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REGULATORY STIMULATORS AND ECONOMIC – MANAGERIAL BARRIERS TO THE DEVELOPMENT OF CIRCULAR SUPPLY CHAINS FOR PLASTICS

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ABSTRACT: Purpose: This study examines regulatory stimulators and economic-managerial barriers to developing circular supply chains for plastics within the circular economy framework. Methodology/approach: Comprehensive literature review, analysis of EU and Polish legal regulations, industry reports, and case study of Zakład Gospodarowania Odpadami Gać sp. z o.o. as a circular supply chain link. Findings: Coercive pressure from EU institutions represents the primary stimulator for circular transformation. Key economic barriers include profitability threshold challenges and high investment risks. Regulatory inconsistency and instability hinder long-term partnership development. Only 10-30% of plastic waste undergoes recycling in Poland, significantly below EU targets. Research limitations: Single case study limits generalizability; dynamic regulatory environment affects findings' currency. Practical implications: Need for stable regulations, continuous waste streams, and specialised recycling infrastructure investments. Social implications: High recycling costs disproportionately burden consumers through increased product prices. Originality/value: Provides comprehensive analysis combining regulatory and economic-managerial perspectives with practical insights from waste management.

KEYWORDS: circular economy, circular supply chains, plastic waste, coercive pressure, recycling barriers

Introduction

Contemporary challenges falling within the category of sustainable development, related to the production and utilisation of plastics, require transformation of existing supply chain management models. The linear economic model based on the take-make-waste scheme proves to be inefficient and harmful to the natural environment (Stumpf et al., 2021). Moreover, it is directly associated with resource depletion and excessive waste generation (Szczech-Pietkiewicz, 2024). This constitutes a significant challenge that has elevated the importance of the circular economy (CE) concept as a distinctive alternative paradigm. It represents a shift toward a more sustainable and regenerative model that aims to close the loop of resource utilisation and minimise waste generation (Hina et al., 2022; Szczech-Pietkiewicz, 2024).

Plastics constitute an important element of the global economy and significantly contribute to economic growth; however, their production, utilisation, and end-of-life management are unsustainable from a long-term perspective (Plastics Europe AISBL, 2024). Particularly problematic is the plastic waste management phase, where materials often end up in the natural environment, causing contamination of terrestrial and aquatic ecosystems. Data indicate that 44% of all plastic produced was manufactured after 2000, only 20% undergoes recycling globally, and 40% of plastics concerns single-use packaging (Parker, 2018). Furthermore, the perspective of analysing circular practices in enterprises across different stages of their operations constitutes a significant research gap, especially considering the fragmentation of supply chains and the departure from their globalisation (Szczech-Pietkiewicz, 2024).

The implementation of CE solutions in plastic supply chains encounters numerous barriers of economic, managerial, technological, and regulatory nature. As indicated by Takacs et al. (2022), these barriers can be divided into five categories: intra-organisational, technological, market-based, legislative, and socio-consumer. Simultaneously, appropriate legal regulations can constitute a significant stimulator for the development of circular supply chains. For example, Arranz et al. (2022) indicate that European Union institutions, through exerting coercive pressure, can effectively influence enterprises, encouraging them to adopt practices consistent with CE principles.

In particular, the European Green Deal's New CE Action Plan (European Commission, 2020) and the Ecodesign Regulation (Proposal, 2022a) and the Clean Industrial Deal (2025) establish legally binding targets to double the EU's circular material use rate to 24% by 2030 and require design-for-recycling in plastics, packaging, batteries, electronics, and vehicles. Recent studies by the Joint Research Centre (2023) and economic modelling analyses indicate that these pan-EU directives, especially when coupled with recycling-stimulus measures and border-adjustment mechanisms, can reduce plastic material use in Europe by up to 8–11% by 2030 and strengthen circular supply-chain resilience across member states.

