Increased focus on WEEE has attracted the interest of researchers worldwide, increasing the number of papers utilising MFA in WEEE management and solid waste management studies. Throughout the study, the researcher first learns the factors that may affect the MFA, then identifies the fundamental issue, conducts system analysis, measures the mass flow of matter, identifies weak points in the system, and develops and evaluates results. Notably, [17,31–37] and many other researchers have conducted the MFA and related the study with other aspects evaluated, such as consumer behaviour, product and material level assessment, environmental impact assessment (EIA), and life cycle analysis (LCA) in their studies. Previous studies often emphasised the issues associated with the MFA of WEEE with environmental and human health implications, as well as recycling/resource recovery technology [30,38–40]. Despite the availability of several studies undertaken by different researchers, there is still non-uniformity in the methodology and aspects evaluated in MFA studies.

In comparison to developing nations, developed countries have better rules and regulations governing WEEE management and treatment. The difference is that it is harder to address concerns of inappropriate WEEE management and treatment in developing countries due to the complexity of the waste stream. Understanding the waste stream, which includes both the official and informal sectors, is therefore critical for all countries in terms of resource conservation, cross-border circulation, and human health protection [41–43]. However, although various studies have attempted to quantify WEEE generation using MFA, there are still significant data gaps in national-level estimates for both developed and developing countries.

Various WEEE management assessments have been conducted to date, offering a wide range of data on worldwide trends in WEEE generation, associated environmental implications, recycling, and recovery issues. However, most of these evaluations only focus on specific WEEE topics, whereas a comprehensive overview of all WEEE literature is limited. Even though previous research by [1,2] covered all aspects of the application of MFA in WEEE, several limitations in the study were found, particularly in the issue of detailed focus towards attaining sustainable WEEE management. Thus, this research aims to (i) address gaps in current MFA studies of WEEE by aggregating past studies without limiting the precise methodology utilised. Simultaneously, (ii) a global comparative analysis of current WEEE management based on economic status is conducted to highlight limitations, and (iii) recommendations for future prospects are made to provide the information obtained to policymakers and researchers for use in developing WEEE management strategies. The novelty of this work can serve as a roadmap for future research to meet the United Nations Sustainable Development Goals (SDGs), especially SDG-8 (decent work and economic growth), SDG-11 (sustainable cities and communities), and SDG-12 (responsible consumption and production).

## 2. Materials and Methods

### *2.1. Collection of Existing Studies*

The search for existing MFA studies in e-waste management began by gathering all existing research publications related to “e-waste management”, “electronic waste management” and “WEEE management” from ResearchGate, Scopus, Web of Science, Science Direct, and Google Scholar. This work was followed by narrowing down with a specific mention of “material flow analysis of e-waste”, “MFA of e-waste”, “material flow analysis of WEEE”, and “MFA of WEEE”. The existing studies were then analysed using the following keywords: “e-waste generation”, “electronic waste generation”, “WEEE generation”, “e-waste flow”, “electronic waste flow”, “WEEE flow”, “e-waste stock”, “electronic waste stock”, and “WEEE stock”. Only articles in English were included in this review. A total of 17,400 studies were found during this stage, and after the initial screening of its abstract and objectives, 270 studies were considered for further in-depth reviews.

### *2.2. In-Depth Review Methods*

The selected 270 research articles were subjected to a detailed qualitative in-depth review ranging from 12 years of study from 2010 to 2022. Individually, the article was reviewed by looking over mentions in the title, abstract, keywords, and objectives in precise detail. During this phase, 155 papers were eliminated from consideration for the final round owing to failure to meet the criteria. The selection criteria for the articles in this part are concerned with the content or discussion of work exclusively focused on using MFA in the context of WEEE-related challenges. However, only one conference paper related to the scope of this study was identified.

Following that, the 115 papers that were chosen were subjected to an additional assessment of the research method, discussion, findings, and conclusion were summarised in Table S1 in the Supporting Information. Throughout the comprehensive text analysis of the articles, the primary topic of discussion was identified to fit into numerous groups. The categories were chosen based on their discussion subject (e-waste category, aspect assessed, e-waste management application) and degree of evaluation (geographical level, product level, material level). We evaluated these papers on potential consumer behaviour drivers, e-waste management, and e-waste MFA associated with various nations, which were chosen based on citation popularity and the frequency of study on various issues. The flow of existing study collection and content analysis is depicted in Figure 2.

The selected manuscripts were reviewed using content analysis for inclusion in this review paper. As per the focus study, 4 significant aspects were considered. The first issue to be investigated is the pattern and distribution of the publication. This considers the distribution of publications based on their publisher and year of publication, as well as the trend of publishing depending on the nation’s economic standing, which was divided into 2 groups: OECD and non-OECD. As the research subject, the e-waste or WEEE categories were then established since they are crucial in analysing the flow, stocks, and generation of e-waste streams. Another analysis was undertaken on the scope and boundary of the study, which looked at the aspect evaluated and the application of MFA in WEEE management.

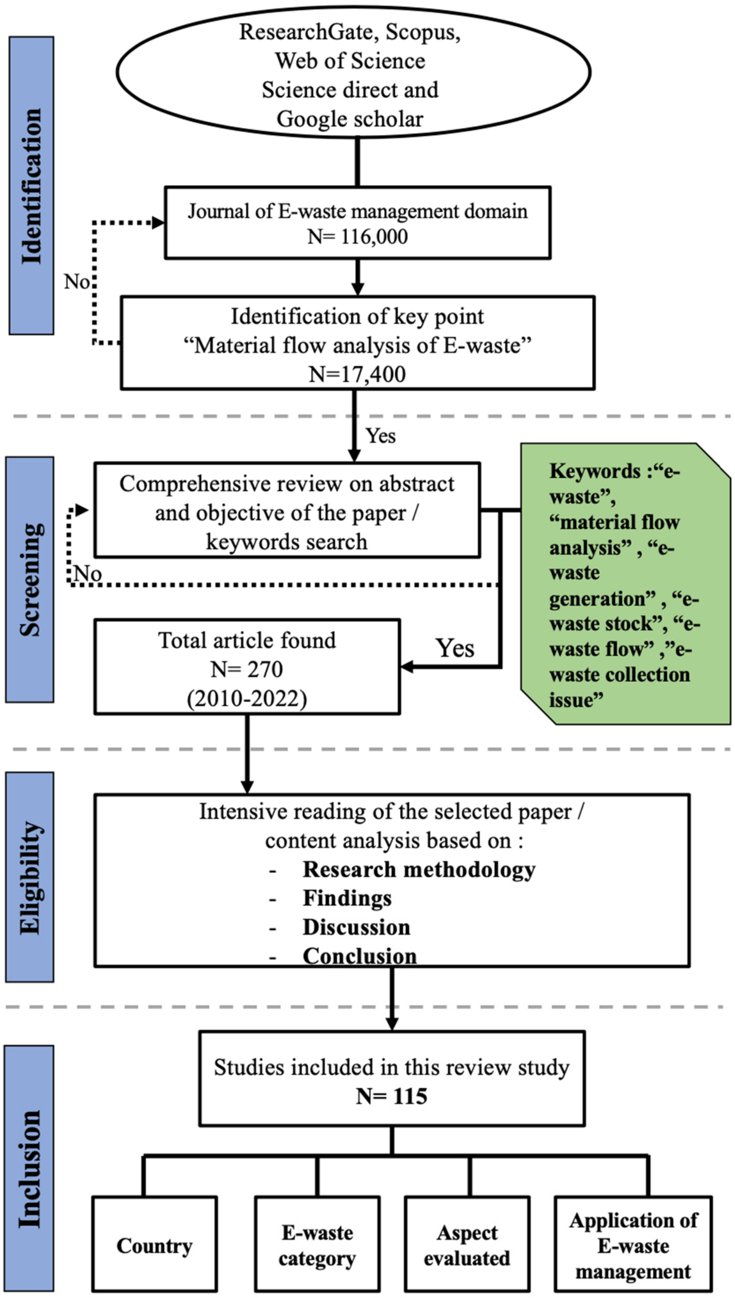


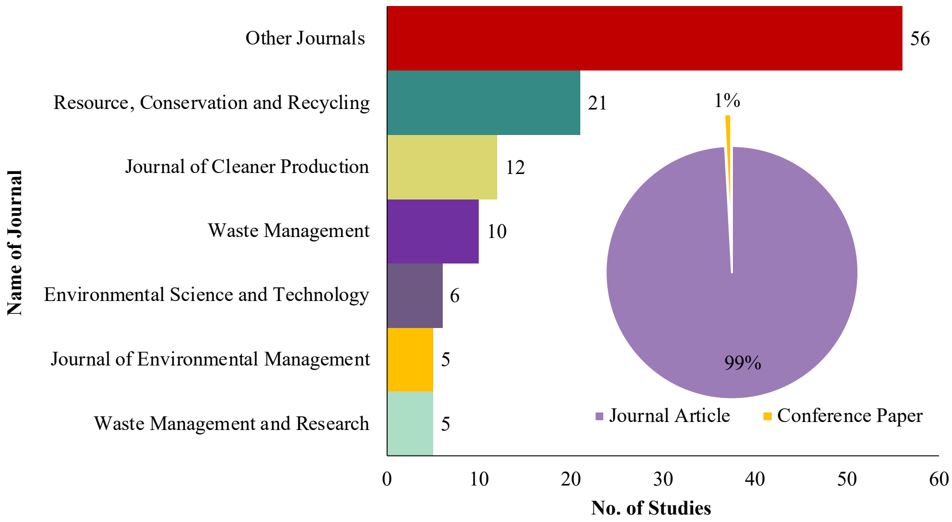

**Figure 2.** Methodology framework.

## 3. Results

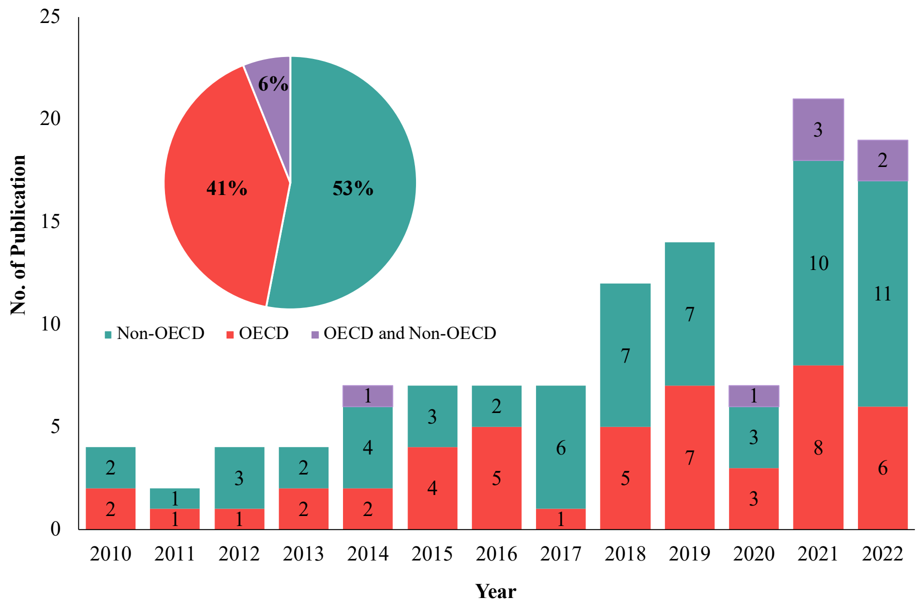
### *3.1. Collection of Existing Studies*

