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Application of the United Nations Framework Classification for Resources (UNFC) and the United Nations Resource Management Systems (UNRMS)

Case Study Template*

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Title

A systems-based approach for sustainable resource management: comparative application of CVORR+ to the plastics value chain in the UK and Indonesia

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Abstract

Plastics value chains operate as complex systems in which sustainability performance emerges from interactions among processes, structures, and values. These interactions are evident in material and monetary flows, stakeholder networks, and the underlying norms and priorities, all of which are influenced by broader enabling conditions. Consequently, reductionist or single waste management indicators often fail to capture these systemic dynamics, offering limited insights into opportunities for resource recovery improvement. To address this challenge, the Complex Value Optimisation for Resource Recovery (CVORR+) provides a systems-based framework and analytical toolkit for holistically examining resource recovery systems and identifying opportunities to enhance value creation across environmental, economic, social, and technical dimensions. This case study presents a comparative assessment of two contrasting national contexts, Indonesia and the United Kingdom (UK), in which CVORR+ is applied to analyse plastics value chains and identify systemic inefficiencies, structural barriers, and key drivers of resource recovery performance. The comparative analysis demonstrates that inefficiencies, constraints and opportunities for intervention vary significantly across governance, infrastructural and socio-economic contexts, highlighting the context-dependent nature of plastics value chains. It further shows how CVORR+ enables a comprehensive, holistic and integrated assessment by capturing system-wide interactions, identifying cause-and-effect relationships and leverage points, and supporting the development of context-specific performance metrics for monitoring sustainability outcomes.

Relevance to the Expert Group on Resource Management (EGRM)

This case study contributes to the objectives of the UNECE by demonstrating how a systems-based analytical approach can support improvements in resource recovery s and broader sustainability transitions. Through the application of CVORR+ to plastics value chains in two contrasting contexts—the UK and Indonesia—the study highlights the importance of systemic analysis in identifying inefficiencies, structural barriers, and key drivers influencing resource recovery performance across diverse spatial, temporal and governance contexts. By identifying cause-and-effect relationships and context-specific intervention points, the approach generates practical, actionable insights for improving resource management practices and supporting evidence-based decision-making. The comparative analysis highlights how system performance varies across governance and institutional settings, underscoring the need for context-sensitive strategies and effective stakeholder coordination. The case study contributes to methodological innovation by advancing the application of holistic and integrated systems-based tools for resource management. It supports global knowledge exchange and collaboration as well as capacity-building by providing a transferable analytical framework that can be applied across different national and regional contexts. Furthermore, it highlights the role of inclusive stakeholder engagement in supporting a just transition towards sustainable resource recovery systems.

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Introduction, Scope and Context

Plastics have become a ubiquitous material in modern economies, yet their production, consumption and management generate complex environmental, social and economic challenges. Increasingly, plastics are recognised not only as waste streams but also as resources, the recovery and circulation of which require coordinated management across multiple sectors. Plastics value chains function as complex resource recovery systems shaped by interconnected processes, structures and values [1]. These dynamics are evident in the movement of material and monetary flows across production, consumption and waste management processes, and are influenced by broader enabling contextual conditions [2]. These include environmental constraints, technological and infrastructure capacities, regulatory and governance frameworks, market and business dynamics, and behavioural, social and cultural factors. These elements determine how resources are recovered, how value is created or lost, and how environmental, economic, technical and social outcomes emerge across different spatial and temporal contexts [1].

This case study demonstrates how the Complex Value Optimisation for Resource Recovery (CVORR+) framework and analytical toolkit can support integrated resource management approaches consistent with UNRMS principles. It examines plastic value chains in two contrasting national contexts: the UK [3] and Indonesia [4-6]. The UK represents a mature policy and infrastructure environment, while Indonesia represents a rapidly evolving system characterised by significant informal sector participation and ongoing environmental challenges. These contexts differ in governance arrangements, infrastructure capacities, stakeholder configurations, levels of economic development and socio-cultural conditions. Comparing these cases provides insights into how systemic inefficiencies, structural barriers and governance challenges vary across systems operating under different institutional and socio-economic conditions and highlights the importance of context-sensitive approaches to achieving sustainability outcomes.

Rationale for selecting the case

Understanding the interconnected nature of system dynamics is critical for resource management strategies aimed at promoting sustainable and resilient resource recovery systems. Plastics value chains offer a meaningful case for the UNECE EGRM, as they represent a complex socio-technical and governance challenge with multidimensional implications across environmental, economic, technical and social domains.