Given the above, the aim of this article is to discuss the stimulators and barriers to the development of circular supply chains for plastics in light of the CE. This is particularly important as, despite the market necessity of linking supply chain management and CE, empirical research in this field remains scarce, and researchers' interest in practices combining these issues is insufficient (Szczech-Pietkiewicz, 2024). A case study of Zakład Gospodarowania Odpadami Gać sp. z o.o. will also be helpful in this regard, as one of many links in the circular supply chain for plastic waste.

Literature review

Circular Supply Chain in the CE Perspective

The subject of circular supply chains is increasingly discussed in contemporary academic literature. The issue of understanding this concept was addressed by, among others, Farooque et al. (2019), who proposed a comprehensive definition of circular supply chain management. Batista et al. (2018) sought the archetype of circular supply chains, while De Angelis et al. (2018) analysed supply chain management concepts in the context of CE. The literature also reveals research on the relationships between sustainable supply chain management and transformation toward a circular economy

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(Genovese et al., 2017), as well as the construction of business models and supply chains for CE (Geissdoerfer et al., 2018). In any case, the approach to circular supply chains is beginning to gain importance among contemporary researchers. Masi et al. (2017) identified supply chain configurations in relation to the circular economy, while Nasir et al. (2017) compared linear (i.e., "classical") and circular supply chains using the construction industry as an example. Research on barriers and motivators for implementing solutions from the broadly understood CE is also evident, which "is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems" (own translation) (Szczech-Pietkiewicz, 2024). Govindan and Hasanagic (2018) conducted a review of factors, barriers, and practices related to the circular economy from a supply chain perspective, while Mangla et al. (2018) identified barriers to effective circular supply chains in the context of developing countries.

Therefore, the literature is rich in cross-cutting approaches to the topic of CE and supply chain management, including specifically its circular form. Circularity is undoubtedly the realisation of the CE concept in the supply chain (Marzantowicz, 2024). Thus, a circular supply chain should be defined as a coordinated system for managing flows of materials, financial resources, and accompanying information, considering cooperating extractive, production, commercial, and service companies, including collection, transport, disposal, storage, and recycling facilities, as well as customers, which incorporates and integrates CE principles to maximise resource value throughout the entire product life cycle. In contrast to the "traditional" linear supply chain, the circular model is characterised by multidirectional flows of materials and products that are designed, manufactured, distributed, used, and recovered in a manner enabling their multiple use, regeneration, renewal, or recycling, while simultaneously minimising negative environmental impact and maximising efficiency (Montag, 2023). However, in practice of managing circular waste supply chains, when it is impossible to achieve all sustainable development goals in the first stage, priority is given to achieving ecological and social goals while accepting lower economic efficiency. According to CE assumptions, the economic effects and price increases of final products, with assumed reduction in primary resource use and waste reuse, should be evenly distributed among all supply chain participants, which should be guaranteed by the principle of extended producer responsibility (EPR). Unfortunately, in practice, the financial consequences of implementing circular supply chains in the form of high recycling and resource recovery costs are transferred disproportionately to all chain stakeholders, particularly resulting in higher prices of final goods purchased by consumers.

A circular supply chain for plastics requires close cooperation among all chain links, from raw material suppliers, through manufacturers, distributors, consumers, to companies engaged in waste management and recycling. A crucial role is also played by transparent information flow, enabling the tracking of materials and products throughout the entire product life cycle (Farooque et al., 2019). Circularity can also be an element of building resilience, but it must be part of a supply chain management strategy (Marzantowicz, 2024). A resilient supply chain adapts its strategies to environmental conditions, thereby becoming resistant to anomalies and all perturbations, which provides the possibility of ensuring continuity in the realisation of material and information flows (Marcinkowski & Kołakowski, 2024). Current over-regulation of the waste market and instability of legal regulations significantly hinder the formulation and implementation of proactive resilience strategies for entities operating in the waste industry and their supply chains.

Meanwhile, implementing a circular supply chain in the plastics sector can lead to numerous economic, environmental, and social benefits, such as reducing dependence on depleting primary raw materials, decreasing greenhouse gas emissions, limiting the amount of waste going to landfills and into the natural environment, creating new jobs in the circular economy sector, and increasing the security of strategic raw material supplies (Ellen MacArthur Foundation, 2023). Supply chain circularity has become a fact, but shaping its resilience, as well as increasing its economic efficiency, requires a synergistic approach to managing its flexibility, adaptability, and robustness (Marzantowicz, 2024).

