



A Review on Extended Producer Responsibility Schemes for Packaging Waste Management and Research Gaps in the Field

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ABSTRACT

Recently, Extended Producer Responsibility (EPR) schemes have been considered as potential policies for solid waste management and many countries have applied them. Researchers, authorities, and producers need a comprehensive and up-to-date understanding of EPR. Therefore, this literature review aims to review the current research status of EPR implementation on packaging, to highlight actual experiences conducting EPR, and to find research gaps. Results indicate that during the last 5 years, there has been an increase in the amount of research on EPR in packaging and that packaging waste recycling under this scheme is the most considered activity. Additionally, the primary metrics used to assess the efficacy of EPRs are recycling and reducing packaging waste. According to the lessons learned, applying EPR to packaging should take stakeholder engagement, policy design, transparency, and incentive strategy into account. Additionally, knowing the economic effectiveness problems small- and medium-sized packaging companies face, the effectiveness of EPR methods on various materials and geographical areas, and the efficacy of monitoring methods are the main areas that need to be researched.

INTRODUCTION

A sustainable waste management policy framework known as Extended Producer Responsibility (EPR) is emerging as a potent organizational and economic instrument (Barbara et al. 2022, Septianingrum et al. 2023). Over the next twenty years, research on EPR is anticipated to increase as more scholars pay attention to these issues (Cai & Choi 2021). This scheme requires manufacturers to take responsibility for every phase of the life cycle of their products, from manufacturing to disposal. This initiative aims to encourage companies to minimize the harmful environmental effects of their packaging and goods by recycling, reusing, and efficiently disposing of them.

Packaging is essential for containment, protection, preservation, shipping, handling, and sales in today's product business (EPA 2023). However, most packaging items are single-use and become garbage after use, resulting in an extremely short product life cycle (Rubio et al. 2019). Therefore, its widespread usage raises substantial environmental issues regarding packaging waste (GIZ 2022, Oscar et al. 2022). In recent years, different nations have applied EPR frameworks to packaging waste management (Destyanto et al. 2019, Rubio et al. 2019). They have applied various EPR approaches in the field of packaging, ranging from stringent legislative requirements to voluntary industry-led programs, each with its aims, methods, and outcomes (Bakar & Mohamed 2023, Mayanti & Helo 2024, Morashti et al. 2022, Pruess & Garrett 2024, Rubio et al. 2019)

Previous studies on EPR performance in packaging have focused on various aspects such as cost-benefit analyses (Marques et al. 2014), effectiveness (Andreasi et al. 2020, Colelli et al. 2022, Löhle 2021, Massarutto 2014, Niza et al. 2014), policy effectiveness and trends (Lorang et al. 2022, Niza et al. 2014, Rubio et al. 2019), and the impact on different responsibility schemes (Arnaud 2015, Gupt & Sahay 2015, Harris et al. 2021, Kim 2012). Still, to the best of the authors' knowledge, no scoping review exists about EPR initiatives for packaging waste. Therefore, this review is conducted for several purposes. First, it seeks to identify and collect relevant literature on the effectiveness of EPR programs in packaging waste management. Second, the study intends to provide policymakers and industry stakeholders with lessons learned from real-life, evidence-based insights into the implementation of the EPR scheme in the packaging sector. Finally, the review will highlight research trends and gaps regarding packaging waste EPR schemes. These aims can be achieved by answering three questions, including "Is implementing the EPR schemes on packaging effective?", "What are the research trends and research gaps on the EPR programs in packaging?" and "What are the lessons learned from implementing EPR schemes on packaging worldwide?"

The article is divided into five sections. The introduction covers the study's goals and the research background. Next, the methodology section provides a detailed explanation of the methods used throughout the investigation. Then, the results section goes into the main findings from the literature review. Finally, the conclusion section summarises the analysis's key findings and suggests future research.

OVERVIEW OF EPR PROGRAMS ON PACKAGING

The European Union (EU) Directive 94/62/EC on Packaging and Packaging Waste, which was adopted by EU member states in 1994 (European Commission 1994), was one of the first reactions to enhance packaging waste management practices. This legislation represented the start of a large government response to the global issue of packaging waste, focusing on packaging waste in Europe. Since then, several political and economic instruments have been developed and geared toward solutions that necessitate increased producer leverage in dealing with problematic materials in the marketplace (Diggle & Walker 2022). Packaging materials (including beverage containers) make up approximately 17% of total EPR schemes globally, whereas waste from electrical and electronic equipment (WEEE) accounts for 35% of programs, tires account for 17%, and use oil, paint, chemicals, big appliances, and light bulbs account for 20% (Kaffine & O'Reilly 2013). By 2024, the application of the

EPR scheme in packaging has gained popularity in many places throughout the world. However, the specific status of EPR implementation varies greatly by jurisdiction, with some regions making tremendous progress while others are still in the planning and enforcement stages.

Europe

The implementation of EPR programs for packaging in Europe is the first of its kind in the global search for sustainable waste management practices. European nations have been at the forefront of adopting and refining EPR regulations for packaging materials due to their proactive dedication to environmental protection.