Supporting sustainability transitions in the plastics value chains requires holistic analytical approaches capable of capturing interactions between natural, social, economic, and political subsystems; interactions that are not fully addressed by single-dimensional assessments [3]. Despite growing global concern about plastic pollution and increasing policy attention to circular economy strategies, plastics management systems often remain fragmented. Many policy frameworks often rely on predefined metrics, such as recycling rates or waste diversion targets, which provide only partial insights into system performance [1]. These metrics tend to overlook the complex, context-specific interactions that shape resource recovery outcomes, often leading to standardised approaches that may be ineffective across diverse settings.

By adopting a systems-based and comparative approach, this case study reveals the value of context-sensitive analyses in identifying effective pathways for improving resource management and supporting effective, evidence-based resource management strategies aligned with EGRM objectives.

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Overview of methodology

The study adopts a comparative case study approach to demonstrate CVORR+ as a transferable, systems-based analytical and decision-support framework for integrated resource management aligned with UNRMS principles. The comparison is used to understand system dynamics, rather than to benchmark national performance [1, 2]. CVORR+ examines how interactions between processes, structures and values influence resource recovery system performance. By analysing material and monetary flows, stakeholder networks and enabling conditions, it identifies systemic inefficiencies, cause-and-effect relationships, feedback loops and potential intervention points, while supporting the development of tailored system-level metrics [2]. Furthermore, CVORR+ evaluates performance across multiple dimensions of value, including environmental, economic, social and technical considerations. Integrating these dimensions within a single analytical framework enables a holistic assessment of resource recovery systems and supports the identification of strategies that enhance value creation while managing trade-offs between competing objectives.

Expected contribution to sustainable resource management, just transition, and/or international knowledge exchange

The application of CVORR+ to plastics value chains in two contrasting national contexts highlights how system performance varies across governance and institutional settings and illustrates the importance of context-specific strategies, stakeholder coordination and integrated performance metrics. Therefore, this study contributes to sustainable resource management by advancing holistic analytical approaches capable of examining complex resource recovery systems while supporting capacity building and international knowledge exchange on improving resource recovery practices across diverse contexts. In addition, the comparative nature of the study supports international knowledge exchange by demonstrating the transferability of the CVORR+ framework across diverse settings, enabling shared learning and capacity-building for improving resource recovery practices globally.

Normative References and Linkages

The study aligns with several international sustainability frameworks. In particular, it contributes to the objectives of the United Nations Sustainable Development Goals (SDGs), including SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), SDG 14 (Life Below Water), SDG 15 (Life on Land), and SDG 17 (Partnerships for the Goals). By examining plastics as resource recovery systems and identifying systemic inefficiencies, the study supports resource efficiency, pollution reduction, and international collaboration for sustainable resource management. It is also relevant to ongoing international efforts to address plastic pollution, such as the Global Plastics Treaty – a legally binding international agreement on plastic pollution under the United Nations Environment Programme (UNEP) and informs the design of Extended Producer Responsibility (EPR), demonstrating how governance arrangements, stakeholder dynamics and economic incentives shape resource recovery outcomes.

Indonesia: The study examines the shift from end-of-pipe approaches toward 3R, EPR and circular economy ambitions, including key policy instruments such as JAKSTRANAS (Presidential Regulation No. 97/2017), the National Action Plan on Marine Debris (Presidential Regulation No. 83/2018), the EPR Regulation (MoEF Regulation No. P.75/2019), and regional single-use plastic bans [5]. Despite Indonesia's policy breadth, implementation remains constrained by governance deficiencies, financing gaps, infrastructure limitations and weak enforcement, making it a strong example of why systems-based analysis is needed to understand regulatory lock-ins and context-specific barriers to circularity.

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UK: The case situates plastic waste management within the circular economy and packaging reforms, including the Resources and Waste Strategy for England, Plastic Packaging Tax, packaging Extended Producer Responsibility (pEPR), Simpler Recycling, and the forthcoming Deposit Return Scheme [3]. These reforms are intended to preserve material resources, improve recycling consistency, shift waste management costs onto producers, and incentivise more recyclable packaging design. Even in this mature policy landscape, characterised by advanced policy instruments, systemic inefficiencies, fragmented implementation, and persistent coordination challenges across the plastics value chain remain.
Comparing these national contexts sheds light on how plastics value chains operate under different governance arrangements, policy maturities and institutional capacities and demonstrates how systems-based analysis can help identify where policy ambition is constrained by implementation barriers, stakeholder dynamics and broader enabling conditions.