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Institutional Coercive Pressure

The transformation toward CE constitutes one of the key priorities of European Union policy and, consequently, of Poland. As indicated by Arranz et al. (2022), EU institutions fulfil the role of "institutional entrepreneur" with the ability to influence enterprises through coercive pressure. The adoption of CE principles by enterprises is significantly determined by mandatory institutional pressure and/or incentives (tax reliefs, subsidies, preferential bank financing rates), as evidenced by various studies (Szczech-Pietkiewicz, 2024; Wegener et al., 2025). The most important regulatory package concerning CE was adopted by the European Commission in December 2015. The overarching intention of implementing this package is transformation and change in the perception of waste, which should be treated as resources, limiting the consumption of primary raw materials. Such an approach results in changes in waste management priorities, within which waste prevention is prioritised first, followed by its maximum utilisation and recycling. Table 1 presents EU and Polish regulations concerning CE in chronological order and according to the main regulatory objective.

Table 1. EU and Polish regulations concerning CE

Year	Level	Regulation	Main Objective
2008	EU	Waste Framework Directive (2008/98/EC)	Establishment of legal framework for waste management in the EU
2012	Poland	Act of 14 December 2012 on Waste (Journal of Laws 2013, item 21)	Implementation of the waste framework directive
2013	Poland	Act of 13 June 2013 on Packaging and Packaging Waste Management (Journal of Laws 2013, item 888)	Regulation of packaging management, 2023 amendment will increase beverage packaging collection
2015	EU	Circular Economy Package (European Commission, 2015)	First comprehensive action plan for CE
2018	EU	Directive on Batteries and Accumulators and Waste Batteries and Accumulators (Directive, 2018a)	Improvement of waste management from vehicles, batteries and electronics
2018	EU	Landfill Directive (Directive, 2018b)	Limiting waste landfilling and promoting waste management hierarchy
2018	EU	Amendment to the Waste Framework Directive (Directive, 2018c)	Strengthening CE principles, including waste prevention
2018	EU	Directive 2018/852 on packaging and packaging waste (Directive, 2018d)	Increasing recycling and recovery of packaging waste
2018	EU	European Strategy for Plastics in CE (European Commission, 2018)	Transformation of plastic design, production and use
2019	EU	SUP Directive (Directive, 2019)	Reducing the impact of selected plastic products on the environment
2019	Poland	CE Roadmap (Ministry of Climate and Environment, 2019)	Strategic framework for transformation toward CE
2020	EU	New CE Action Plan (European Commission, 2020)	Accelerating transformation toward CE as part of the Green Deal
2021	EU	Regulation on Batteries and Waste Batteries (Proposal, 2020)	Sustainable batteries and accumulators throughout their life cycle
2021	Poland	Amendment to the Waste Act (Journal of Laws 2021, item 2151)	Adaptation to EU CE package requirements
2022	EU	Packaging Regulation (Proposal, 2022b)	Prevention of packaging waste generation and promotion of CE
2023	EU	Ecodesign Regulation (Proposal, 2022a)	Product design considering the entire life cycle
?	Poland	Extended Producer Responsibility Act	Implementation of the "polluter pays" principle
Year	Level	Regulation	Main Objective