In the 1990s, the EU took strong legislative measures to manage and reduce packaging waste, and EPR was accepted as one of the primary policy tools within a comprehensive plan aimed at reducing landfill usage and recycling waste (Walter et al. 2019). With the adoption of EU Directive 94/62/EC on Packaging and Packaging Waste in 1994, the EU started legal measures towards improved recovery and diverting landfills of the rising amounts of domestic packaging trash that many European countries were disposing of annually (European Union 2020). The EU Directive 94/62/EC specifies current overall package recycling objectives of 55% until 2025, with a 25% by-weight plastic recycling target (European Commission). Many European countries that have implemented an EPR program for packaging have established plastic recycling rates that comply with or exceed the EU's current recycling objectives (Eurostat). New standards will demand at least 65% by weight of all packaging waste be recycled by December 31, 2025, with 50% targets varied by material for plastic recycling. Furthermore, by December 31, 2030, objectives will be raised to require that at least 70% by weight of all packaging waste be recycled, with a 55% recycling target for plastic. In 2019, Lithuania and Czechia had the largest plastics recycling rates in the EU, although presently, very little analysis is available on the administration and efficacy of these member states' programs. Meanwhile, companies in the Netherlands must obey the rules from the 2014 Packaging Management Decree. EPR covers to all packaging, and only producer responsibility organisation (PRO), 'Afvalfonds Verpakkingen', is responsible. Since the program's inception in 2008, the Netherlands has achieved considerable advances in EPR for packaging (European Environment Agency 2022).

America

Countries in North and South America have recognized the environmental impact of packaging waste, so they have integrated EPR frameworks into their waste management

strategies early on. From the 1970s, the United States was one of the early users of EPR for numerous materials, employing advanced-disposal fees for hazardous wastes, WEEE, and beverage containers. Oregon and Maine have currently established fee-based, obligatory EPR programs for packaging waste. In 2021, Oregon passed the Plastic Pollution and Recycling Modernisation Act, and Maine passed LD 1541, an “Act to support and improve municipal recycling programs and save taxpayer money” (Maine Department of Environmental Protection, Oregon Department of Environmental Quality). Additionally, Canada, at present, has five regional EPR programs implemented for packaging. Ontario was the first province to launch the program in 2004, followed by Québec in 2005, Manitoba in 2010, British Columbia in 2014, and Saskatchewan in 2016 (Diggle & Walker 2020). Harmonized EPR for packaging trash adoption in Canada has been identified as an essential phase for improved entire plastic waste management and a circular plastics economy (Canadian Council of Ministers of the Environment 2019, Diggle & Walker 2020). Moreover, Chile authorized a mandatory EPR program for packaging in June 2019 via the EPR Decree for Packaging (Prevent Waste Alliance 2021a). In addition, regarding Resolution No. 0191, Venezuela adopted an obligatory EPR program for packaging in 2020 (Gonzalez 2020).

Africa

The implementation of the EPR framework for packaging waste in African countries has had a variety of applications. As of May 2021, the South African Ministry of Forestry, Fisheries, and the Environment approved Section 18 of the National Waste Management Act for a national fee-based, mandatory EPR for packaging that covers paper, packaging, and some single-use (Arp et al. 2021, Geyer et al. 2017, Prevent Waste Alliance 2021b). In 2020, Kenya took significant steps, with the Ministry of Environment and Forestry enacting legislation to authorize fee-based, mandatory EPR schemes for packaging materials (WWF 2022). In 2014, the Nigerian government implemented optional EPR for products and packaging by establishing guidelines for EPR policy implementation through the National Environmental Standards and Regulations Enforcement Agency (Ajania & Kunlerea 2019). In Africa, continuous efforts are being made to apply EPR for packaging in the foreseeable future.

Asia

Currently, the state of EPR implementation for packaging differs across Asia. EPR programs for packaging materials are mandated in Taiwan, South Korea, Japan, and Vietnam. In 1998, Taiwan’s Waste Disposal Act approved an EPR

program for packaging materials (Taiwan Environmental Protection Agency 2021). In 2003, South Korea began a program with the passage of the Act on Promoting Resource Saving and Recycling (Prevent Waste Alliance 2021c) that covers four packaging materials (paper packaging, glass bottles, metal cans, and plastic packaging) under this EPR program (Ministry of Environment 2010). In 1995, Japan’s packaging EPR program began with the Act on the Promotion of Sorted Collection and Recycling of Containers and Packaging. During the first decade of the program’s implementation, Japan’s program was regarded as advantageous between 1997 and 2010; package recycling rates increased by 27% (OECD 2014).

Furthermore, in 2020, India established an EPR program via the Rules for Plastic Waste Management exclusively for plastic packaging materials, which it called the Uniform Framework of EPR (India Ministry of Environment 2020). India’s EPR scheme has evolved from the voluntary proactiveness among its stakeholders (Pani & Pathak 2021). In the Philippines, recyclers and private-sector actors conduct several voluntary schemes (Johannes et al. 2021). Indonesia has an EPR framework for packaging under the Law of Solid Waste Management (2008), which is reinforced by Ministerial Regulation 81/2012. However, this framework has never been applied (Johnson 2022). Furthermore, since 2010, Australia has run a voluntary packaging industry program called the Australian Packaging Covenant, which seeks to improve the environmental effects of packaging materials. Signatories must follow an action plan and report yearly, although they are not subject to a mandated EPR program (Australian Packaging Covenant Organization 2017). From January 1, 2024, EPR in the field of packaging in Vietnam was adopted by Decree No. 08/2022/ND-CP. Each type of packaging that must be recycled will have a mandated recycling rate determined by the package’s life cycle, disposal and collection rate, national recycling objectives, environmental protection standards, and socioeconomic factors (The Government of Vietnam 2022).

MATERIALS AND METHODS

The effectiveness of various monitoring systems for EPR scheme compliance in packaging is investigated in this study using qualitative and quantitative methods to meet the aforementioned goals. Moreover, this review protocol followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting standards (Liberati et al. 2009). To identify future research direction and trends in the fields of packaging waste management, a three-stage review technique was employed, comprising planning, searching, and reporting (Johnsen et al. 2017,

Tranfield et al. 2003). Details of the search method are described in the next section.