This case study aligns with UNECE/EGRM priorities and supports the United Nations Resource Management System (UNRMS) by examining plastics as anthropogenic resources within resource recovery systems. The analysis advances UNRMS objectives to: improve efficiency and responsible use of resources; enhance transparency in resource information; promote circular and low-carbon resource systems; address environmental and social impacts across resource value chains; and strengthen resource supply chain resilience.

The study demonstrates how a holistic systems-based analytical toolkit like CVORR+ can support integrated resource management by identifying systemic inefficiencies, governance barriers, and context-specific intervention points. It further illustrates the value of developing tailored, multidimensional performance metrics to inform evidence-based policy and decision-making. In doing so, the case study contributed to the operationalisation and broader adoption of UNRMS principles in the management of secondary and anthropogenic resources.

Definitions and Terminology

For this case study, the following key terms are used:

CLD	Causal loop diagram
CVORR+	Complex Value Optimisation for Resource Recovery - a systems-based analytical toolkit used to assess resource recovery systems
EPR	Extended producer responsibility
FMCG	Fast moving consumer goods
LoI	Level of information
MCPs	Materials, components and products
Plastics value chain	The interconnected system of production, consumption, collection, sorting, processing and recovery activities associated with plastic materials, components and products
Resource recovery system	Resource recovery systems are the interconnected processes, governance structures, and value frameworks that enable the recovery and reintegration of materials, components, and products into economic use, reducing reliance on primary resources while maximising environmental, economic, social, and technical value.
System structures	Represented by stakeholders, institutions, and networks that shape system organisation and governance
System values	Represented by the norms, cultural factors, and priorities guiding stakeholder decision-making and system behaviour
System processes	Represented by mass and monetary flows that move through the system and the interactions they generate

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System enabling conditions	Represented by environmental, technological, economic, institutional and socio-cultural factors that influence the operation, performance and evolution of resource recovery systems
Value domains	The environmental, economic, social, technical, and political dimensions of value that a system, process, or intervention can generate or influence

Background Information

Plastics are widely used materials, components and products (MCPs) whose production, consumption and end-of-life fate generate multidimensional challenges for circularity. Within circular economy strategies, post-consumer plastics are increasingly recognised as secondary resources that can be recovered through collection, sorting and recycling processes. The effective management of these materials, therefore, relies on complex systems involving multiple stakeholders, infrastructure networks, regulatory frameworks and market dynamics.

This analysis compares the outcomes of CVORR+ applications on plastics value chains in two national contexts: Indonesia, an upper-middle-income country [4-6] and the UK, a high-income country [3]. These cases represent diverse socio-economic conditions and stages of development in plastics resource management systems.

Indonesia: the plastics recovery system is rapidly evolving, driven by increasing consumption of plastic packaging. Simultaneously, formal waste management systems are either absent or underperforming, highlighting an infrastructure gap that impacts millions of Indonesians who lack access to waste management services and rely on mismanagement, as well as the activities of the informal recycling sector, which plays a critical role in recovering recyclable materials. System performance in Indonesia is constrained by infrastructural limitations, uneven policy implementation and complex stakeholder dynamics. National initiatives aimed at reducing marine plastic pollution and strengthening waste management systems have begun to address these challenges [5].

UK: represents a more mature and institutionalised waste management system, characterised by established recycling infrastructure and formal governance structures. Policy instruments such as EPR schemes, recycling targets and improvements in collection systems. Have contributed to relatively high recovery rates. However, persistent challenges remained, including inconsistent collection practices across municipalities, losses during sorting and processing, and reliance on export markets for certain plastic fractions [3].

By comparing the outcomes on CVORR+ applications in these contexts, the study highlights how distinct governance, infrastructure, market characteristics, and socio-economic factors shape system performance and resource recovery potential.

Ownership, governance, permitting, stakeholders

The plastics resource recovery systems in both Indonesia and the UK were developed through collaborative research initiatives involving academic institutions, government bodies and industry stakeholders. Governance in this context refers to the institutional arrangement, partnerships and coordination mechanisms underpinning the design, implementation and validation of the studies.