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Legal regulations create a series of stimuli for the development of circular supply chains for plastics, although, as already mentioned, they have the character of coercive pressure. Ambitious targets for recycling and recovery of plastic packaging waste force enterprises to invest in recycling infrastructure and design products with their future recycling in mind. As indicated by Directive (2018d), by 2030, 55% of plastic packaging waste should be subjected to recycling. Meanwhile, the European Strategy for Plastics in CE (European Commission, 2018) assumes that by 2030, all plastic packaging on the EU market will be recyclable. This forces transformation in the design, production, and recycling of plastics, which directly translates to supply chains. The New CE Action Plan (European Commission, 2020) provides for significant reduction of plastic waste by 2030, leading to the development of new business models, ecodesign, and circularity in supply chains. Bans on specific single-use plastic products (Directive, 2019) and restrictions on waste landfilling (Directive, 2018b) stimulate the search for alternative materials and the development of reuse systems. Meanwhile, the Packaging Regulation (Proposal, 2022b) establishes a target of 65% recycling of all packaging waste by 2025, influencing packaging standardisation and increasing recycled content. Requirements for minimum recycled content in new products (e.g., in PET bottles) create demand for recyclates, stimulating the development of the secondary raw materials market. Extended Producer Responsibility (EPR) systems, both at EU and national levels, transfer financial responsibility for waste management to producers, encouraging ecodesign and packaging optimisation. The introduction of deposit return systems for beverage packaging increases collection rates and quality of collected materials, translating to higher recyclate quality. Meanwhile, taxes on non-recycled plastics (e.g., the EU tax on non-recycled plastic packaging waste) and financial incentives for enterprises implementing CE principles stimulate transformation toward circularity.

Despite visible regulatory stimulators, there are also legislative barriers that hinder the development of circular supply chains for plastics. As indicated by Takacs et al. (2022), one of the key legislative barriers is so-called hindering legislation, i.e., regulations that impede the implementation of circular solutions. An example may be inconsistency between waste regulations and food safety regulations, which may limit the use of recyclates in food packaging. The lack of uniform standards and certification systems for recycled materials hinders the development of the secondary raw materials market. Sileryte et al. (2022) point to problems related to lack of continuity in waste data management and difficulties in tracking material flows. Despite the introduction of various economic instruments, they are often insufficient to balance the higher costs associated with implementing circular solutions. Meanwhile, Arranz et al. (2022) indicate that a lack of incentives for eco-innovation may produce negative effects. Complicated administrative procedures related to transboundary waste movement and obtaining waste processing permits constitute a barrier to the development of circular supply chains (cf. Wegener et al., 2025). Ineffective enforcement of existing regulations, particularly regarding illegal waste disposal and waste export, undermines regulatory effectiveness and creates unequal competitive conditions. Additionally, supply chain fragmentation, particularly visible in the construction sector, as noted by Yu et al. (2021), hinders the implementation of industrial symbiosis necessary for CE. The lack of a holistic approach to supply chain dynamics and economic aspects of circular supply chains therefore constitutes a significant managerial barrier.

Economic-Managerial Barriers to Circular Supply Chain Development

Kołakowski and Marcinkowski (2024) provided a comprehensive compilation of external and internal determinants of supply chain circularity. Based on quantitative research, they classified the most significant factors from the broader and closer environment as well as internal factors. From their review, those that directly correspond to the previously mentioned economic-managerial barriers can be distinguished, although without particular emphasis on those concerning plastics.

In the area of economic barriers, currency exchange rate instability is a significant problem, causing uncertainty about the final value of planned investments in circular technologies, which discourages enterprises from undertaking such initiatives. Meanwhile, high interest rates and their rapid changes negatively affect enterprises' investment capabilities in this area. The research by Kołakowski and Marcinkowski (2024) shows that this factor received one of the highest ratings as a barrier to circularity development. Enterprises with limited access to diversified financing sources have fewer opportunities to implement costly circular solutions. In industries where economies of scale are difficult to achieve, implementing such solutions may be economically unprofitable. Research addi-

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tionally indicates that the occurrence of economies of scale in an industry is an important factor affecting supply chain circularity. Meanwhile, transformation from the "classical" linear model to circular involves high initial outlays, which constitute a significant economic barrier, particularly for smaller entities – also within the supply chain.