Stage 1: Planning

In the planning stage, the potential benefit of undertaking a systematic literature review on the EPR schemes within the packaging sector was identified in consideration of a) the growing number of countries that are planning or implementing EPR, b) the importance of packaging and the environmental impact of packaging waste, c) the hesitation of the government authorities on managing EPR for packaging sector throughout the implementation stage, d) the difficulties of gaining knowledge of the efficacy, and e) the research directions of EPR in the packaging context. Second, the PCC framework is applied to establish the fundamental analysis and research questions (Table 1) (Pollock et al. 2023). Finally, three research questions are defined to accomplish the paper's aims.

Stage 2: Searching

The search stage for a literature review involves an in-depth identification of relevant publications. A clear and organized review procedure was developed, including the search strategy, inclusion and exclusion criteria, and data extraction and synthesis process.

On March 26, 2024, a thorough online search was performed through Scopus and Web of Science using three keywords: “Extended Producer Responsibility”, “EPR”, and “packaging”, to guarantee complete coverage of accessible literature. These databases use a consistent search syntax, made possible using Boolean operators (AND, OR) to link the keywords efficiently (see Table 2). The “TITLE-ABS-KEY” field was chosen for the term “packaging” in all databases to avoid limiting the sample size because it might not always appear in titles and abstracts, or it might appear as sources (food and beverage, pharmacy, agriculture, etc.) or material (carton, plastic, paper, etc.). This stage also strictly enforced inclusion and exclusion criteria (Mengist et al. 2020). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were used to screen the publications to evaluate their relevance to

Table 1: PCC framework elements of the paper.

PCC element	Feature in this review
Population	NA *
Concept	Extended Producer Responsibility schemes for packaging waste management
Context	Across the world

* Not applicable here because we examined EPR frameworks broadly, not a particular population or condition.

the study issue (Morashti et al. 2022). Only peer-reviewed papers published in English that focused on EPR programs in packaging were evaluated. Additionally, duplicate articles, inaccessible articles, and non-peer-review journals, i.e., conference proceedings, grey literature, and book chapters, were excluded. The titles and abstracts of the records were reviewed, and publications that did not fulfill the inclusion requirements were discarded (Saed et al. 2019). The writer carefully reviewed the remaining publications' contents to remove irrelevant articles. The process of searching all manuscripts was conducted via Covidence software, and a final collection of 51 qualified articles was produced. Details of the search protocol for this review are shown in Fig. 1.

Stage 3: Reporting

Following the multi-step searching phase, Microsoft Excel was used to extract data, and the VOSviewer was chosen to develop networks, highlighting relationships among the studied data. This software helped to generate a map that shows publishing trends and the major subject areas with the greatest interest in the study topic. Because keyword data in Web of Science and Scopus is inconsistent, generating maps with this program requires a thesaurus file containing keywords with the same meaning (Eck & Waltman 2019). To illustrate this, keywords such as “Extended Producer

Table 2: The search queries conducted and the total number of articles.

Databases	Searching string and searching terms	No of articles
Scopus	(TITLE (“Extended Producer Responsibility”) OR TITLE (“EPR”))	19,951
	(TITLE (“Extended Producer Responsibility”) OR TITLE (“EPR”) AND TITLE-ABS-KEY (“packaging”))	64
	(TITLE (“Extended Producer Responsibility”) OR TITLE (“EPR”) AND TITLE-ABS-KEY (“packaging”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (DOCTYPE, “ar”)) OR LIMIT-TO (DOCTYPE, “re”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (PUBSTAGE, “final”))	44
Web of Science	“Extended Producer Responsibility” (Title) or “EPR” (Title)	19,758
	“Extended Producer Responsibility” (Title) or “EPR” (Title) and “packaging” (*all fields)	208
	“Extended Producer Responsibility” (Title) or “EPR” (Title) and “packaging” (*exclude criteria)	163
Sum		207