#### 3.1.1. Analysis of Publication

Following a thorough content evaluation of the 115 selected papers, all were classified as journal articles except for one conference paper [44]. The majority of the chosen papers were published in Resources, Conservation, and Recycling (21), Journal of Cleaner Production (12), Waste Management (11), Environmental Science and Technology (6), Journal of Environmental Management (5), and Waste Management and Research (5). Figure 3a depicts the publishing patterns of the selected publications. Future statistical study of the pattern of paper publication shows that the number of publications increased between 2010 and 2022. The progressive growth in published paper trends after 2010 implies that more academics have begun to research WEEE management in more depth, particularly in MFA studies. The number of papers published has increased with the establishment of the SDGs programme. Figure 3b depicts the distribution of publishing years.




(**a**)




(**b**)

**Figure 3.** Distribution of (**a**) existing studies by journal and conference paper and (**b**) existing studies by years of publication based on the country's economic status.

### 3.1.2. Geographical Distribution of MFA Studies

Further analysis was conducted based on the nation's involvement in the Organization for Economic Cooperation and Development (OECD), which determines whether it is a developed country or a non-member of the OECD, (non-OECD) developing country. This study section is critical because it identifies differences in the metrics used to analyse variables and how e-waste management is carried out. The OECD now has 38 member countries spread across five major continents. As shown in Figure 3b, 53% of the chosen papers were published in non-OECD countries, whereas 41% were published in OECD countries. Meanwhile, 6% of the research compares WEEE management in OECD and non-OECD countries to uncover shortcomings, similarities, and limitations in WEEE management in both countries.

Figure 4a depicts the distribution of publications per country. Australia, the United States of America, and Switzerland published the most papers under OECD membership, with eight, seven, and three publications, respectively. Meanwhile, when compared to non-OECD nations, the researcher has focused more on China (20), India (9), and Malaysia (5). Thus, according to the continental distribution (Figure 4b), Asia accounts for 58% of the research, followed by Europe (27%), America (25%), Oceania, and Africa (10% and 4%, respectively).

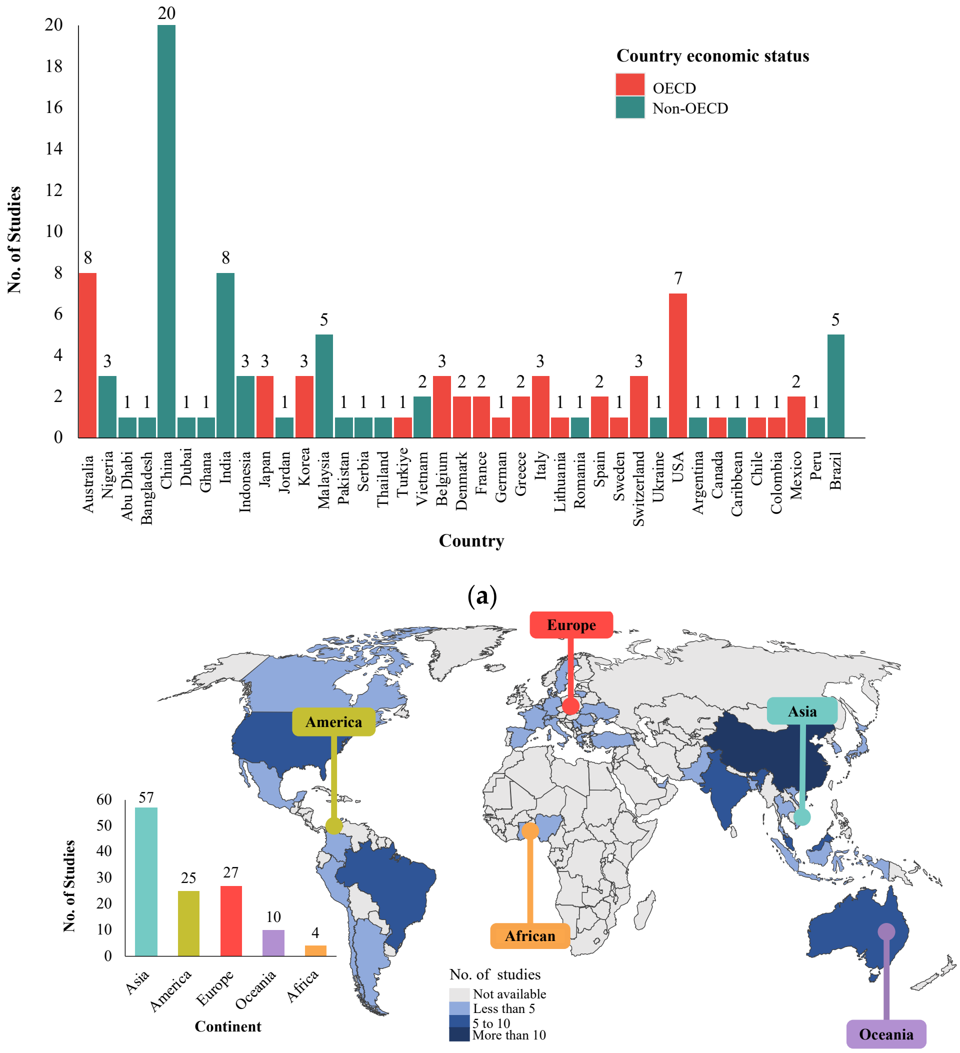



**Figure 4.** Distribution (**a**) of no of studies and geographical area based on the country's economic status and (**b**) of geographical area based on its continent.

### 3.1.3. Progress and Status of Policy in WEEE Management of Selected Studies

Effective policies play a crucial role in shaping the MFA studies of WEEE worldwide. Policies, regulations, and laws can have a significant effect on the direction and progress of research in a given field, especially in the issues of waste management [45].Thus, additional analysis was conducted on the impact of WEEE management strategies which may strongly influence the number of publications regionally.

As soon as the Basel treaty was established in 1989, the European Union (EU) Commission implemented the Waste Shipment Regulation in 1993. This regulation made it illegal to export dangerous e-waste to non-OECD nations. They established the Restriction of Hazardous Compounds Directive a decade later, which focused on redesigning goods and packaging to decrease the use of hazardous substances and enhance the recycling rate for domestically generated WEEE [46,47]. The EU Commission approved the WEEE Directive in 2012, which governs the collection, recycling, and recovery of e-waste resources in its member countries [48,49]. This directive also emphasises the collecting of abandoned e-waste in a systematic and distinct manner for certain materials and components of e-waste, as well as storage locations, to guarantee an environmentally friendly disposal and treatment process [50–53]. The regulation also includes the notion of extended producer responsibility (EPR), which holds manufacturers accountable for recycling obsolete items. In addition, each EU member state, as well as other European countries such as the United Kingdom, Switzerland, and Norway, have implemented their legislation to manage e-waste treatment in accordance with their local ecosystems [4,5]. In addition, pressure has been put on other European countries and Russia to establish a legislative and institutional framework for e-waste disposal as well as to address environmental concerns [54,55].

For decades, the Americas region, which includes both North and South America, has been a major producer of e-waste. The Americas' leading manufacturers of e-waste are the United States and Canada, followed by Brazil and Mexico. Despite this, the United States has yet to ratify the Basel Convention and presently has no federal legislation in place to handle e-waste [56,57]. Some states have enacted their e-waste legislation, but there is little consistency among them. Without federal legislation, e-waste export is permissible in the United States, making it even more critical for lawmakers to tackle this problem [58–61] In addition, Canada lacks national laws for e-waste management, even though several Canadian provinces have their municipal regulations. Only a few countries in Latin America have national policies in place for e-waste recycling, including Bolivia, Chile, Colombia, Costa Rica, Ecuador, Mexico, and Peru. Due to a lack of stringent national rule in the Americas, e-waste recycling is handled by the informal sector and private organisations that exclusively recycle lucrative e-waste. This has resulted in environmental damage and the illegal shipment of discarded electronic equipment from the United States to most non-OECD countries [62–64].

Different scenarios were seen in the Oceania region as this region, which comprises Australia, New Zealand, and the Pacific Islands, has acknowledged the significance of effective e-waste laws. The Product Stewardship Act of 2011 distinguishes Australia as the only country in the area to have enacted legislation, particularly for e-waste treatment [65–68]. This law, which focuses on recycling televisions and computers, will serve as a model for other nations in the area looking to enforce producer duties in e-waste management. New Zealand and other Pacific Island governments are following Australia's lead and creating product stewardship regimes. Many of the region's island nations have general regulations in place to preserve the environment and manage garbage, including e-waste. Some smaller Pacific countries are also collaborating with the European Union to control hazardous waste [69–74].

The African region has considerable problems with WEEE since it is economically undeveloped, and so the great bulk of EEE is imported from OECD countries in the Americas and Europe. Due to the lack of e-waste regulation, a considerable volume of e-waste is illegally sent to numerous African countries, where it is recycled using crude and informal procedures. This has resulted in environmental contamination and health risks. Nevertheless, major African countries have grown increasingly conscious of the hazards of crude e-waste processing in recent years and are working to establish legislation and rules to limit the unlawful informal treatment of e-waste. Only a few countries, including Kenya, Ghana, Madagascar, and Nigeria, have enacted e-waste regulations that limit e-waste imports from other countries and use the EPR concept [75–81]. On the other hand, South Africa, which is more developed than other areas of Africa, has legislation in place for environmental protection, consumer protection, labour safety, and trash management, but no specific legislation for e-waste treatment is currently in place. The South African government and organisations such as the South African Waste Electrical and Electronic Enterprise Development Association (SAWEEDA) are actively working on laws for e-waste management. A bill containing laws for e-waste disposal and processing as well as the application of the EPR concept is likely to be passed soon.