Managerial barriers primarily include organisational structure complexity. The more complex and rigid they are, or based on high degrees of formalisation and power centralisation, the more difficult it is for entities to implement CE solutions. Such a perspective directly translates to subsequent supply chain functioning, which more readily assumes a centralised and efficient form rather than an adaptive one. Moreover, enterprises using highly specialised machines, equipment, and ICT systems encounter difficulties in redesigning processes to be circular. Digital technologies are utilised to a moderate extent in closed-loop supply chain management, despite widespread access to diversified technological solutions (Nowicka, 2024). Meanwhile, basing operations on specialised knowledge and employee competencies may lead to staff resistance to changes related to circularity implementation. Paradoxically, the research by Kołakowski and Marcinkowski (2024) shows that this factor received the highest rating among internal factors. Insufficient knowledge of managers about the CE concept and its practical implementation therefore constitutes an important barrier. The authors' research also indicates the importance of access to current and reliable market information. Furthermore, the more diversified the product and service portfolio, the more difficult it is to implement comprehensive circular solutions. This requires greater time and financial effort, and effects may be difficult to identify.

In the context of inter-organisational barriers, the research by Kołakowski and Marcinkowski (2024) shows that supplier and customer loyalty is an important factor affecting supply chain circularity, and its absence constitutes a significant barrier. Strong dependence on a limited number of suppliers may hinder the implementation of circular solutions if suppliers are not interested in changes. Meanwhile, overly dispersed and heterogeneous customers may cause difficulties in closing the chain cycle across all market segments. Also crucial from the entire supply chain perspective is the lack of common goals and leadership, which hinders building the relational architecture necessary for CE implementation. Meanwhile, geographical distance from key supply chain links hinders building lasting relationships and effective material loop closure. Building and shaping circular supply chains requires, above all, close relationships with direct supply chain links, both backward (supply chain) and forward (distribution chain: suppliers, customers, consumers) (Marcinkowski & Kołakowski, 2024).

Research method

The research adopted the case study method as a way to explore complex social and organisational phenomena in depth. This approach was chosen because the development of circular supply chains for plastics is strongly context-dependent, shaped by regulatory frameworks, economic conditions, and managerial practices. Unlike large-scale quantitative studies, a case study allows for a holistic view of interactions between institutional pressure, technological capabilities, and operational decisions. It is particularly suitable for examining how theoretical assumptions of circular supply chains, such as multidirectional flows, resilience, and extended producer responsibility, manifest in practice.

The analysis was conducted in three structured steps:

- regulatory and literature review to identify stimulators and barriers described in prior research and EU/Polish legal acts,
- data collection from Zakład Gospodarowania Odpadami Gać sp. z o.o., including operational reports, waste stream volumes, and recycling rates,
- synthesis linking observed practices with theoretical concepts from the literature review, focusing on barriers.

This design ensured methodological rigour and provided practical insights into how circular economy principles are implemented under real-world constraints.

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Case study analysis based on the example of Zakład Gospodarowania Odpadami Gać sp. z o.o.

Figure 1 presents the circular supply chain considering the role of Zakład Gospodarowania Odpadami Gać sp. z o.o. (ZGO Gać) as the central coordinator of municipal waste streams. The domain of ZGO Gać's operations is the management of non-hazardous and inert waste, mainly through:

- segregating waste for recovery and recycling,
- sorting and selling secondary raw materials (metals, paper, glass, and plastics),
- generating electrical and thermal energy from biodegradable waste,
- fermentation and composting of biological waste as cultivation material,
- managing bulky waste,
- waste disposal through deposition at its own landfill.