The UK case study was conducted in collaboration with the Department for Environment, Food and Rural Affairs (DEFRA) under an Economic and Social Research Council (ESRC) Business Boost Impact Acceleration Award [3]. This collaboration provided access to official datasets, policy insights, and expert input from government bodies,

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industry (e.g., SUEZ), trade associations (e.g., Plastics Europe), NGOs (e.g., WRAP), ensuring that the analysis was grounded in current regulatory and operational realities. Governance of the study was structured through formal collaboration mechanisms, including data-sharing agreements, joint workshops, and iterative validation of findings with policy and academic stakeholders.

The Indonesia case study was developed within the PISCES research programme, funded by the Natural Environment Research Council (NERC), under the Global Challenges Research Fund [4-6]. This programme adopted a multi-stakeholder and participatory research approach, engaging stakeholders across the plastics value chain, including government agencies (e.g., Ministry of Environment and Forestry (MoEF) and former Coordinating Ministry for Maritime and Investment Affairs (CMMAI), the Indonesian National Research and Innovation Agency (BRIN)), industry representatives (e.g., IPEN, Borealis, recyclers), enterprises (e.g., SYSTEMIQ, Enviu), trade associations (e.g., IRPO), NGOs (e.g., Emvitrust, Sungai Watch), and informal sector participants. Study governance was characterised by collaborative design and co-production of knowledge, with workshops, stakeholder consultations, and field-based engagement forming key components of the research process.

Across both case studies, stakeholders involved in the research are categorised into two broad groups:

- **Core research stakeholders**, including academic researchers, funding bodies, and institutional partners responsible for study design, data analysis, and methodological development.
- **Contributing stakeholders,** including policymakers, industry representatives, and community participants, who provided data, contextual insights, and validation of findings through participatory processes.

Stakeholder engagement played a critical role in shaping the analytical approach and ensuring the relevance and robustness of the findings. In Indonesia, particular emphasis was placed on incorporating perspectives from informal sector actors, whose experiential knowledge was essential for understanding material flows and recovery practices. In the UK, engagement with government agencies and regulated industry actors supported detailed system mapping and policy-relevant analysis.

The governance structures of both studies emphasised transparency, data triangulation, and iterative validation. Findings were cross-checked through multiple data sources and stakeholder inputs, while collaborative workshops and consultations were used to refine system boundaries, validate assumptions, and identify key intervention points.

Historical data, prior assessments, or baseline resource/reserve estimates

The application of CVORR+ in Indonesia and the UK provides an important empirical basis for understanding baseline conditions and system dynamics within the plastics value chains.

In Indonesia, our work has primarily examined the scale and drivers of plastic leakage. The food and beverage sector is the dominant user in Indonesia, accounting for approximately 60% of domestically produced and imported plastics in 2022. The total volume of plastic packaging reaching consumers is estimated at 11,300 kilo tonnes (kt). This generates significant environmental challenges, particularly plastic waste leakage, due to the lack of formal waste collection systems. This limited access to waste collection affects 160 million Indonesians and results in widespread mismanagement practices, such as open burning, dumping and land burial [4-6]. To this end, the role of informal waste recovery systems and the governance challenges associated with coordinating multiple stakeholders across fragmented waste management have been investigated [4-6]. These studies highlighted the contribution of the informal recycling sector in recovering recyclable materials, while also identifying persistent

systemic barriers, including infrastructural gaps, volatility in secondary materials markets and uneven policy implementation [4-6]. Collectively, this work establishes a baseline understanding of leakage pathways, recovery practices and governance constraints within the Indonesian context.

In the UK, plastic packaging placed on the market in 2011 has been estimated at 2,535 kt, with post-consumer plastic packaging waste in England alone accounting for approximately 1,829 kt. This formed the baseline for analysing plastic packaging flows and system performance. Our research examined the performance of municipal recycling systems and the effectiveness of policy instruments such as recycling targets and EPR schemes [3]. This includes assessment of material recovery efficiency, contamination levels in recycling streams and operational challenges associated with sorting mixed plastic waste. The findings document measurable progress in collection and recycling infrastructure over time, while also identifying persistent inefficiencies, such as material losses during sorting processes and the continued reliance on export markets for certain plastic fractions [3].

These prior assessments illustrate the complexity and contextual variability of plastics value chains across different socio-economic and governance settings.

Resource Description and Estimation

For Indonesia, the estimates reflect the conditions of the plastics value chain during the 2019–2024 period, corresponding to the timeframe of the PISCES research programme, during which system assessments and stakeholder analyses were conducted. For the UK, the estimates correspond to the most recent national assessments of plastic packaging flows and recycling system performance available at the time of the study, reflecting conditions of the UK plastics value chain during the late 2018-2019, before the implementation of the latest packaging EPR reforms.