Countries in Asia have diverse economic backgrounds which influence their domestic e-waste production and management. Asian countries have long grappled with illegal e-waste imports and informal e-waste processing. Countries such as China, Japan, Korea, and Singapore have recently implemented e-waste laws to control e-waste management. For years, China has been the leading producer of e-waste in Asia, as well as a popular destination for e-waste from other countries [82]. To address the issue, China banned WEEE imports with the implementation of the Basel ban and WEEE regulations in the EU. These regulations aimed to reduce the generation of WEEE and improve recycling efforts. The laws aimed to address informal practices and standardise the WEEE recycling process through national and provincial management programs. In 2012, like most European countries, China adopted the EPR law to require manufacturers to recycle discarded equipment and incorporate recycled resources in their products [83–86].

In India, on the other hand, prior to 2011, there was no explicit law in India for e-waste management. While there were laws in place to protect the environment and manage hazardous waste, they did not differentiate e-waste from other solid waste, resulting in a lack of rules for WEEE processing from collection to recycling. Similar to the European WEEE law, the e-waste legislation implemented in 2011 established the EPR concept, making producers of electronic equipment liable for WEEE recycling [87–90]. In the Asian OECD countries, Japan has been at the forefront of implementing comprehensive WEEE rules and regulations. In Japan, there are two laws: the Law for the Promotion of Effective Utilisation of Resources (LPUR) and the Law for the Recycling of Specified Home Appliances (LRHA) [91–96]. Similar to the EPR, the LPUR encourages producers to take responsibility for recycling and waste reduction. The LRHA imposes tougher recycling duties on both consumers and producers. Taxes on new computer sales were introduced beginning in October 2003, and users who wish to recycle their older computers must pay a nominal charge to cover the recycling costs, making them accountable for recycling their products.

### *3.2. Analysis of Boundaries and Scope of the Study*

#### 3.2.1. Research Subject

Existing studies on the evaluation of WEEE generation found that study subjects were chosen based on e-waste categories, technology-based electrical appliances, specific electrical appliances, or various electrical appliances. As a result, the present research's target e-waste varies, with some studies concentrating on an e-waste category and others on a specific e-waste product. As seen in Figure 5, differences in research subject or e-waste category can be highly influenced by the country's national rules and regulations on WEEE, differences in the scope of the study, and other factors such as data availability.

As the EEE are divided into several categories based on their function and user usage, e-waste evaluations are commonly based on WEEE derivatives and various electrical equipment studies based on WEEE created in a household, organisation, or business. According to the analysis (Figure 5), the field of waste from electrical and electronic equipment (WEEE directive) has the most studies (38%). This research frequently assessed the 10 e-waste categories defined by the European WEEE Directive, including small household appliances, IT and telecommunications equipment, temperature exchange equipment, etc. Table S2 in the Supporting Information illustrates the e-waste categories and their examples according to the European WEEE Directive. Similarly, the study on WEEE can also be found in most OECD countries such as Australia, Japan, and Korea.

29% of the studies were found to be focused on various electrical appliances, with the entire quantity of WEEE produced by families, enterprises, and industries being analysed. The purpose of these studies was to figure out the total quantity of waste generated by households, companies, and industries. The overall volume of WEEE produced can give a thorough knowledge of the generation and disposal of e-waste, as well as its environmental effect. Furthermore, analysing various electrical appliances allows researchers to examine society's general behaviour and practises around the usage, disposal, and recycling of e-waste. These data can assist policymakers in formulating strategies for improved e-waste management and lowering negative environmental consequences.

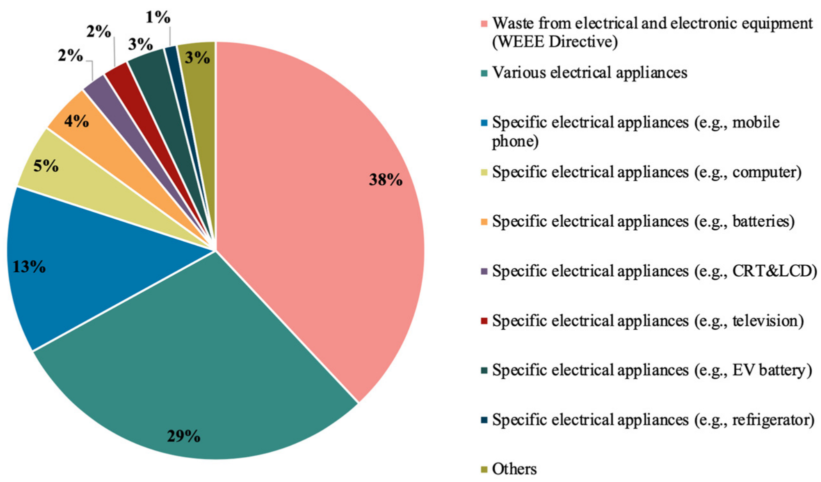



**Figure 5.** Distribution of research subjects.

Simultaneously, due to the variable EOL of each EEE, studies on individual electrical appliances such as mobile phones (13%), laptops (5%), batteries (4%), and refrigerators (1%) have grown in popularity. Evaluating each appliance separately allows for a better understanding of the specific difficulties and potential for managing e-waste in each case. Furthermore, as these appliances gain popularity, there is a growing interest in their management and disposal, which drives research in this area.

### 3.2.2. Aspect Evaluated in MFA Studies

Numerous variables were assessed to comprehend the MFA of WEEE based on the 115 selected MFA studies. Understanding the primary topic of discussion and the system boundary aided in determining the scope or degree of evaluation. Although the objective of each study and the degree of analysis may differ, most researchers investigated a variety of criteria, emphasising future applications in WEEE management or following existing habits and preferences in their own countries.

According to [97–99], while utilising an MFA in a WEEE management study, it is also important to consider to whether the MFA model is static (a single year assessment of product and material flow with a set product life expenditure) or dynamic (lifetime distribution of a material's static flow to analyse and anticipate its flow over time). The static model uses linear correlation, whereas the dynamic model uses probabilistic lifespan distributions. The current in-depth examination discovered that 46 studies used the dynamic MFA model, whereas 13 used the static MFA model. Meanwhile, 96 studies were not specified.

As shown in Figure 6, 24% of the research focuses on exploring the MFA via the perspective of product-level assessment. This is because there are already thousands of EEE products on the market, which may present problems with EOL management, as well as the fact that this sort of evaluation channelled a complicated topic that requires more attention [100]. Another evaluation level typically analysed by research is the material level (18%). The precious metals and rare earth elements (REEs) found in WEEE have a high recovery potential. An MFA at the industrial scale may reveal a possible system constraint, such as recycling efficiency and related material loss [101–108].

Several studies examined the MFA at the geographical (10%), national, and regional levels. E-waste management (14%) is becoming more critical at the national and regional levels. Depending on the product type, several studies are applied to specific difficulties. The e-waste stream may cross the geographical transboundary that tracks import and export movements in the international commerce of EEE [109–116]. Furthermore, research on consumer behaviour (habits, practices, and preferences) in EEE disposal is critical for comprehending the MFA. It was observed that 12% of the studies were chosen to address this issue.

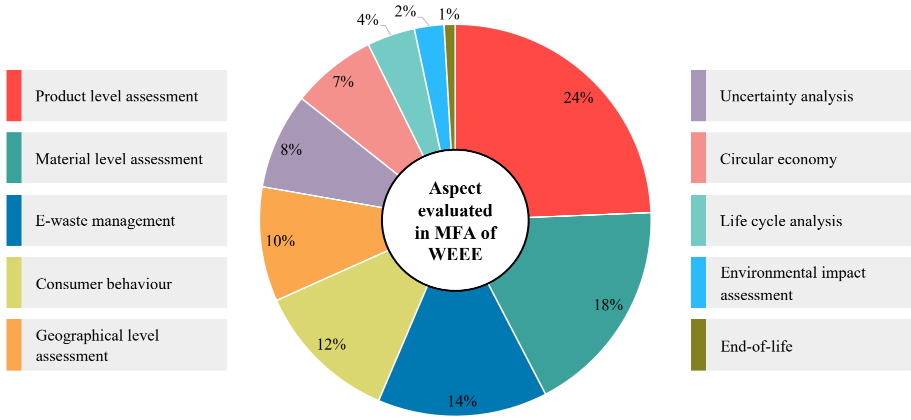



**Figure 6.** Distribution of aspect evaluated.

When analysing the MFA of WEEE, the top-down approach frequently produced uncertainty. Uncertainty analysis is a critical issue in MFA models that may be reduced by surveying a more significant sample [12,117–120]. However, only 8% of research takes these factors into account. In addition to the introduction of SGDs, the aspects of CE and LCA are still under development. Regardless of the many studies identified through our review, there is potential for further research on the application of CE principles in WEEE management. Other elements, such as the EIA and EOL of the specific product, were also discussed.

3.2.3. Application of MFA in Existing Studies

a. WEEE generation. The development of those earlier applications and the diversity of WEEE management assessments would surely provide information on WEEE generation. According to an in-depth evaluation of previous studies, 75 studies used MFA to measure WEEE generation (Table S1). The development of WEEE inventory may be gained by assigning the WEEE generation from data from demographic statistics, as well as the high EEE penetration rate and GDP, which will be another factor in calculating e-waste generation and projecting e-waste in the future [121–126]. It may also help to improve the current e-waste management system

b. WEEE stock. Currently, 61 studies have utilised MFA to evaluate the WEEE stock created or to anticipate the WEEE stock possession in their nation. Since EEE possession may be established from each household, organization, or industry based on market supply and customer demand, WEEE stock may be linked to e-waste flow. For example, the stock-driven dynamic MFA was used to research the number of television sets in China [127]. Based on this research, a dynamic analysis is created by estimating the supply of TVs by market and comparing it to the number of TVs available in Chinese households.

c. WEEE flow. Understanding the in- and outflow of WEEE is a critical component of appraising the MFA research. Not only inside the WEEE system borders, but as previously stated, the WEEE steam may traverse worldwide trans-boundaries via export and import factors [128–132]. Ninety-five studies on this WEEE flow have been conducted, including restricting the WEEE stream and examining a few areas such as customer behaviour, product level evaluation, e-waste management and practises, market supply, and consumption. Field studies were often undertaken through questionnaire surveys or walk-in interviews to collect information on the composition of various disposal paths used by WEEE sources, such as households, commercial, or industrial, etc.