Note. Date of acquisition: March 26, 2024

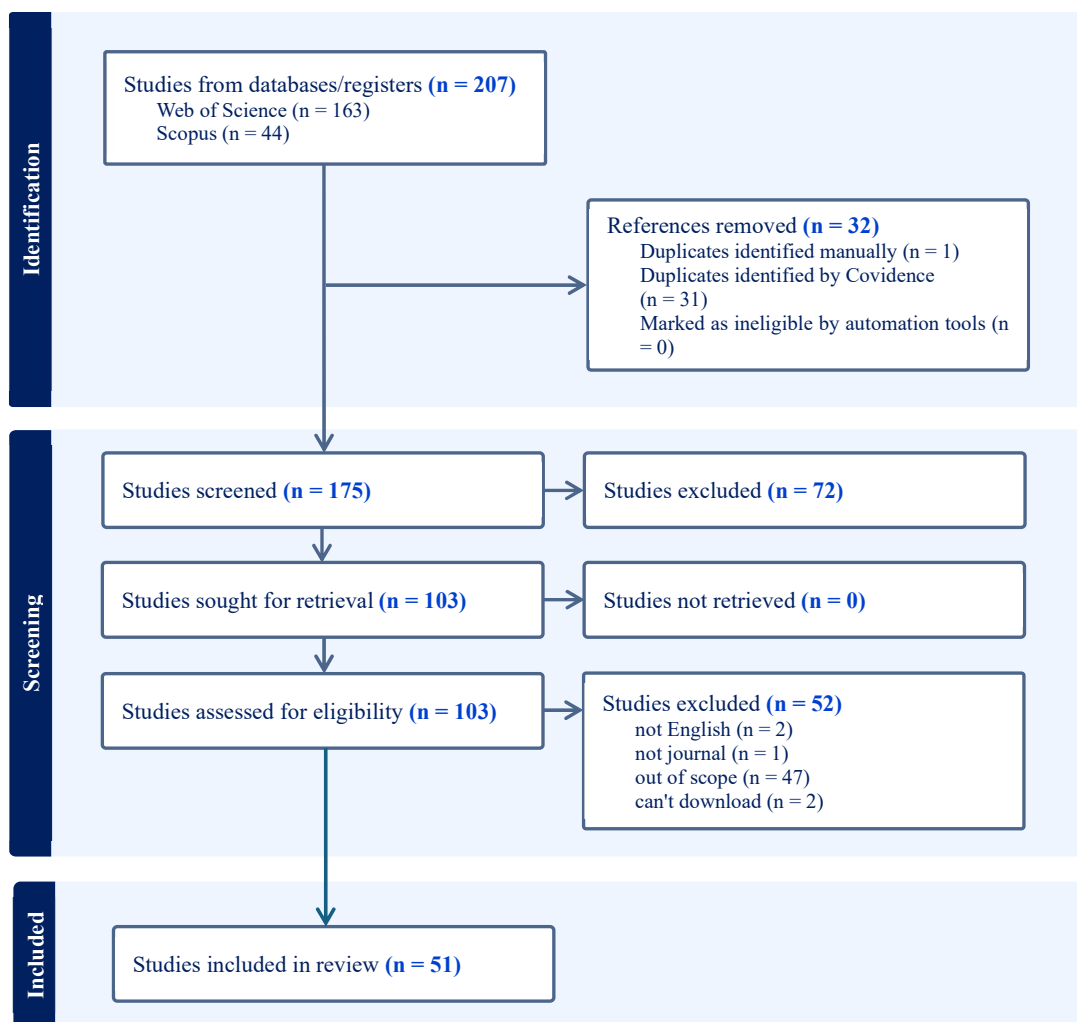


Fig. 1: The PRISMA flow chart showing the process of selecting articles.

Responsibility”, “Extended Producer Responsibility (EPR)”, and “responsibility” were combined into a single phrase, “Extended Producer Responsibility”. The thesaurus summary is listed in Table 3.

The data were analyzed and organized into five categories: bibliometric and network analysis, literature analysis, lesson learned, and research gaps. The final report aims to contribute to the body of knowledge and practices on EPR schemes in packaging, offering valuable insights for improving solid waste management.

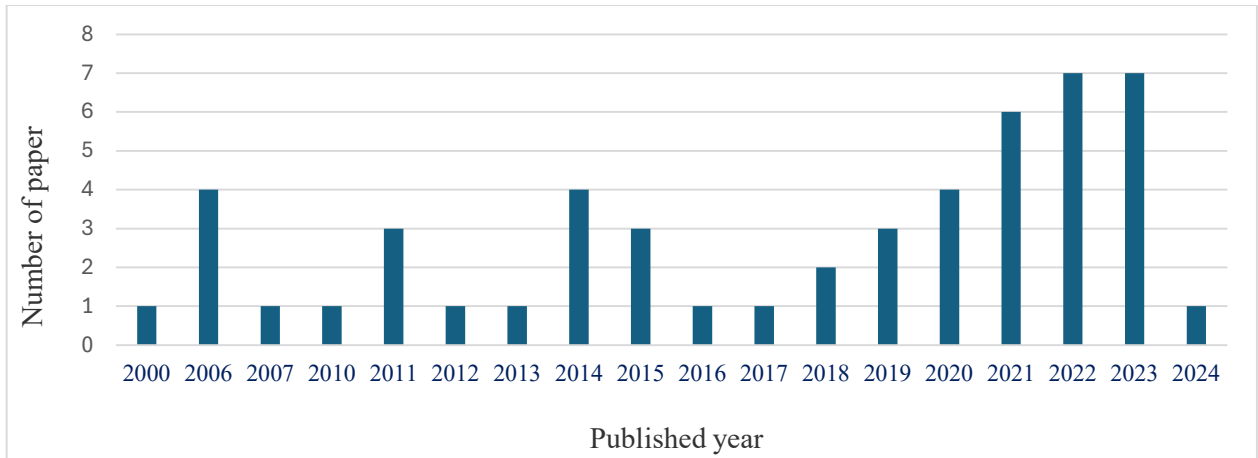
RESULTS AND DISCUSSION

Bibliometric and Network Analysis

The analysis of the 51 articles collected from Scopus and Web of Science indicates that, before 2000, no journal article

Table 3: Thesaurus of various keywords.

Keyword	Replaced by
Extended producer responsibility (EPR) EPR	Extended producer responsibility
European Union	Europe
Product packaging	Packaging
Plastic waste	Packaging waste
Economic aspect	Economics
Government regulation	Policy
Environmental policy	
Plastic	Plastics
Environmental management	Management
Waste management	
Priority journal	
Sustainability	Sustainable development



* Note: The total for articles published in 2024 has not been completed because the search period ended on March 26, 2024.

Fig. 2: Number of published papers annually.

could be found on the topic of EPR on packaging. Moreover, between 1991 and 2023, a small number of articles were published before 2018, as shown in Fig. 2, with 7 papers (14 %) published from 2000 to 2010 and 16 papers (31 %) published between 2011 and 2018. In line with trends in publications on “EPR on packaging”, 28 papers (55%) articles that were gathered for examination in this study were published between 2019 and 2024, meaning the continuous rapid growth of packaging management under the EPR programs’ research papers in recent years, because EPR and CE concepts have increased in significance since 2010.

The literature analysis also reveals the top journals with the largest number of articles, as follows: Waste Management and Research (8), Journal of Cleaner Production (7), Journal of Industrial Ecology (5), Waste Management (4), and Resources, Conservation and Recycling (3). Moreover, regarding publications published by the country, it is revealed that most publications are from Europe (10), Canada (4), China (3), and the United States (2). Few publications on “EPR on packaging” originated in developing nations compared to developed countries, namely Europe, where nations are leading EPR activities, such as Indonesia, Iran, India, etc.