The focus of this comparative analysis is plastic packaging waste in Indonesia and the UK. In Indonesia, the analysis initially considered the broader spectrum of MCPs present in municipal waste streams and then narrowed it down to plastic packaging, which represents a substantial proportion of waste contributing significantly to plastic leakage. These include plastic sachets, bags, wrappers and multilayer packaging of which a large share is from the food and beverage sector (ca. 60% [6]. Their widespread use, combined with low recyclability and limited market value, poses significant challenges for resource recovery.

In the UK, the analysis focuses specifically on post-consumer plastic packaging, reflecting its central role in national packaging recycling policies and targets. The resource products considered include common packaging formats such as plastic bottles, pots, trays, tubes and films, which constitute the primary materials managed through municipal recycling systems and packaging recovery schemes [3].

Basis for Estimates (data sources, modelling methods, assumptions)

For both case studies in Indonesia and the UK, system estimates and performance assessment were derived using the CVORR+ framework and systems-based analytical toolkit. The framework integrates qualitative and quantitative methods to assess resource flows, stakeholder dynamics and system performance across environmental, economic, social and technical dimensions.

The CVORR+ framework consists of three sequential components:

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1) **Baseline analytical tool** – systematically examines the existing system by analysing its processes, stakeholder structures, value orientations and enabling conditions across environmental, economic, social and technical dimensions. This assessment allows the identification of inefficiencies, trade-offs and opportunities for improving resource management [2].
2) **Intermediary stage** – integrates and interprets the baseline findings, identifies critical intervention points and aids the selection and development of multidimensional metrics for monitoring system performance [2, 7].
3) **Advanced complex value flow evaluation tool** – enables quantitative assessment of system performance using multidimensional metrics that capture value creation and losses across different value domains [7].

Figure 1 illustrates the conceptual structure of the CVORR analytical framework.

Figure 1. CVORR+ Framework: A comprehensive system-wide analytical toolkit organised into three interconnected stages: the core, intermediary and final phases. The baseline analytical tool is combined with a complex value flow evaluation tool through the intermediary stage, enabling a system-wide, holistic assessment of resource recovery and waste management value chains. Adopted by [2, 7].

The quantification of material flows and system behaviour is supported by a combination of analytical methods [4, 6, 8]. Material and monetary flows are mapped using Mass Flow Analysis (MFA). Stakeholder structures and roles are analysed using principles from stakeholder theory, with influence and interest assessed through the Mendelow matrix, and the CVORR+-extended external stakeholder identification, mapping and power dynamics tools. [2] System dynamics were further explored using CVORR's Five Levels of Information (5LoI) framework,

complemented with causal loop diagrams (CLDs) to identify feedback loops and leverage points for intervention. The development of performance metrics is guided by the Metrics Selection Framework (MSF) [7].

The analysis draws on both primary and secondary data sources.

- Primary data were collected through stakeholder engagement, including personal communication, participatory workshops, surveys and field observations. These interactions involved representatives from government agencies, industry, recycling enterprises, NGOs, trade associations, community initiatives, informal sector participants (Indonesia only) and academic experts.
- Secondary sources included official datasets, peer-reviewed literature, grey literature and reports from national and international organisations.

To ensure analytical robustness, data triangulation and cross-referencing were applied, comparing information across sources and stakeholder groups to verify consistency and identify key system characteristics. Both analyses were subject to several assumptions and limitations. Data availability and quality varied across contexts, with greater reliance on stakeholder-derived and relevant literature data in Indonesia due to limited formal datasets. These limitations were mitigated through triangulation and iterative validation with stakeholders. Furthermore, estimates on informal recycling sector activities and flows in Indonesia remain uncertain.

Reference Point (geographical/physical /conceptual reference)

The reference point for the resource assessment is defined by the system scope, goals and boundaries (Steps 1 &2 in the CVORR+ framework illustrated in Figure 1), allowing the analysis to reflect the contextual characteristics of plastics value chains in Indonesia and the UK. The system boundaries were defined geographically, temporally and conceptually to capture the behaviour and performance of plastics resource recovery systems at an appropriate level of granularity, as shown in Table 1.