### *3.3. Overall Summary of Existing Studies*

After evaluating over 115 articles, it is possible to conclude that there is still potential for discovery in applying material flow analysis to WEEE management. Compared to solid waste management, the use of MFA in WEEE research is relatively new and continually changing due to the discovery of new methodologies and approaches. This content review study did not restrict its reviews to the specific approach used. As noted in Section 3.1, the present studies were chosen to cover the period from 2010 to the end of 2022 due to their relevance and upgrading, as well as the inclusion of more issues and research subjects to the MFA of WEEE management. However, during the identification step (Figure 2) of this in-depth review analysis, it was discovered that the early MFA studies were from the early 2000s. Those studies were quite restricted in terms of the aspects studied and their relevance to WEEE management. Another element that influenced the study's choice after 2010 was a movement in consciousness toward more sustainable living and environmental stewardship [133–135].

It was also discovered that MFA studies were more popular in non-OECD countries than in OECD countries (Figure 3b). This is due to non-OECD countries' challenges with excessive WEEE generation, unpredictable waste stream flows, and a lack of systematic WEEE management. In contrast, the WEEE management in OECD countries is more advanced than in non-OECD countries. The current endeavour to achieve more sustainable waste management may be one of the critical causes motivating more MFA research in non-OECD nations. Under non-OECD nations, China, India, Malaysia, and Brazil published the most papers. Meanwhile, most of the research was published in OECD nations, particularly Australia, Japan, Switzerland, and the United States of America (Figure 4a). The European Union (EU) and Japan have been forerunners in developing and implementing large-scale e-waste management norms and regulations. Switzerland, for example, is credited with creating the first comprehensive e-waste management system, which includes e-waste collection, disposal, and treatment. Meanwhile, Japan has been at the forefront of the "Reused, Recycled, and Recovery" (3Rs) system and the take-back system, which the 3Rs facilitate.

Notably, another form of study (Figure 4a) that has been seen to be expanding is comparative research on MFA of WEEE management in both OECD and non-OECD nations [62,100,111,114,115,118]. This study examined and assessed the gaps and offered information for future comparative studies in MFA of WEEE in both the OECD and non-OECD countries. With the evolution of technologies of EEE, it is necessary to assess the research subject, scope, and boundaries thoroughly. In most OECD nations, the assessment of research subjects was based on the WEEE derivative, which rated research subjects based on waste produced by households, organisations, or businesses. Non-OECD nations, on the other hand, are more inclined to evaluate the research subject based on its distinct purpose, product, or technology.

Section 3.2 assessed the scope and boundaries of the current research subject to comprehend its relevance to WEEE management. Previous studies discovered several assessment levels to be regularly appraised when both static and dynamic models of MFA were considered (product, material, and geographical level assessment). Researchers frequently assessed product level assessments to evaluate the flow of a specific product or any research subject that comes under the WEEE derivative (Table S2).

Meanwhile, material level assessments are frequently performed on a given product and its component, such as [129] evaluating the levels of important raw materials in outmoded mobile phones, [135] estimating waste printed circuit board flows and metal recovery values in Australia and [59] using dynamic MFA models to forecast metal stocks and WEEE flows. WEEE flows and generation were assessed geographically through a variety of consumer behaviour studies at the national or regional levels.

As a result of this research, the complete flow of EEE involving all stakeholders may be determined, as consumers in the WEEE problem can be divided into two groups: those who are EEE producers and consumers or users and those who are e-waste holders or disposers. These positions reflect the utilisation phase of the product life cycle, as well as an intermediary phase between other stakeholders, particularly the manufacturer and recycler, and their responsibilities, which are crucial in resolving the WEEE problem. These studies are frequently undertaken with a narrow focus on one or a few electronic items.

Notably, [5,27,48,95,121] studies concentrate on WEEE generated in the regional area and its flow when WEEE becomes outdated.

Although MFA investigations incorporate several fluxes and quantities, as well as an empirical stock of EEE, significant uncertainty may arise during system analysis and mass flow qualification. However, little research has addressed the uncertainties of MFA (Figure 6). As previously stated, the top-down method usually results in inconsistency owing to a lack of data or comprehension of the many dimensions of uncertainty and their features, size, and means of dealing with the complexity of WEEE management. Simultaneously, it was observed that there is an unstandardized technique used for uncertainty analysis, such as [10,35,59,63,67,81] using subSTance flow ANalysis (STAN Software), and some of the studies [26,70,102,123] used a Monte Carlo simulation (MC) in analysing the uncertainty of their MFA investigations.

Simultaneously, MFA has indeed been considered a decision-making tool for modifying current policies to attain social, economic, and environmental sustainability. MFA is particularly valuable as a tool for measuring the sustainability of socioeconomic growth and environmental change, as it improves material flow efficiency. Only 81 publications out of the total number of papers assessed were found to have linked their study to all of the sustainability pillars. In terms of other environmental aspects, just 10 papers studied the social-environmental aspect, while more research was discovered to assess the economic-environmental aspect. However, combining MFA with other evaluation approaches such as LCA, multi-criteria decision-making (MCDM), and extended producer responsibilities (EPR) might strengthen MFA's position in sustainable development assessment.

This form of integration not only strengthens the MFA result, but also contributes to the improvement of sustainability indicators and the ongoing development of standardised procedures for material categorisation, data collecting and processing, and assessing indirect and underutilised flows. Of all of the integrations, MFA–LCA is undoubtedly gaining favour among researchers due to the fact that they contain several common elements as well as the ability to interact effectively with each other. Among the 115 studies, [56,57] were among the first to include LCA and the CE in their research. LCA is generally cited as one of the best techniques for assessing the environmental implications of waste management and comparing the environmental performance of various waste management systems, including the handling and treatment of WEEE [17,23,32,40,56,94]. Due to the complexity of WEEE as a waste stream, a comprehensive approach is required for correctly evaluating related environmental consequences, which is best provided by the LCA application, making LCA an intrinsically important tool in the WEEE study.

In contrast, environmental protection paradigms, such as the circular economy emphasise sustainable e-waste management as a shared obligation of manufacturers, stakeholders, and consumers. CE may provide immediate assistance by extending product life cycles and recovering functional and material value from WEEE. With the help from MFA, it allows material flow monitoring from various chains involved. Such monitoring allows for studies of demand composition, projection, and management of secondary resources, as well as identification of stakeholders controlling the flows, which may aid in policy formation and targeted involvement of major stakeholders. Simultaneously, since MFA used time-based series calculation, it will undoubtedly aid in the analysis and monitoring of resource consumption for the implementation of waste management techniques in order to stimulate long-term efforts from all economic players in the supply chain that produce WEEE [6,36,98,103,112,130].

## 4. Limitations and Gaps in MFA Studies

The present content analysis, using a holistic approach, reveals how the MFA concept has been implemented over a wide range of scopes and boundaries at various stages of the WEEE management cycle. Several limitations and gaps were identified when reviewing the present research. The maps in Figure 4b in relation to publication distribution offer an overview of the general publishing trend, which is currently restricted, particularly in non-OECD countries with an excess of WEEE generation. For example, in countries such as Nigeria, Indonesia, Bangladesh, and Ghana, which have emerged as key WEEE importers in Asia and Africa, the number of studies and the scope and boundary of the study have been found to be limited. At the same time, additional research is needed, particularly on WEEE stocks and flows in these non-OECD countries, to assess the performance of present official and informal WEEE recycling systems and identify potential development areas. Among the research undertaken in non-OECD countries, the number of studies conducted in China was quite encouraging.

Meanwhile, a positive number of studies have been observed in OECD countries such as Europe and America, and more studies are analysing the MFA in assessing the stocks and flow of domestic WEEE. This is because countries such as Switzerland and the United States of America (USA) have established electrical and electronic trash recycling centres and accept such waste at these centres at no cost, and it is vital to examine where the setup is successfully executed by stakeholders and accepted across their nation. However, studies of MFA in eastern and northern Europe, as well as the South American region, have remained relatively unexplored, and it is recommended that further research be conducted in those areas to represent the overall scenario of WEEE management in countries under OECD categorisation. At the same time, this has undoubtedly resulted in the development of various methodological approaches by each country.

As different methodological techniques in MFA improve and expand, more studies favour the use of dynamic MFA models over static MFA models. Several studies have shown that dynamic models may be used to foresee WEEE generation, stock, and flow over time. Static MFA models, on the other hand, were proven to be less successful since they only assessed the in-stock and flow of WEEE over a one-year period. Nonetheless, some of the research included did not mention which model was employed in their research. The main issue that hindered further research was a lack of comprehensive and up-to-date analyses on this topic, as well as data availability. This is because, to design an MFA flowchart, accurate and unlimited data of the stock and flow of the WEEE are required to guarantee that the analysis can be performed optimally.

Uncertainty analysis may be used to solve the challenges raised by the various techniques in MFA studies. However, given to the complexity and lack of data on current WEEE creation, stock, and flow, several studies avoided undertaking uncertainty analysis. Furthermore, when dealing with product and material-level MFAs, more care and preparation are necessary to standardise the MFA at this level of analysis. This is because precious metals can considerably contribute to economic recovery; consequently, further studies utilising standardised methodologies in this sector might generate more interest and motivation for a recycling economy.

As shown in Figure 6, the scope and boundaries of MFA studies were still constrained to assessing product material and geographical level while also studying consumer behaviour in the context of WEEE management. Only a fraction of the 115 studies would go into detail on the other aspects, especially the CE, EOL, and LCA. The circular economy requires WEEE management solutions and encourages persistent efforts across all economic entities in the supply chain that create garbage. The limited studies on this are due to the fact that not all countries have a strict regulation governing local law on WEEE, as well as a lack of awareness among stakeholders and consumer acceptance of changes to more sustainable waste management and economic barriers, particularly in non-OECD countries.

## 5. Future Outlook and Its Application

As MFA studies in WEEE management become increasingly common because of the great need for sustainable waste management following the SDGs and the necessity to manage WEEE in a more ESM, several future outlooks and recommendations are required to improve the presently available studies. Since the sustainable management of WEEE is a collective responsibility, researchers from small countries, whether OECD or non-OECD, are strongly urged to participate in the publication of a paper in the MFA of e-waste research and to use the critical information on WEEE generation from the UN as a starting point for constructing sustainable WEEE management.