This analysis only includes terms that appear at least four times. Of these terms (513), 40 fulfilled the criteria, which decreased to thirty-one after applying the thesaurus file. The frequency map of these terms is shown in Fig. 3. The thickness of the lines represents the strength of the relationship among the nodes (keywords), which was calculated using the number of papers in which the two keywords appeared together. The distance between nodes represents their relationship and the similarity of their themes, with shorter distances indicating tighter links. The most commonly recurring keyword is “Extended Producer

Responsibility” (n=38), which is essential to the map. Other frequent keywords include “management” (n=27), “recycling” (n=25), “packaging” (n=22), and “packaging waste” (n=15), among others. The map shows that plastic is the most common material and has generated more research interest than other materials in the packaging industry under EPR initiatives. This map also shows that recycling is mostly considered to promote solid waste management.

Fig. 4 depicts the time-series growth of the subjects in the examined 51 chosen papers published between 1991 and 2024. The articles’ themes were restricted to “environmental planning”, “cost-benefit analysis,” and “landfill” by 2014. From 2016 to 2018, subjects have expanded to include “Extended Producer Responsibility”, “management”, “policy”, and “Europe”. However, in 2018, the issues that garnered the most interest are “circular economy”, “sustainability”, and “recycling”. These challenges are expected to grow in the future since they have received media attention and are part of government policy. In contrast, waste treatment research has declined over time.

Regarding the research methodologies, there is a predominant focus on quantitative methods, which comprised 76% of the approaches employed. This means that statistical inference in this research field is widespread. In addition, qualitative methods were also found, to a lesser extent, with 4% of the approaches dedicated to in-depth exploration and understanding of actual case studies. A mixed-method approach was used in 14% of the total in addressing complex research questions. These methodological approaches offer a clear picture of EPR frameworks in packaging.

Some Facts About the Effectiveness of EPR Scheme on Packaging

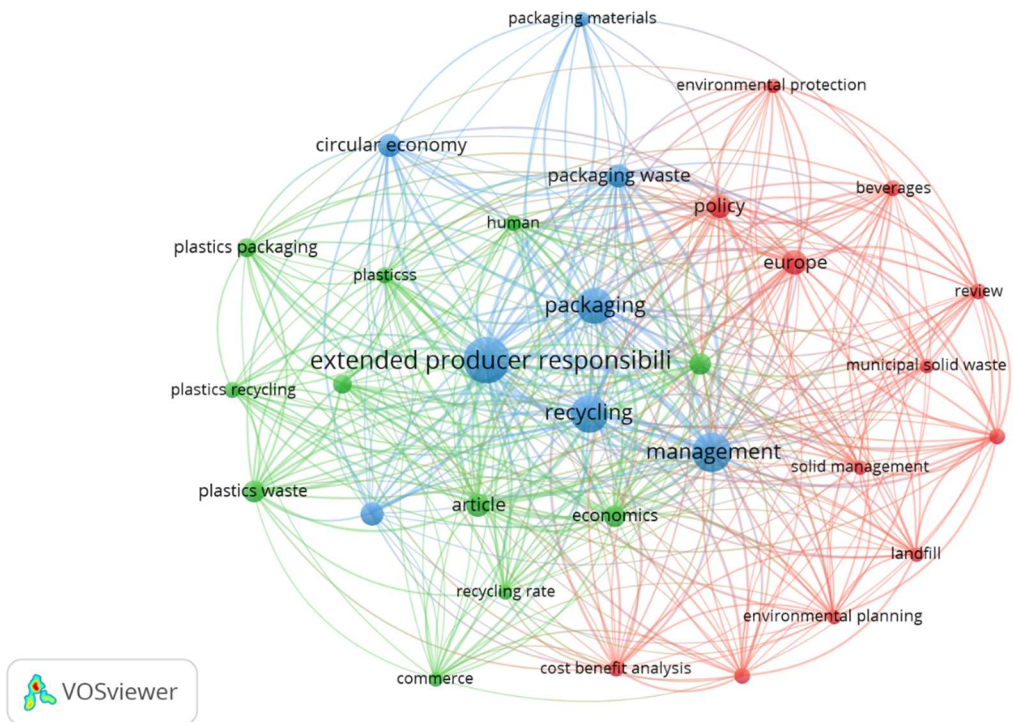


Fig. 3: Keywords Co-occurrence in 51 publications.