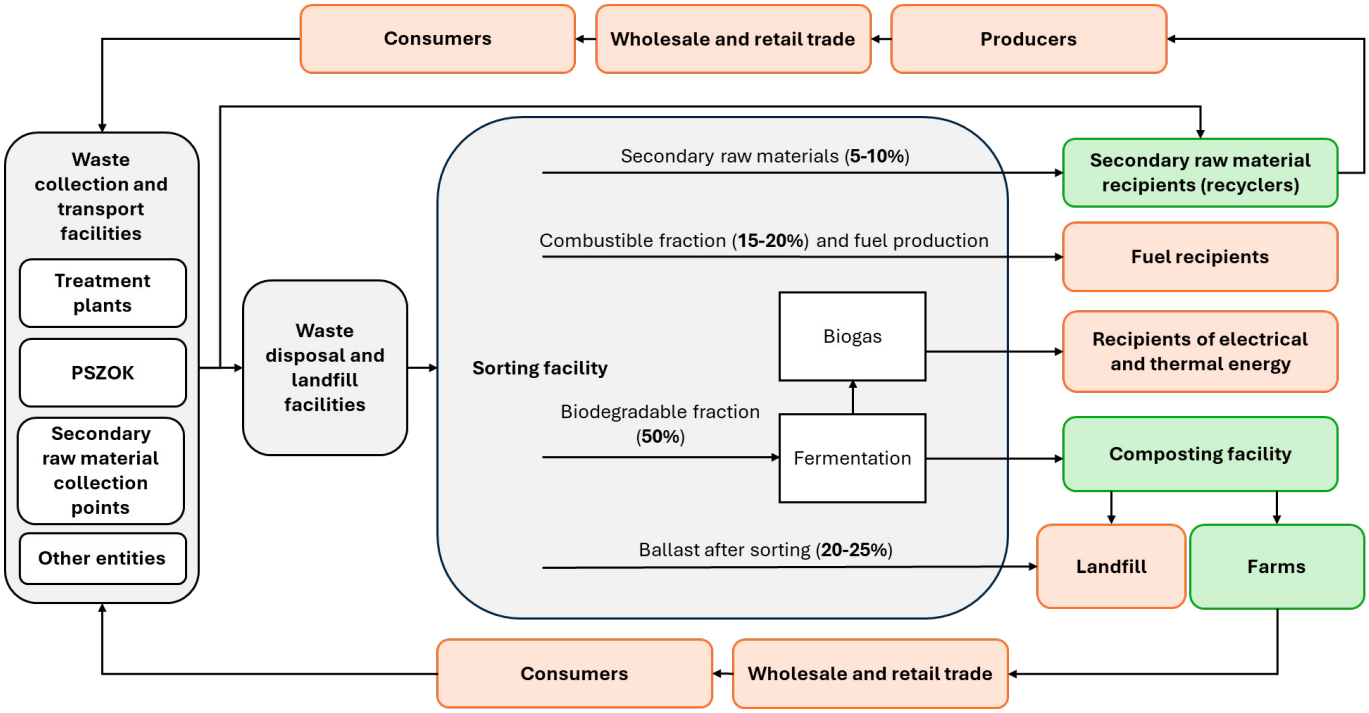

Figure 1. Circular supply chain including the role of waste management and disposal facilities

Regional and local waste management facilities do not always possess adequate intellectual, organisational, and infrastructural potential that allows them to assume the role of leader and central coordinator of flows in circular supply chains. In the case of the inter-municipal Waste Management Facility located on the border of Lower Silesia and Opole voivodeships of Poland in the village of Gać, the possessed human and material resources and several years of experience became the foundation for achieving a leadership position in the circular supply chain, but only regarding municipal waste streams collected within an approximately 20-kilometre radius.

Despite infrastructure investments realised in recent years with a total value of several dozen million PLN and continuous modernisation and diversification of pro-ecological installations for waste segregation and recovery, up to 30% of the municipal waste stream still constitutes ballast for placement at a landfill with strictly controlled and limited capacity. ZGO Gać conducts sales of secondary raw materials including plastics (mainly PET bottles and household chemical packaging), whose volume by weight and sales revenues systematically increase (in 2024, these were increases of 5 to 10% depending on waste type). However, in the case of plastic waste streams from bulky waste (household appliances, mattresses, construction elements, etc.), particularly polyurethane foams, ZGO Gać plays a marginal role compared to Selective Waste Collection Points (PSZOK) and specialised plastic waste recycling enterprises located within its operational radius. Unlike typical municipal waste management facilities, whose activity is usually limited to selection, sale, incineration, or landfilling of contaminated plastic waste fractions, specialised enterprises possess technologies enabling

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their physical or chemical recycling for reuse in various industrial sectors (packaging, household appliances, furniture industry, etc.) and in construction.