Unstandardized procedures may pose a challenge; consequently, more comprehensive studies on methodologies are necessary to identify the most acceptable approaches in conducting the MFA by selecting the most relevant methods depending on their study scope and bounds and data availability. Another key consideration for future researchers is that while analysing or performing MFA investigations, factors such as inconsistency in the material analysis and uncovering e-waste streams for formal and informal e-waste collectors must be treated seriously. As a result of a dynamic material flow study, future research should adopt a combined MFA–LCA technique with caution.

Integrating MFA with LCA makes it possible to examine all three components of the sustainability pillars—social, economic, and environmental. Finally, to achieve sustainable WEEE, the problem should be viewed from a global perspective, with researchers conducting more studies in the future to evaluate the MFA via the global transboundary e-waste stream. Table 1 details the issues and recommendations for the future outlook of MFA research.

**Table 1.** The issues and recommendations for the future outlook of MFA research.

| No. | Issues | Recommendation/Future Outlook |
|---|---|---|
| 1. | Lack of number of studies<br>- Out of 195 countries, only 29 countries have actively published papers on MFA e-waste studies. | • It is suggested that researchers worldwide participate actively, particularly from countries lacking publications and those less prolific in this study field.<br>• It was emphasised that nations with an excess of WEEE should aggressively perform MFA research to reduce it.<br>• Extensive research is needed to evaluate several aspects of electronic waste assessment, such as data and their quality, as well as consumer-related characteristics, since these may help in understanding the generation, flow, and stock of WEEE. |
| 2. | Unstandardised methodologies<br>- The absence of comprehensive and up-to-date assessments of this study topic was the principal deterrent to future inquiry in this field. | • The evolution of numerous techniques for e-waste generation over the years might give soundproof that researchers from all over the globe actively established a new methodology for e-waste generation by employing diverse statistical models and approaches.<br>• More comprehensive studies on methodology are needed to find the most suitable approaches to conducting the MFA.<br>• Integrating the newly established techniques with the many current approaches accessible provides numerous opportunities for other researchers to analyse MFA by picking the most appropriate methodology depending on their study scope and boundaries, as well as data availability.<br>• In addition, a few steps can be taken to reduce data limitations, such as limiting data collection to only reverent stakeholders in the WEEE management system and conducting a pilot study prior to the start of the MFA flow chart, which may help to identify unexpected problems that are likely to occur during the study, thus reducing the amount of missing data.<br>• Expanding the scope of the study, on the other hand, can aid in addressing shortcomings. For example, if the initial scope was confined to a single nation or region, broadening the scope to include other countries or regions may aid in the identification of broader trends and patterns. This might give significant insights for policymakers and stakeholders working to address WEEE management and recycling challenges.<br>• Researchers might also clarify the specific types of research subjects that will be included in the study and set specified limitations for the study. This might assist to narrow the scope of the study and ensure that the information gathered is relevant and valuable. |

**Table 1.** *Cont.*

| No. | Issues | Recommendation/Future Outlook |
|---|---|---|
| 3. | Dynamic material flow analysis<br>- The existing MFA study may use dynamic MFA with the addition of LCA and CE.<br>- Utilising system dynamic modelling and simulation-based for MF studies. | • To minimise uncertainty, the exact material composition of specific e-waste products must be determined using an MC simulation to comprehend the advantages and potential improvements of recovery from the WEEE.<br>• Future studies should use a combined MFA–LCA strategy and utilise a system dynamic (SD) model and simulation with prudence. Combining MFA with LCA allows an option for examining all three aspects of the sustainability pillars (social, economic, and environmental).<br>• One of the key benefits of using SD modelling and simulation in policy research is the ability to analyse a policy's long-term consequences. Another advantage is the ability to explore the interplay of numerous aspects within a system, which is prevalent in public policy due to multiple stakeholders and extensive interactions between different components of the system.<br>• Overall, SD modelling and simulation may be beneficial tools for policymakers seeking to understand the potential repercussions of a policy and make informed decisions about its implementation. By analysing the long-term repercussions of a policy and the interplay of numerous components within a system, decision-makers may better understand prospective outcomes and make more informed decisions about how to effectively tackle public policy concerns.<br>• Furthermore, since CE is a development model in which economic activities are pursued decoupled from negative environmental externalities, future studies can actively incorporate it into their study.<br>• It was also suggested that more WEEE management studies incorporate the usage of a circular economic element in which production and consumption cycles are completed through reuse and recycling behaviours, since this could extend the useful lifetime (EOL) of the EEE. |
| 4. | Reduce data uncertainty | • Data triangulation: this entails leveraging numerous data sources to cross-check and validate the information. This can assist to improve the quality and dependability of the MFA data.<br>• Expert elicitation: this involves acquiring information from expert stakeholders, especially from manufacturers and recyclers to fill in data gaps. Collaboration with other researchers and organisations, such as government agencies and industry associations, can help to access data and increase the accuracy of the MFA.<br>• Conduct surveys and case studies: conducting surveys or case studies of specific industries or regions can provide additional information on the flow of WEEE, as well as obtain primary sources of data.<br>• Data quality assessment and interpolation and extrapolation. It is critical to undertake a data quality evaluation to check the completeness, correctness, consistency, and reliability of the data utilised in the MFA by maximising the use of use mathematical approaches (interval, stochastic, and Bayesian) to estimate data based on previously known information. |
| 5. | Global e-waste perspective | • It is proposed that the researcher conduct more studies evaluating the MFA via the global transboundary e-waste stream in the future.<br>• Taking advantage of the data provided by the UN and employing GPS-based e-waste flow tracking might be valuable. Customs authorities may play an essential role by providing reliable statistics on cross-border shipments and publishing such data annually. |

## 6. Conclusions

This content evaluation provides a comprehensive overview of 115 existing studies from the previous 12 years of WEEE management literature research, as well as a detailed analysis of the application of MFA as a tool for analysing WEEE generation, flow, and stock. As WEEE is a growing waste stream, major insights from research can assist in addressing the concerns of unlawful and difficult WEEE handling. It was discovered that the number of publications in both OECD and non-OECD countries is still small, but they are significant as research has increased over the years and is anticipated to expand. The WEEE directive, specific electrical appliances such as mobile phones and televisions, including technology-based electrical appliances such as LCDs, were all reviewed as the research subject.

Furthermore, information regarding the extent and bounds of the research field is critical for future MFA research. Although many studies have attempted to estimate the generation, stock, and in- and outflow of WEEE using MFA, there are still significant data gaps in the degree of assessment for both OECD and non-OECD countries. At the same time, MFA research into WEEE processing at pre-processing and recycling facilities is limited. Thus, the active participation and continuous research efforts of academics worldwide are critical, since WEEE research can contribute to decision-making in connection to the management of complex waste streams such as WEEE.

Nonetheless, efficient WEEE management was expected to contribute to SDG-8 attainment by providing jobs in the recycling and waste management industries. It can also help to reach SDG-11 by lowering WEEE environmental consequences, such as pollution and greenhouse gas emissions, and enhancing resource efficiency. With the function of MFA as a tool for understanding the fluxes of materials, notably WEEE, this system can be utilised to uncover opportunities to enhance WEEE management and lessen environmental problems connected to its production, use, and disposal. It can aid in the achievement of SDG-12 objectives by encouraging responsible resource usage and waste reduction.

Overall, this study might serve as a starting point for any researcher working on circular economic and sustainable WEEE management to grasp the essential research topic, scope, and boundaries, as well as the application of MFA in various e-waste-related scenarios. The highlighted limits and future prospects may assist in the growth of MFA research and increase the number of studies in order to attain more sustainable WEEE management.

**Supplementary Materials:** The supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15043505/s1. Table S1: Summary of existing studies, Table S2: Waste from Electrical and Electronic Equipment (WEEE directive).

**Author Contributions:** Formal analysis, writing—original drafts, D.D.S.A.; supervision, writing—original draft, writing—review and editing, funding acquisition, M.M.H.; supervision, writing—review and editing, K.S.W. All authors have read and agreed to the published version of the manuscripts.

**Funding:** This research was funded by the grant code FRGS/1/2021/WAB02/UKM/01/1 and GUP-2020-034.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

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

## References

1. Elgie, A.R.; Singh, S.J.; Telesford, J.N. You can't manage what you can't measure: The potential for circularity in Grenada's waste management system. *Resour. Conserv. Recycl.* **2020**, *164*, 105170. [CrossRef]
2. Gusukuma, M.; Kahhat, R. Electronic waste after a digital TV transition: Material flows and stocks. *Resour. Conserv. Recycl.* **2018**, *138*, 142–150. [CrossRef]