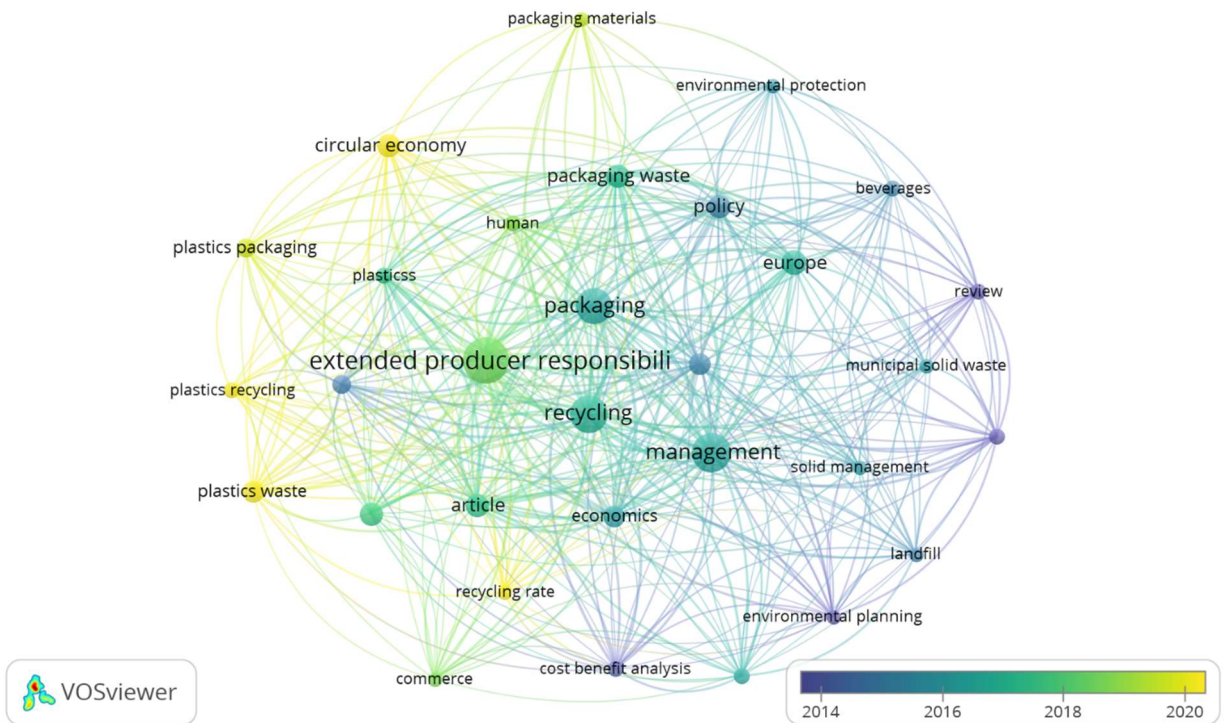


Fig. 4: Topics throughout the research period.

Understanding EPR's influence on waste management is critical for assessing its contribution to encouraging sustainable behaviors, lowering environmental damages, and creating a circular economy. This section analyses empirical data, case studies, and expert opinions to examine real-life cases and potential opportunities for implementing EPR programs in the context of packaging waste.

Waste Reduction and Recycling Rates

Overall, EPR for packaging has been effectively implemented across Europe in accordance with European Parliament and Council Directive 94/62/EC goals (Cahill et al. 2011). Germany and Austria have drastically decreased the total amount of packaging on the marketplace, used less material in packaging, and recycled more packaging. For example, between 1991 and 1997, Germany decreased packaging waste by 1.4 million tons (13%), encouraged by EPR legislation and industry cooperation. According to surveys of producers in Germany and Austria, implementing an obligatory EPR policy has been the critical driver of package optimization. (Quinn & Sinclair 2006). Furthermore, the economies of Portugal and Spain have been able to boost recycling and recovery rates over the years in the direction of the EU goals: a) achieving 100% of the area's coverage, b) growing the quantities of waste selectively collected, c) raising the public's understanding of the importance of recycling through constantly awareness campaigns for the individuals, d) supporting recycling of recyclable materials from the undifferentiated collection, and e) promoting recycling of recyclable materials (Niza et al. 2014, Rubio et al. 2019). An investigation of the EPR for plastic packaging waste in Spain, Italy, France, Germany, and Poland found that the EPR systems also helped enhance recycling rates. In addition, between 2006 and 2018, waste collection rates rose while employing the EPR system. EPR initiatives have demonstrated outstanding achievements in plastic packaging waste collection and recycling, meeting waste management expenses, and varied effectiveness, depending on each country's environment. (Lorang et al. 2022). The EU's recovery and recycling programs for food and beverage containers (and other packaging waste), such as the Belgian Fost Plus and German Green Dot System, reflect EPR's success. More than 130,000 enterprises currently participate in the Green Dot scheme, and the Green Dot emblem appears on 460 billion consumer items. Furthermore, approximately 14.7 million tonnes of used packaging trash was collected and repurposed by European organizations (Agamuthu & Visvanathan 2014).

In Canada, before the EPR program's adoption in 1989, beverage litter constituted 72% of the waste collected in the region, and by 2004, this was reduced to 7.5% (Ajanja &

Kunlerea 2019). Beverage container EPR programs have produced significant recovery rates, frequently surpassing 80% (McKerlie et al. 2006, Quinn & Sinclair 2006). However, a study by Harris et al. (2021) revealed that there was no decrease in shoreline pollution levels in British Columbia after implementing the EPR policy for packaging (Harris et al. 2021).

Except for Korea, the writers could not locate much information about waste reduction and recycling under EPR initiatives in Asian nations. Since implementing the EPR scheme in 2003, product recycling in Korea has steadily grown. Between 2003 and 2007, 6,069,000 tonnes of waste materials were recycled. In 2007, recycling rose by 32.3% compared to the period before the EPR system was adopted (Kim 2012). However, according to Kim & Mori (2015), the recycling rate in Korea between 2000 and 2011 decreased from 59% to 40%, respectively, and the recycling volume fell accordingly. The fundamental reason for this decline is that small and medium-sized producers are not subjected to mandatory recycling under the EPR program.

Eco-Design and Innovation in the Packaging Industry

EPR schemes motivate producers to consider environmental concerns in product design and promote consumer knowledge about the environmental effect of products, resulting in greater demand for eco-friendly products and packaging, thus inspiring producers to implement eco-design practices (Barbara et al. 2022, Schamber & Bon 2022, Susanna et al. 2017, Wiesmeth & Hackl 2011, Peng et al. 2020). However, unfortunately, excluding British Columbia, EPR has had much less of an impact on product innovation and ecological design (Massarutto 2014, Walls 2006). The producer responsibility system in British Columbia encouraged redesigns of 2-liter soft drink bottles because of glass breakage and recyclability difficulties. The shift to thinner plastic walls with molded ridges for structural support reflects the EPR program's goal of encouraging industry-wide transitions toward more sustainable packaging (McKerlie et al. 2006). By contrast, Røine & Lee (2008) showed that the majority of companies in Norway's plastic packaging sector do not prioritize environmental concerns, such as green goods and eco-design. While specific industrial organizations and Producer Responsibility Organisations promote eco-design, the reaction from businesses has been limited. Similarly, in India, under the EPR initiative, producers and users of plastic packaging have investigated innovative alternatives, such as bamboo for items such as straws, bowls, plates, and cutlery, with local trials. At the same time, the Indian government and stakeholders have experimented with various technologies such as incineration, use in road construction, and fuel oil conversion to add value to plastic waste management.