The operational practice of ZGO Gać reflects key elements discussed in the literature on circular supply chains. The facility acts as a central coordinator of material flows, integrating collection, segregation, and recovery processes to maintain resource value throughout the product life cycle. This confirms the multidirectional flow concept emphasised in circular supply chain theory, where waste streams are redirected toward reuse and recycling rather than disposal.

The case also illustrates institutional coercive pressure. Compliance with EU directives, such as the Packaging Regulation and Extended Producer Responsibility (EPR) systems, forces ZGO Gać to invest in advanced segregation and recovery technologies. These investments align with literature findings that regulatory stimulators are key drivers of circularity but simultaneously create economic barriers, including high capital requirements and profitability threshold challenges. Despite modernisation efforts, up to 30% of municipal waste remains non-recyclable, confirming barriers such as technological limitations and lack of uniform standards for recyclates.

Moreover, the case demonstrates the resilience dimension. ZGO Gać adapts its operations to fluctuating waste streams and market conditions by diversifying recovery processes (e.g., PET bottle recycling, composting, energy generation from biodegradable waste). However, persistent challenges such as discontinuity in plastic waste streams, volatility in recyclate prices, and fragmented supply chain relationships hinder full implementation of circular principles. These barriers confirm literature observations that achieving circularity requires stable flows, collaborative networks, and economic incentives to overcome structural and managerial constraints.

Nonetheless, a significant barrier to complete plastic waste recycling is the lack of continuity in minimum streams of individual plastic waste fractions that ensure exceeding the profitability threshold. An additional economic barrier is the rising costs of waste management and price instability in the secondary raw materials market, which limits willingness and increases the risk of investing in specialised installations for plastic sorting, processing, and recovery. According to the "Plastics Review" Report (Plastics Online, 2023), the plastic recycling sector is still relatively small and dispersed. Its entity structure in 2021 consisted of approximately 150 enterprises whose net revenues exceeded 1 million PLN annually. Despite systematically growing revenue value (in 2021 by nearly 50% year-on-year) and satisfactory profitability levels (nearly 11%), only 10% of plastics are still recycled (i.e., approximately 400 thousand tons of waste annually compared to approximately 4 million tons of primary plastics introduced to the market in Poland). It should be noted that the results of this report significantly differ from official government agency data, according to which approximately 30% of waste is recycled. Differences in estimates regarding the scale of plastic recycling in Poland (from 10 to 30%) result from the lack of a waste stream monitoring system and pathologies arising from false documentation and trading in documents confirming recycling (DPR) and recovery (DPO). In reality, the vast majority of plastic waste is still incinerated or landfilled, with a small portion exported for foreign recycling enterprises.

Conclusions

Based on the conducted literature review, applicable legal acts, industry reports, and a case study of a selected waste management facility as a link in the circular supply chain for plastic waste, the following conclusions can be formulated:

- the key stimulator for developing circular supply chains in accordance with CE principles is growing pressure from EU and national legal regulations. Research shows that for 78% of enterprises, legal regulations are important for closing flow cycles in the supply chain (Dembińska & Marzantowicz, 2022),
- inconsistency, instability, and overly ambitious assumptions regarding the percentage share of recycling in legal regulations hinder integration and development of long-term, partnership relations between supply chain participants,
- high investment risk means that the current level of plastic waste recovery and recycling still significantly deviates from unrealistic assumptions specified in EU directives regarding the percentage share of recovery and recycling of individual plastic waste fractions,

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- currency exchange rate instability and high credit interest rates are risk factors that limit willingness to further invest in costly infrastructure and specialised plastic recycling installations,
- the main economic barrier in the transformation process toward circular plastic waste supply chains is overcoming the profitability threshold barrier by ensuring continuity of minimum waste streams to specialised enterprises with technologies for their physical or chemical recycling,
- high plastic recycling costs cause increased manufacturing and distribution costs throughout the supply chain, which will result in significant price increases for products for the weakest and most dispersed participants, who are usually consumers,
- overly fragmented entity structure and existing pathologies related to documenting economic turnover in the waste industry hinder configuring circular supply chains based on long-term relationships, trust, and information transparency.