3. Shevchenko, T.; Laitala, K.; Danko, Y. Understanding Consumer E-Waste Recycling Behavior: Introducing a New Economic Incentive to Increase the Collection Rates. *Sustainability* **2019**, *11*, 2656. [CrossRef]
4. Rene, E.R.; Sethurajan, M.; Ponnusamy, V.K.; Kumar, G.; Dung, T.N.B.; Brindhadevi, K.; Pugazhendhi, A. Electronic waste generation, recycling and resource recovery: Technological perspectives and trends. *J. Hazard. Mater.* **2021**, *416*, 125664. [CrossRef]
5. Van Yken, J.; Boxall, N.J.; Cheng, K.Y.; Nikoloski, A.N.; Moheimani, N.R.; Kaksonen, A.H. E-Waste Recycling and Resource Recovery: A Review on Technologies, Barriers and Enablers with a Focus on Oceania. *Metals* **2021**, *11*, 1313. [CrossRef]
6. Neidhardt, M.; Mas-Peiro, J.; Schulz-Moenninghoff, M.; Pou, J.O.; Gonzalez-Olmos, R.; Kwade, A.; Schmuelling, B. Forecasting the Global Battery Material Flow: Analyzing the Break-Even Points at Which Secondary Battery Raw Materials Can Substitute Primary Materials in the Battery Production. *Appl. Sci.* **2022**, *12*, 4790. [CrossRef]
7. Attia, Y.; Soori, P.K.; Ghaith, F. Analysis of Households' E-Waste Awareness, Disposal Behavior, and Estimation of Potential Waste Mobile Phones towards an Effective E-Waste Management System in Dubai. *Toxics* **2021**, *9*, 236. [CrossRef]
8. Lase, I.S.; Ragaert, K.; Dewulf, J.; De Meester, S. Multivariate input-output and material flow analysis of current and future plastic recycling rates from waste electrical and electronic equipment: The case of small household appliances. *Resour. Conserv. Recycl.* **2021**, *174*, 105772. [CrossRef]
9. Zeng, X.; Gong, R.; Chen, W.-Q.; Li, J. Uncovering the Recycling Potential of "New" WEEE in China. *Environ. Sci. Technol.* **2016**, *50*, 1347–1358. [CrossRef]
10. Alsheyab, M.A.T. Potential recovery of precious metals from waste laptops in Jordan. *Rare Met.* **2015**, *34*, 517–521. [CrossRef]
11. Habib, K.; Parajuly, K.; Wenzel, H. Tracking the Flow of Resources in Electronic Waste—The Case of End-of-Life Computer Hard Disk Drives. *Environ. Sci. Technol.* **2015**, *49*, 12441–12449. [CrossRef]
12. Islam, T.; Huda, N. Assessing the recycling potential of "unregulated" e-waste in Australia. *Resour. Conserv. Recycl.* **2019**, *152*, 104526. [CrossRef]
13. Arain, A.L.; Neitzel, R.L.; Nambunmee, K.; Hischier, R.; Jindaphong, S.; Austin-Breneman, J.; Jolliet, O. Material flow, economic and environmental life cycle performances of informal electronic waste recycling in a Thai community. *Resour. Conserv. Recycl.* **2021**, *180*, 106129. [CrossRef]
14. Tran, H.P.; Schaubroeck, T.; Nguyen, D.Q.; Ha, V.H.; Huynh, T.H.; Dewulf, J. Material flow analysis for management of waste TVs from households in urban areas of Vietnam. *Resour. Conserv. Recycl.* **2018**, *139*, 78–89. [CrossRef]
15. Ismail, H.; Hanafiah, M.M. Management Of End-Of-Life Electrical And Electronic Products: The Challenges And The Potential Solutions For Management Enhancement In Developing Countries Context. *Acta Sci. Malays.* **2017**, *1*, 05–08. [CrossRef]
16. Ismail, H.; Hanafiah, M.M. A review of sustainable e-waste generation and management: Present and future perspectives. *J. Environ. Manag.* **2020**, *264*, 110495. [CrossRef]
17. Ismail, H.; Hanafiah, M.M. Evaluation of e-waste management systems in Malaysia using life cycle assessment and material flow analysis. *J. Clean. Prod.* **2021**, *308*, 127358. [CrossRef]
18. Jaibee, S.; Rahim, A.K.A.; Mohamad, F.; Jamian, S.; Kiong, S.C.; Seiji, Y.; Nor, N.H.M. Review on Current Status of Waste Electric and Electronic Product in Malaysia. *Appl. Mech. Mater.* **2015**, *773–774*, 898–907. [CrossRef]
19. Hanafiah, M.M.; Leuven, R.S.E.W.; Sommerwerk, N.; Tockner, K.; Huijbregts, M.A.J. Including the Introduction of Exotic Species in Life Cycle Impact Assessment: The Case of Inland Shipping. *Environ. Sci. Technol.* **2013**, *47*, 13934–13940. [CrossRef]
20. Gollakota, A.R.; Gautam, S.; Shu, C.-M. Inconsistencies of e-waste management in developing nations—Facts and plausible solutions. *J. Environ. Manag.* **2019**, *261*, 110234. [CrossRef]
21. de Oliveira, J.A.P. Intergovernmental relations for environmental governance: Cases of solid waste management and climate change in two Malaysian States. *J. Environ. Manag.* **2019**, *233*, 481–488. [CrossRef] [PubMed]
22. De Meester, S.; Nachtergaele, P.; Debaveye, S.; Vos, P.; Dewulf, J. Using material flow analysis and life cycle assessment in decision support: A case study on WEEE valorization in Belgium. *Resour. Conserv. Recycl.* **2018**, *142*, 1–9. [CrossRef]
23. Withanage, S.; Habib, K. Life Cycle Assessment and Material Flow Analysis: Two Under-Utilized Tools for Informing E-Waste Management. *Sustainability* **2021**, *13*, 7939. [CrossRef]
24. Herat, S.; Agamuthu, P. E-waste: A problem or an opportunity? Review of issues, challenges and solutions in Asian countries. *Waste Manag. Res.* **2012**, *30*, 1113–1129. [CrossRef] [PubMed]
25. Cordova-Pizarro, D.; Aguilar-Barajas, I.; Romero, D.; Rodriguez, C.A. Circular Economy in the Electronic Products Sector: Material Flow Analysis and Economic Impact of Cellphone E-Waste in Mexico. *Sustainability* **2019**, *11*, 1361. [CrossRef]
26. Islam, T.; Huda, N. Material flow analysis (MFA) as a strategic tool in E-waste management: Applications, trends and future directions. *J. Environ. Manag.* **2019**, *244*, 344–361. [CrossRef]
27. Modoi, O.-C.; Mihai, F.-C. E-Waste and End-of-Life Vehicles Management and Circular Economy Initiatives in Romania. *Energies* **2022**, *15*, 1120. [CrossRef]
28. Appolloni, A.; D'Adamo, I.; Gastaldi, M.; Santibanez-Gonzalez, E.D.; Settembre-Blundo, D. Growing e-waste management risk awareness points toward new recycling scenarios: The view of the Big Four's youngest consultants. *Environ. Technol. Innov.* **2021**, *23*, 101716. [CrossRef]
29. Villalba, L. Material Flow Analysis (MFA) and waste characterizations for formal and informal performance indicators in Tandil, Argentina: Decision-making implications. *J. Environ. Manag.* **2020**, *264*, 110453. [CrossRef]
30. Allesch, A.; Brunner, P.H. Material Flow Analysis as a Decision Support Tool for Waste Management: A Literature Review. *J. Ind. Ecol.* **2015**, *19*, 753–764. [CrossRef]

31. Kim, H.; Jang, Y.-C.; Hwang, Y.; Ko, Y.; Yun, H. End-of-life batteries management and material flow analysis in South Korea. *Front. Environ. Sci. Eng.* **2018**, *12*, 3. [CrossRef]
32. Wang, Y.; Ma, H.-W. Analysis of uncertainty in material flow analysis. *J. Clean. Prod.* **2018**, *170*, 1017–1028. [CrossRef]
33. Navazo, J.M.V.; Méndez, G.V.; Peiró, L.T. Material flow analysis and energy requirements of mobile phone material recovery processes. *Int. J. Life Cycle Assess.* **2014**, *19*, 567–579. [CrossRef]
34. Parajuly, K.; Habib, K.; Liu, G. Waste electrical and electronic equipment (WEEE) in Denmark: Flows, quantities and management. *Resour. Conserv. Recycl.* **2017**, *123*, 85–92. [CrossRef]
35. Agamuthu, P.; Kasapo, P.; Nordin, N.A.M. E-waste flow among selected institutions of higher learning using material flow analysis model. *Resour. Conserv. Recycl.* **2015**, *105*, 177–185. [CrossRef]
36. Islam, T.; Huda, N. Application of Material Flow Analysis (MFA) in Electronic Waste (E-Waste) Management: A Review. *Proceedings* **2018**, *2*, 1457. [CrossRef]
37. Baars, J.; Rajaeifar, M.A.; Heidrich, O. Quo vadis MFA? Integrated material flow analysis to support material efficiency. *J. Ind. Ecol.* **2022**, *26*, 1487–1503. [CrossRef]
38. Bao, Z.; Zhang, S.; Chen, Y.; Liu, S.; Zhang, Y.; Wang, H. A Review of Material Flow Analysis. In Proceedings of the 2010 International Conference on Management and Service Science, Wuhan, China, 24–26 August 2010; pp. 1–8. [CrossRef]
39. Shad, K.M.; Tan, Y.L.; Karim, M.E. Sustainable E-Waste Management in Malaysia: Lessons from Selected Countries. *IIUM Law J.* **2020**, *28*, 415–447. [CrossRef]
40. Fiore, S.; Ibanescu, D.; Teodosiu, C.; Ronco, A. Improving waste electric and electronic equipment management at full-scale by using material flow analysis and life cycle assessment. *Sci. Total. Environ.* **2019**, *659*, 928–939. [CrossRef]
41. Yu, J.; Williams, E.; Ju, M.; Yang, Y. Forecasting Global Generation of Obsolete Personal Computers. *Environ. Sci. Technol.* **2010**, *44*, 3232–3237. [CrossRef]
42. Duygan, M.; Meylan, G. Strategic management of WEEE in Switzerland—Combining material flow analysis with structural analysis. *Resour. Conserv. Recycl.* **2015**, *103*, 98–109. [CrossRef]
43. Zhang, L.; Yuan, Z.; Bi, J. Predicting future quantities of obsolete household appliances in Nanjing by a stock-based model. *Resour. Conserv. Recycl.* **2011**, *55*, 1087–1094. [CrossRef]
44. Wang, M.; You, X.; Li, X. Assessing the Recycling efficiency of Resource in E-waste Based on MFA of Reverse logistic System. In *Proceedings of the Eleventh International Conference on Management Science and Engineering Management*; Springer: Cham, Switzerland, 2018.
45. Jang, Y.-C. Waste electrical and electronic equipment (WEEE) management in Korea: Generation, collection, and recycling systems. *J. Mater. Cycles Waste Manag.* **2010**, *12*, 283–294. [CrossRef]
46. Steubing, B.; Böni, H.; Schluep, M.; Silva, U.; Ludwig, C. Assessing computer waste generation in Chile using material flow analysis. *Waste Manag.* **2010**, *30*, 473–482. [CrossRef]
47. Dwivedy, M.; Mittal, R. Estimation of future outflows of e-waste in India. *Waste Manag.* **2010**, *30*, 483–491. [CrossRef]
48. Gurauskienė, I.; Stasiškienė, Z. Application of material flow analysis to estimate the efficiency of e-waste management systems: The case of Lithuania. *Waste Manag. Res.* **2011**, *29*, 763–777. [CrossRef]
49. Kahhat, R.; Williams, E. Materials flow analysis of e-waste: Domestic flows and exports of used computers from the United States. *Resour. Conserv. Recycl.* **2012**, *67*, 67–74. [CrossRef]
50. Song, Q.; Wang, Z.; Li, J.; Duan, H. Sustainability evaluation of an e-waste treatment enterprise based on emergy analysis in China. *Ecol. Eng.* **2012**, *42*, 223–231. [CrossRef]
51. Dwivedy, M.; Mittal, R. An investigation into e-waste flows in India. *J. Clean. Prod.* **2012**, *37*, 229–242. [CrossRef]
52. Zhang, L.; Yuan, Z.; Bi, J.; Huang, L. Estimating future generation of obsolete household appliances in China. *Waste Manag. Res. J. Sustain. Circ. Econ.* **2012**, *30*, 1160–1168. [CrossRef]
53. Ibrahim, F.B.; Adie, D.B.; Giwa, A.-R.; Abdullahi, S.A.; Okuofu, C.A. Material Flow Analysis of Electronic Wastes (e-Wastes) in Lagos, Nigeria. *J. Environ. Prot.* **2013**, *04*, 1011–1017. [CrossRef]
54. Lau, W.K.-Y.; Chung, S.-S.; Zhang, C. A material flow analysis on current electrical and electronic waste disposal from Hong Kong households. *Waste Manag.* **2013**, *33*, 714–721. [CrossRef]
55. Lam, C.W.; Lim, S.-R.; Schoenung, J.M. Linking Material Flow Analysis with Environmental Impact Potential. *J. Ind. Ecol.* **2013**, *17*, 299–309. [CrossRef]
56. Kiddee, P.; Naidu, R.; Wong, M.H. Electronic waste management approaches: An overview. *Waste Manag.* **2013**, *33*, 1237–1250. [CrossRef]
57. Andarani, P.; Goto, N. Potential e-waste generated from households in Indonesia using material flow analysis. *J. Mater. Cycles Waste Manag.* **2014**, *16*, 306–320. [CrossRef]
58. Habuer; Nakatani, J.; Moriguchi, Y. Time-series product and substance flow analyses of end-of-life electrical and electronic equipment in China. *Waste Manag.* **2014**, *34*, 489–497. [CrossRef]
59. Müller, E.; Hilty, L.M.; Widmer, R.; Schluep, M.; Faulstich, M. Modeling Metal Stocks and Flows: A Review of Dynamic Material Flow Analysis Methods. *Environ. Sci. Technol.* **2014**, *48*, 2102–2113. [CrossRef]
60. Shumon, R.H.; Ahmed, S.; Islam, T. Electronic waste: Present status and future perspectives of sustainable management practices in Malaysia. *Environ. Earth Sci.* **2014**, *72*, 2239–2249. [CrossRef]