Nevertheless, these acts are infrequent, and the outcomes are not ideal (Pani & Pathak 2021). In addition, according to the mechanism test of Peng et al. (2020), the EPR system may promote companies that develop innovative green technology through government subsidies, but it has little effect on encouraging the development of green technology through corporate environmental responsibility. Similarly, the authors' heterogeneity research revealed that the EPR system promotes corporate green technology innovation more significantly in non-state-owned and non-high-tech businesses.

Public Awareness

Rubio et al. (2019) showed that conducting EPR policies favored waste awareness over time in Portugal and Spain. This is apparent in the population's growing understanding of the importance of recycling, which has been assisted by continuing awareness programs to encourage recycling recyclable goods from undifferentiated collections. In addition, the Green Dot program in Germany, including more than 130,000 companies and 460 billion consumer packages indicates the growth in public awareness of recovery and recycling waste. Similarly, the FostPlus initiative in Austria has been successful, with 95% of residents sorting their waste packaging for recycling (Agamuthu & Visvanathan 2014).

In conclusion, these international performance outcomes of EPR practices indicate the importance of EPR schemes in terms of the amount of packaging waste, recycling rates, public awareness, and eco-design. Unfortunately, information about stakeholder collaboration, financial effectiveness, energy savings, and job creation could not be obtained through the collected articles. Therefore, despite such apparent success, the effectiveness of the EPR frameworks could not be easily concluded from the preceding information. It can also be said that recycled and reduced rates of packaging waste are the primary and more manageable factors used for evaluating EPR effectiveness, and there is a lack of control and study on other efficiencies of EPR schemes. These gaps should be examined more in the foreseeable future by continuously evaluating and reviewing them in different databases, such as NGOs and government reports, conference proceedings, etc.

Lessons Learned on EPR Implementation for Packaging Around the World

The global examination of EPR programs for packaging brings valuable insights and lessons for policymakers, industry stakeholders, and environmental campaigners alike. As governments face the complex problems of controlling packaging waste and achieving sustainability goals, examining the experiences and achievements of EPR

projects provides significant information for developing successful policies and strategies. In this review, numerous critical lessons have emerged from adopting EPR programs for packaging globally, shining a light on packaging waste management approaches.

Policy Design

The policy design for EPR adoption in packaging waste management is critical (Carola 2000). Specific targets, objectives, and processes in EPR regulations motivate action and stimulate the creation of waste management systems to achieve goals. In 2021, the research results of a case study in British Columbia revealed that there had been no improvement in pollution levels following the implementation of an inadequate EPR policy for packaging to minimize shoreline pollution, indicating the need for policy interventions (Harris et al. 2021). Lessons learned from the research findings of Park (2021) on the efficacy of the steel can packaging EPR program complement previous studies that show that a more severe EPR policy does not result in increased recycling. In other words, the government's approach of establishing high recycling rate objectives does not always result in higher recycling rates. As a result, governments should consider setting realistic goal recycling rates for manufacturers rather than presuming that high recycling targets will result in more recycling. In contrast, effective EPR policies have increased trash collection, recycling, and recovery performance for certain waste flows in Portugal and Russia (Liubarskaia & Putinceva 2021, Niza et al. 2014). Furthermore, it is important to develop EPR policies for packaging that are tailored to specific locations and packaging waste management systems. Tailoring policies to the local environment can result in more effective implementation and better outcomes. South Africa's experience with EPR in the packaging sectors demonstrates that obligatory, government-imposed laws (as in the plastic bag business) do not appear to be effective in driving recovery compared to voluntary industry initiatives (as in the can, glass, and PET industries) (Nahman 2010). In addition, when establishing EPR policies, it is essential to have a thorough understanding of specific sectors, market features, and product characteristics because no single type of EPR policy suits every business (Røine & Lee 2008). Finally, Harris et al. (2021) notably suggested that policy interventions need to incorporate comprehensive monitoring and evaluation systems to quantify the outcomes of pollution reduction initiatives directly.

Stakeholder Engagement

EPR initiatives require participation from stakeholders

such as producers, retailers, waste management companies, consumers, and government agencies to ensure success (Polzer et al. 2016). The participation of all essential stakeholders from the early stages of policy creation to implementation is critical to the efficacy of EPR (Mayers 2008). Several studies and real-world situations support this inclusive approach. By including all stakeholders in the entire procedure through the EPR framework, nations such as Korea have raised recycling rates, minimized waste, and provided economic advantages and job possibilities in the recycling business (Kim 2012). In Europe, the efficacy of EPR programs, notably in beverage carton management, has been attributed to collaboration between manufacturers and the concerned public, as well as governmental initiatives. Additionally, Cahill et al. (2011) found that benefits are more evident when local governments actively develop and implement national systems, use existing trash infrastructure, and establish defined responsibilities for producers and local governments. Lessons from India's EPR framework emphasize the significance of incorporating several stakeholders, including the informal sector, to guarantee buy-in, collaboration, and long-term viability (Pani & Pathak 2021).

Transparency and Accountability

Under the EPR scheme, successful waste management relies heavily on establishing precise regulations and guarantees of accountability and transparency in packaging waste collection, recycling, and handling (Mayers 2008). Building trust among stakeholders and guaranteeing the integrity of EPR schemes requires transparency in financial aspects, data reporting, and decision-making processes, as noted by Lifset et al. (2023). Joltreau (2022) also emphasized the need for effective monitoring and continuous evaluation systems to track progress, identify weaknesses, and guarantee that stakeholders fulfill their responsibilities. Robust data management systems are required to track product life cycles, waste generation, and recycling rates. More importantly, according to Quinn and Sinclair (2006), these initiatives need to be governed by the government.