The analysis results presented in this article allowed for the realisation of the assumed research objective, which was to discuss stimulators and barriers to the development of circular supply chains for plastics in light of CE. The identified regulatory stimulators and economic-managerial barriers constitute a comprehensive answer to the research question posed in the introduction. Coercive pressure from EU institutions proves to be the main stimulator of transformation toward circular supply chains, while economic barriers related to the profitability threshold and investment risk constitute the most significant obstacles in the practical implementation of CE principles.

The conducted analysis of stimulators and barriers to circular plastic supply chain development is subject to certain methodological and cognitive limitations. First and foremost, research based on a literature review and a single case study (ZGO Gać sp. z o.o.) does not allow for full generalisation of conclusions to the entire waste management sector in Poland. Regional specificity and local conditions may significantly differentiate individual entities' experiences in implementing CE principles. Moreover, the dynamic nature of the regulatory environment means that some conclusions may quickly lose relevance in the face of new EU directives and regulations and their national implementations.

Directions for further research should focus on several areas. First, it would be advisable to conduct comparative studies covering a larger number of entities from different regions of Poland, which would allow for identification of specific regional conditions regarding plastic supply chain circularity. Second, it would be important to deepen the economic analysis of investment efficiency in recycling infrastructure in the context of variable macroeconomic and regulatory conditions. Particularly valuable would be developing prognostic models determining the profitability threshold for different plastic waste fractions depending on the scale of operations and applied technologies. Third, future research should include the consumer perspective, including willingness to bear higher costs of products manufactured in accordance with CE principles and the effectiveness of educational campaigns regarding proper waste segregation. Finally, it would be worthwhile to conduct longitudinal studies tracking the evolution of circular supply chains in response to changing regulations and technological innovations in the plastic recycling sector.

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The contribution of the authors

Conceptualisation, J.W. and J.M.; literature review, J.W. and J.M.; formal analysis, J.W. and J.M.; writing, J.W. and J.M.; conclusions and discussion, J.W. and J.M.

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REGULACYJNE STYMULATORY I EKONOMICZNO-ZARZĄDCZE BARIERY ROZWOJU CYRKULARNYCH ŁAŃCUCHÓW DOSTAW TWORZYW SZTUCZNYCH

STRESZCZENIE: Niniejsze badanie analizuje regulacyjne stymulatory oraz ekonomiczno-zarządcze bariery rozwoju cyrkularnych łańcuchów dostaw tworzyw sztucznych w ramach gospodarki obiegu zamkniętego. Metodyka/podejście: Kompleksowy przegląd literatury, analiza regulacji prawnych UE i Polski, raportów branżowych oraz studium przypadku Zakładu Gospodarowania Odpadami Gać sp. z o.o. jako ogniwa cyrkularnego łańcucha dostaw. Wyniki: Presja regulacyjna instytucji UE stanowi główny stymulator transformacji w kierunku cyrkularności. Kluczowe bariery ekonomiczne obejmują wyzwania związane z progiem rentowności oraz wysokie ryzyko inwestycyjne. Niespójność i niestabilność regulacji utrudnia rozwój długoterminowych relacji partnerskich. Jedynie 10-30% odpadów tworzyw sztucznych podlega recyklingowi w Polsce, znacznie poniżej celów UE. Ograniczenia badania: Pojedyncze studium przypadku ogranicza możliwość generalizacji; dynamiczne otoczenie regulacyjne wpływa na aktualność wyników. Implikacje praktyczne: Potrzeba stabilnych regulacji, ciągłych strumieni odpadów oraz inwestycji w specjalistyczną infrastrukturę recyklingową. Implikacje społeczne: Wysokie koszty recyklingu nieproporcjonalnie obciążają konsumentów poprzez wzrost cen produktów. Oryginalność/wartość: Zapewnia kompleksową analizę łączącą perspektywy regulacyjne i ekonomiczno-zarządcze z praktycznymi spostrzeżeniami z gospodarki odpadami.

SŁOWA KLUCZOWE: gospodarka obiegu zamkniętego, cyrkularne łańcuchy dostaw, odpady z tworzyw sztucznych, presja regulacyjna, bariery recyklingu

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