61. Espinoza, V.S.; Erbis, S.; Pourzahedi, L.; Eckelman, M.J.; Isaacs, J.A. Material Flow Analysis of Carbon Nanotube Lithium-Ion Batteries Used in Portable Computers. *ACS Sustain. Chem. Eng.* **2014**, *2*, 1642–1648. [CrossRef]
62. Breivik, K.; Armitage, J.M.; Wania, F.; Jones, K.C. Tracking the Global Generation and Exports of e-Waste. Do Existing Estimates Add up? *Environ. Sci. Technol.* **2014**, *48*, 8735–8743. [CrossRef]
63. Öztürk, T. Generation and management of electrical–electronic waste (e-waste) in Turkey. *J. Mater. Cycles Waste Manag.* **2015**, *17*, 411–421. [CrossRef]
64. Li, B.; Yang, J.; Lu, B.; Song, X. Estimation of retired mobile phones generation in China: A comparative study on methodology. *Waste Manag.* **2015**, *35*, 247–254. [CrossRef] [PubMed]
65. Vadoudi, K.; Kim, J.; Laratte, B.; Lee, S.-J.; Troussier, N. E-waste management and resources recovery in France. *Waste Manag. Res.* **2015**, *33*, 919–929. [CrossRef] [PubMed]
66. Golev, A.; Werner, T.T.; Zhu, X.; Matsubae, K. Product flow analysis using trade statistics and consumer survey data: A case study of mobile phones in Australia. *J. Clean. Prod.* **2016**, *133*, 262–271. [CrossRef]
67. Yedla, S. Development of a methodology for electronic waste estimation: A material flow analysis-based SYE-Waste Model. *Waste Manag. Res.* **2016**, *34*, 81–86. [CrossRef]
68. Petridis, N.E.; Stiakakis, E.; Petridis, K.; Dey, P. Estimation of computer waste quantities using forecasting techniques. *J. Clean. Prod.* **2016**, *112*, 3072–3085. [CrossRef]
69. Sugiyama, K.; Honma, O.; Mishima, N. Quantitative Analysis of Material Flow of Used Mobile Phones in Japan. *Procedia CIRP* **2016**, *40*, 79–84. [CrossRef]
70. Miller, T.R.; Duan, H.; Gregory, J.; Kahhat, R.; Kirchain, R. Quantifying Domestic Used Electronics Flows using a Combination of Material Flow Methodologies: A US Case Study. *Environ. Sci. Technol.* **2016**, *50*, 5711–5719. [CrossRef]
71. Mishima, K.; Rosano, M.; Mishima, N.; Nishimura, H. End-of-Life Strategies for Used Mobile Phones Using Material Flow Modeling. *Recycling* **2016**, *1*, 122–135. [CrossRef]
72. Hao, H.; Liu, Z.; Zhao, F.; Geng, Y.; Sarkis, J. Material flow analysis of lithium in China. *Resour. Policy* **2017**, *51*, 100–106. [CrossRef]
73. Babayemi, J.; Osibanjo, O.; Weber, R. Material and substance flow analysis of mobile phones in Nigeria: A step for progressing e-waste management strategy. *J. Mater. Cycl. Waste Manag.* **2017**, *19*, 731–742. [CrossRef]
74. Guo, X.; Yan, K. Estimation of obsolete cellular phones generation: A case study of China. *Sci. Total. Environ.* **2017**, *575*, 321–329. [CrossRef]
75. Lu, B.; Liu, J.; Yang, J. Substance flow analysis of lithium for sustainable management in mainland China: 2007–2014. *Resour. Conserv. Recycl.* **2017**, *119*, 109–116. [CrossRef]
76. Song, X.; Hu, S.; Chen, D.; Zhu, B. Estimation of Waste Battery Generation and Analysis of the Waste Battery Recycling System in China. *J. Ind. Ecol.* **2017**, *21*, 57–69. [CrossRef]
77. Borthakur, A.; Govind, M. Emerging trends in consumers' E-waste disposal behaviour and awareness: A worldwide overview with special focus on India. *Resour. Conserv. Recycl.* **2017**, *117*, 102–113. [CrossRef]
78. Wang, M.; You, X.; Li, X.; Liu, G. Watch more, waste more? A stock-driven dynamic material flow analysis of metals and plastics in TV sets in China. *J. Clean. Prod.* **2018**, *187*, 730–739. [CrossRef]
79. Wang, M.; You, X.; Li, X. *Proceedings of the Eleventh International Conference on Management Science and Engineering Management*; Springer: Cham, Switzerland, 2018. [CrossRef]
80. Islam, T.; Huda, N. Reverse logistics and closed-loop supply chain of Waste Electrical and Electronic Equipment (WEEE)/E-waste: A comprehensive literature review. *Resour. Conserv. Recycl.* **2018**, *137*, 48–75. [CrossRef]
81. He, P.; Wang, C.; Zuo, L. The present and future availability of high-tech minerals in waste mobile phones: Evidence from China. *J. Clean. Prod.* **2018**, *192*, 940–949. [CrossRef]
82. Bahers, J.-B.; Kim, J. Regional approach of waste electrical and electronic equipment (WEEE) management in France. *Resour. Conserv. Recycl.* **2017**, *129*, 45–55. [CrossRef]
83. Dias, P.; Bernardes, A.M.; Huda, N. Waste electrical and electronic equipment (WEEE) management: An analysis on the australian e-waste recycling scheme. *J. Clean. Prod.* **2018**, *197*, 750–764. [CrossRef]
84. Nguyen, H.T.T.; Hung, R.-J.; Lee, C.-H. Determinants of Residents' E-Waste Recycling Behavioral Intention: A Case Study from Vietnam. *Sustainability* **2018**, *11*, 164. [CrossRef]
85. Singh, M.; Thind, P.S.; John, S. An analysis on e-waste generation in Chandigarh: Quantification, disposal pattern and future predictions. *J. Mater. Cycl. Waste Manag.* **2018**, *20*, 1625–1637. [CrossRef]
86. Ikhlayel, M. An integrated approach to establish e-waste management systems for developing countries. *J. Clean. Prod.* **2018**, *170*, 119–130. [CrossRef]
87. Ismail, H.; Hanafiah, M.M. Discovering opportunities to meet the challenges of an effective waste electrical and electronic equipment recycling system in Malaysia. *J. Clean. Prod.* **2019**, *238*, 117927. [CrossRef]
88. Golev, A.; Corder, G.D.; Rhamdhani, M.A. Estimating flows and metal recovery values of waste printed circuit boards in Australian e-waste. *Miner. Eng.* **2019**, *137*, 171–176. [CrossRef]
89. Althaf, S.; Babbitt, C.W.; Chen, R. Forecasting electronic waste flows for effective circular economy planning. *Resour. Conserv. Recycl.* **2019**, *151*, 104362. [CrossRef]
90. Song, J.; Yan, W.; Cao, H.; Song, Q.; Ding, H.; Lv, Z.; Zhang, Y.; Sun, Z. Material flow analysis on critical raw materials of lithium-ion batteries in China. *J. Clean. Prod.* **2019**, *215*, 570–581. [CrossRef]