Incentives Strategy

Developing incentive strategies for EPR implementation impacts EPR participation and waste management. According to Wiesmeth & Hackl (2011), incentive-compatible frameworks that promote environmentally friendly behaviors while penalizing noncompliance are vital for encouraging producer engagement and supporting sustainable practices. In addition, Sui et al. (2024) noted that dynamic subsidy policies influence producers' participation behavior. Specifically, providing economic incentives to producers can improve

the products' design and environmental impact (Kunz et al. 2018, Mayers 2008). The achievement of EPR schemes for beverage containers in Nova Scotia is an example of the value of incentivizing (Diggle & Walker 2020). However, Joltreau (2022) discovered that the EPR financial incentive did not trigger any consistent shifts in packaging materials. Therefore, Agamuthu & Visvanathan (2014) argue that it is prudent to establish government incentives to encourage the increasing use of recycled products as raw materials to create new ones. These insights underscore the importance of developing comprehensive and dynamic incentive strategies to drive meaningful change and progress in EPR implementation.

Excluding the above lessons, other experiences involving the existence of sustainable end markets and integration of an EPR with two bonus/penalty programs should be considered while implementing EPR in the packaging industry (Agamuthu & Visvanathan 2014, Arnaud 2015)

Research Gaps on EPR Scheme for Packaging

While research on packaging waste EPR schemes has brought significant insights, there are still several research gaps in current EPR systems that require further investigation. Following the literature review, some ideas emerged, as described following.

One notable shortcoming is a lack of understanding about the economic efficacy of the EPR scheme. Barbara et al. (2022) discovered that existing research has focused primarily on European nations and ignored the economic aspect. However, the experiences of the Netherlands, Italy, Austria, Spain, and France show that EPR can act as a financial mechanism promoting the transition to a circular economy, in particular in the realm of packaging. Therefore, there needs to be more research on how finances change or the cost-benefits of EPR deployment for both governments and producers in different economic contexts. It is also critical to investigate how EPR systems might affect consumer pricing. Economic assessments can assist governments and industry stakeholders in making decisions about building and managing EPR systems.

Moreover, a full awareness of the issues faced by small- and medium-sized packaging businesses conforming to EPR policies is critical for promoting inclusiveness and delivering equitable outcomes (Wiesmeth & Hackl 2012). They frequently confront specific challenges, such as limited financial resources, technical competence, and regulatory complexities, which could limit their ability to meet EPR standards. Researching these issues and designing tailored solutions to help them participate in EPR programs is critical. By tackling the specific needs and constraints of small and

medium-sized packaging enterprises, policymakers can ensure that EPR schemes on packaging are accessible and equitable for all stakeholders, ultimately improving the efficacy and longevity of packaging waste management attempts.

Furthermore, another area that requires attention is the limited knowledge of the recycling performance of EPR programs on packaging, with a primary focus on plastics and, to a lesser extent, steel or paper (Agamuthu & Visvanathan 2014, Diggle et al. 2023, Park 2021). This limited scope prevents a thorough knowledge of the efficacy of EPR methods over a wide range of packaging materials and geographic settings. Research should cover a broader spectrum of packaging materials, such as glass, aluminum, and other metals, to close this gap. Scholars can gain insight into the problems and possibilities associated with diverse material streams by examining the recycling success of EPR programs across various packaging materials in both developed and developing nations.

Finally, the design of EPR programs for packaging waste management is never independent of the monitoring systems (OECD 2016). Therefore, systems designed to monitor the amount of money generated from license fees, the companies registered, the technologies utilized to convert wastes, the quantity of packaging recovered, and so on need to be conducted. Monitoring methods are required for every system to work effectively (Mwanza & Mbohwa 2019). However, no articles describe monitoring methods or analysis of the contribution of monitoring ways to the success of EPR implementation. By examining monitoring technologies, researchers can identify the best methods and give policymakers and industry stakeholders with evidence-based insights into the efficacy and implications of various monitoring approaches for EPR compliance in the packaging sector.

Addressing these research gaps is necessary for expanding our understanding and improving the efficacy of EPR systems for packaging waste management. By encouraging more studies, EPR frameworks may considerably help worldwide efforts to move to a more circular and sustainable economy.

CONCLUSIONS

In conclusion, the EPR programs for packaging waste management have been thoroughly examined in this article, which has also provided an overview of the field's current research state and actual implementations across the globe and highlighted research needs. The findings have shown that the research on EPR in packaging has recently been investigated more, and this program's most thought-out activity is recycling waste. Additionally, some evidence about the effectiveness of EPR on packaging, involving

recycling and reducing packaging waste, eco-design, and public awareness, was found. Moreover, the lessons learned indicate that when implementing EPR in packaging, policies should consider stakeholder engagement, transparency tactics, and incentive approaches. Specific research gaps for future investigation have also been identified. These include analyzing the financial effectiveness of EPR systems for different stakeholders, looking into potential obstacles that small- and medium-sized businesses may face under the EPR scheme, and evaluating the efficacy of surveillance techniques on compliance from many stakeholders.

Academics, legislators, and industry professionals can find the study's conclusions useful as a reference because they could help comprehend or make decisions regarding EPR on packaging. However, there are certain limitations to this study as well. First, the sample size might be constrained because the data was taken from the Web of Science and Scopus databases and was limited to journal articles published in English. Second, it remains unclear whether EPR schemes are truly effective regarding packaging. Furthermore, the present study has not yet profoundly analyzed lessons learned for countries under specific conditions. These limitations will be tackled in future research with a deep analysis.

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