91. Sajid, M.; Syed, J.H.; Iqbal, M.; Abbas, Z.; Hussain, I.; Baig, M.A. Assessing the generation, recycling and disposal practices of electronic/electrical-waste (E-Waste) from major cities in Pakistan. *Waste Manag.* **2019**, *84*, 394–401. [CrossRef]
92. Singh, N.; Tang, Y.; Li, J. Uncovering material flow analysis of waste cathode ray tubes television in China. *Waste Manag. Res.* **2019**, *37*, 1170–1177. [CrossRef]
93. Ismail, H.; Hanafiah, M.M. An overview of LCA application in WEEE management: Current practices, progress and challenges. *J. Clean. Prod.* **2019**, *232*, 79–93. [CrossRef]
94. Li, X.; Ren, Q.; You, X.; Yang, Y.; Shan, M.; Wang, M. Material flow analysis of discarded refrigerators from households in urban and rural areas of China. *Resour. Conserv. Recycl.* **2019**, *149*, 577–585. [CrossRef]
95. Kuong, I.H.; Li, J.; Zhang, J.; Zeng, X. Estimating the Evolution of Urban Mining Resources in Hong Kong, Up to the Year 2050. *Environ. Sci. Technol.* **2019**, *53*, 1394–1403. [CrossRef]
96. Yi, S.; Lee, H.; Lee, J.; Kim, W. Upcycling strategies for waste electronic and electrical equipment based on material flow analysis. *Environ. Eng. Res.* **2019**, *24*, 74–81. [CrossRef]
97. Islam, T.; Huda, N. Reshaping WEEE management in Australia: An investigation on the untapped WEEE products. *J. Clean. Prod.* **2020**, *250*, 119496. [CrossRef]
98. Islam, T.; Dias, P.; Huda, N. Waste mobile phones: A survey and analysis of the awareness, consumption and disposal behavior of consumers in Australia. *J. Environ. Manag.* **2020**, *275*, 111111. [CrossRef]
99. Parajuly, K.; Fitzpatrick, C.; Muldoon, O.; Kuehr, R. Behavioral change for the circular economy: A review with focus on electronic waste management in the EU. *Resour. Conserv. Recycl. X* **2020**, *6*, 100035. [CrossRef]
100. Rodrigues, A.C.; Boscov, M.E.; Günther, W.M. Domestic flow of e-waste in São Paulo, Brazil: Characterization to support public policies. *Waste Manag.* **2020**, *102*, 474–485. [CrossRef]
101. Guzzo, D.; Rodrigues, V.P.; Mascarenhas, J. A systems representation of the Circular Economy: Transition scenarios in the electrical and electronic equipment (EEE) industry. *Technol. Forecast. Soc. Chang.* **2021**, *163*, 120414. [CrossRef]
102. Althaf, S.; Babbitt, C.W.; Chen, R. The evolution of consumer electronic waste in the United States. *J. Ind. Ecol.* **2021**, *25*, 693–706. [CrossRef]
103. Mohammadi, E.; Singh, S.J.; Habib, K. Electronic waste in the Caribbean: An impending environmental disaster or an opportunity for a circular economy? *Resour. Conserv. Recycl.* **2020**, *164*, 105106. [CrossRef]
104. He, P.; Hu, G.; Wang, C.; Hewage, K.; Sadiq, R.; Feng, H. Analyzing present and future availability of critical high-tech minerals in waste cellphones: A case study of India. *Waste Manag.* **2021**, *119*, 275–284. [CrossRef] [PubMed]
105. Hlavatska, L.; Ishchenko, V.; Pohrebennyk, V.; Salamon, I. Material Flow Analysis of Waste Electrical and Electronic Equipment in Ukraine. *J. Ecol. Eng.* **2021**, *22*, 198–207. [CrossRef]
106. Koshta, N.; Patra, S.; Singh, S.P. Estimation of E-waste at micro level for reverse logistics: A case of Delhi. *J. Clean. Prod.* **2021**, *314*, 128063. [CrossRef]
107. Velásquez-Rodríguez, O.F.; Løvik, A.N.; Moreno-Mantilla, C.E. Evaluation of the environmental impact of end-of-life refrigerators in Colombia by material flow analysis. *J. Clean. Prod.* **2021**, *314*, 127884. [CrossRef]
108. Babatunde, A.; Matthew, O.; Margret, O. Determinants of Households' E-Waste Disposal in Southwestern States, Nigeria. *Int. J. Eng. Appl. Sci. Technol.* **2021**, *5*, 29–36.
109. Yang, W.-D.; Sun, Q.; Ni, H.-G. Cost-benefit analysis of metal recovery from e-waste: Implications for international policy. *Waste Manag.* **2021**, *123*, 42–47. [CrossRef]
110. Panchal, R.; Singh, A.; Diwan, H. Economic potential of recycling e-waste in India and its impact on import of materials. *Resour. Policy* **2021**, *74*, 102264. [CrossRef]
111. Mairizal, A.Q.; Sembada, A.Y.; Tse, K.M.; Rhamdhani, M.A. Electronic waste generation, economic values, distribution map, and possible recycling system in Indonesia. *J. Clean. Prod.* **2021**, *293*, 126096. [CrossRef]
112. Berežni, I.; Castro, F.D.; Batinić, B.; Vaccari, M.; Stanisavljevic, N. WEEE treatment and system management in Italy and Serbia: A comparison. *Waste Manag. Res. J.* **2021**, *39*, 1302–1316. [CrossRef]
113. Murthy, V.; Ramakrishna, S. A Review on Global E-Waste Management: Urban Mining towards a Sustainable Future and Circular Economy. *Sustainability* **2022**, *14*, 647. [CrossRef]
114. Roy, H.; Rahman, T.U.; Suhan, M.B.K.; Al-Mamun, M.R.; Haque, S.; Islam, M.S. A Comprehensive Review on Hazard-ous Aspects and Management Strategies of Electronic Waste: Bangladesh and Global Perspectives. *SSRN Electron. J.* **2022**, *8*, 1856–1874. [CrossRef]
115. Mansuy, J.; Lebeau, P.; Verlinde, S.; Macharis, C. Who is in charge? An analysis of waste electrical and electronic equipment management in Brussels. *Bruss. Stud.* **2022**, *2022*, 167. [CrossRef]
116. Ajekwene, K.K.; Aigbokhan, E.E.; Akindele, O.E.; Yibowei, M.E.; Momoh, F.P.; Ugonna, U.K. Electronic Waste (E-Waste): Sources, Proliferation, Effects & Management in Developing Nations. *IOSR J. Eng.* **2022**, *12*, 12–27.
117. Alblooshi, B.G.K.M.; Ahmad, S.Z.; Hussain, M.; Singh, S.K. Sustainable management of electronic waste: Empirical evidences from a stakeholders' perspective. *Bus. Strat. Environ.* **2022**, *31*, 1856–1874. [CrossRef]
118. Kahhat, R.; Miller, T.; Ojeda-Benitez, S.; Cruz-Sotelo, S.E.; Jauregui-Sesma, J.; Gusukuma, M. Proposal for used electronic products management in Mexicali. *Resour. Conserv. Recycl. Adv.* **2022**, *13*, 200065. [CrossRef]

119. Habib, H.; Wagner, M.; Baldé, C.P.; Martínez, L.H.; Huisman, J.; Dewulf, J. What gets measured gets managed—Does it? Uncovering the waste electrical and electronic equipment flows in the European Union. *Resour. Conserv. Recycl.* **2022**, *181*, 106222. [CrossRef]
120. Tutton, C.G.; Young, S.B.; Habib, K. Pre-processing of e-waste in Canada: Case of a facility responding to changing material composition. *Resour. Environ. Sustain.* **2022**, *9*, 100069. [CrossRef]
121. Neto, J.F.D.O.; Monteiro, M.; Silva, M.M.; Miranda, R.; Santos, S.M. Household practices regarding e-waste management: A case study from Brazil. *Environ. Technol. Innov.* **2022**, *28*, 102723. [CrossRef]
122. Li, A.; Li, B.; Lu, B.; Yang, D.; Hou, S.; Song, X. Generation estimation and material flow analysis of retired mobile phones in China. *Environ. Sci. Pollut. Res.* **2022**, *29*, 75626–75635. [CrossRef]
123. Naik, S.; Eswari, J.S. Electrical waste management: Recent advances challenges and future outlook. *Total. Environ. Res. Themes* **2022**, *1–2*, 100002. [CrossRef]
124. Santos, S.M.; Ogunseitan, O.A. E-waste management in Brazil: Challenges and opportunities of a reverse logistics model. *Environ. Technol. Innov.* **2022**, *28*, 102671. [CrossRef]
125. Nurdiawati, A.; Agrawal, T.K. Creating a circular EV battery value chain: End-of-life strategies and future perspective. *Resour. Conserv. Recycl.* **2022**, *185*, 106484. [CrossRef]
126. Dzah, C.; Agyapong, J.O.; Apprey, M.W.; Agbevanu, K.T.; Kagbetor, P.K. Assessment of perceptions and practices of electronic waste management among commercial consumers in Ho, Ghana. *Sustain. Environ.* **2022**, *8*, 2048465. [CrossRef]
127. Kastanaki, E.; Giannis, A. Forecasting quantities of critical raw materials in obsolete feature and smart phones in Greece: A path to circular economy. *J. Environ. Manag.* **2022**, *307*, 114566. [CrossRef] [PubMed]
128. Dias, P.; Palomero, J.; Cenci, M.P.; Scarazzato, T.; Bernardes, A.M. Electronic waste in Brazil: Generation, collection, recycling and the covid pandemic. *Clean. Waste Syst.* **2022**, *3*, 100022. [CrossRef]
129. Macauley, M.; Palmer, K.; Shih, J.-S. Dealing with electronic waste: Modeling the costs and environmental benefits of computer monitor disposal. *J. Environ. Manag.* **2003**, *68*, 13–22. [CrossRef]
130. Streicher-Porte, M.; Widmer, R.; Jain, A.; Bader, H.-P.; Scheidegger, R.; Kytzia, S. Key drivers of the e-waste recycling system: Assessing and modelling e-waste processing in the informal sector in Delhi. *Environ. Impact Assess. Rev.* **2005**, *25*, 472–491. [CrossRef]
131. Fraj, E.; Martinez, E. Environmental values and lifestyles as determining factors of ecological consumer behaviour: An empirical analysis. *J. Consum. Mark.* **2006**, *23*, 133–144. [CrossRef]
132. Nnorom, I.C.; Osibanjo, O. Electronic waste (e-waste): Material flows and management practices in Nigeria. *Waste Manag.* **2008**, *28*, 1472–1479. [CrossRef]
133. Hischier, R.; Wäger, P.; Gauglhofer, J. Does WEEE recycling make sense from an environmental perspective: The environmental impacts of the Swiss take-back and recycling systems for waste electrical and electronic equipment (WEEE). *Environ. Impact Assess. Rev.* **2005**, *25*, 525–539. [CrossRef]
134. Jang, Y.-C.; Lee, S.; Ko, Y.; Choi, K. Material Recycling and Flow of Waste Electrical and Electronic Equipment in Korea. *Int. J. Appl. Eng. Res.* **2014**, *9*, 25221–25230. [CrossRef]
135. Helena, L.; Ottoni, M.; Lepawsky, J. Circular economy and e-waste management in the Americas: Brazilian and Canadian frameworks. *J. Clean. Prod.* **2021**, *297*, 126570. [CrossRef]