Table 1. Reference points defining system scope, goals and boundaries for the UK and Indonesia case studies under the CVORR+ framework

Parameter		*UK case study [3]*	*Indonesia case study [5, 6]*
Scope	**Challenge**	Low plastic packaging recycling rates and loss of material value	Plastic pollution and loss of material value
	Level of detail	Plastic packaging waste collected by local authorities	Plastic MCPs within the broader plastics value chain
	Timeframe analysis	Current system performance under business-as-usual conditions	Current system performance under business-as-usual conditions
Goals		Support the UK's policy targets to increase plastic packaging recycling to 70% by 2025, achieve 30% recycled content in plastic packaging, and develop metrics for assessing and monitoring sustainability performance of the plastic packaging system.	Assess progress toward Indonesia's National Action Plan targets on reducing marine plastic debris by 70% by 2025 and identify intervention points that can support transformative change towards more circular and sustainable plastics management.

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System boundaries	**Spatial**	Regional scale – England	National scale – Indonesia
	Temporal	One-year system analysis reflecting current system conditions	One-year system analysis reflecting current system conditions

UNFC Criteria Narratives

The assessment of plastics resource recovery systems across Indonesia and the UK highlights how enabling conditions, including policy frameworks, technical capacity, market dynamics, institutional arrangements and societal behaviours, and data availability jointly shape system performance, in line with the E–F–G axes of the UNFC/UNRMS framework. Within the CVORR+, the Five Levels of Information (5LoI) framework captures all enabling conditions (step 5 of Figure 1), including the socio-economic viability of recovery systems (E-axis), the feasibility and maturity of infrastructure and technologies (F-axis), and the level of confidence in system knowledge and data (G-axis).

Indonesia is characterised by emerging policy frameworks aimed at addressing plastic pollution and marine debris, alongside uneven socio-economic conditions (E3), where plastics recovery relies heavily on the informal sector and is constrained by weak market incentives for low-value and low-recyclability plastic packaging, which dominates the FMCG market [5]. Technical feasibility remains limited (F3) due to relatively outdated manufacturing technologies and limited incentives for circular material design, low collection coverage, uneven distribution of waste management infrastructure, and capacity gaps in recycling systems [5]. At the same time, knowledge confidence is moderate to low (G2), reflecting fragmented data and the difficulty of capturing informal sector activities. Nevertheless, the combination of national statistics, academic studies and stakeholder-based system analyses provides a sufficiently robust knowledge base for assessing the plastics value chains examined in this study.

In contrast, the UK exhibits more mature regulatory and market conditions (E2), supported by established policy instruments and structured waste governance systems. However, the economic viability of recycling certain plastic fractions remains constrained by the relatively low value of some plastic packaging MCPs and fluctuations in demand for secondary plastics [3]. Technical systems are more developed (F2), with advanced collection and sorting infrastructure, although inefficiencies such as contamination, material losses during sorting and the limited recyclability of certain plastic packaging formats persist. In addition, the system has historically relied on the export of certain plastic waste fractions for processing overseas, reflecting constraints in domestic recycling capacity and structural dependencies on external infrastructure [3]. Data availability and monitoring systems provide relatively high confidence in system characterisation (G1-2), enabling more robust tracking of material flows and performance. **Table 2** summarises key system indicators and their relevance to the E–F–G axes, illustrating how differences in governance, infrastructure and data availability translate into distinct resource recovery outcomes across the two contexts.

Table 2. Comparative indicators aligned with UNFC/UNRMS axes

Indicator	Indonesia	UK	UNFC/UNRMS axis relevance
Plastic packaging waste generation (kt)	11,600	1,829	G (data baseline)
Population (million)	270	53.1[1]	G (data baseline)

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Waste collection coverage rate (of total population)	41%	100% (assumed)	E/F (infrastructural capacity and governance arrangements)
Formal vs informal collection rate (of total plastic waste generated)	31-32% (formal) & 13-15% (informal)	99.6% formal (negligible informal)	E/F (governance and infrastructure/service provision)
Leakage rate (of total plastic waste generated)	70[2]	1[3]	E/F (system performance and environmental outcome)
Domestic recycling rate (of total plastic waste generated)	10%	4.2%	E/F (technical performance and governance arrangements)
Formal vs informal recycling contribution rate (of total plastics sent for reprocessing)	10% (formal) 90% (informal)	100% formal	E (governance arrangement - system structures)
Waste to Energy rate (of total plastic waste generated)	Emerging but currently negligible	28.3% (517 kt)	F (technology maturity)
Recycling capacity (per year)	2,000 kt (mainly PET and polyolefins)	260 kt (mainly dense plastic packaging)	F (technology maturity)
Plastic waste exports (per year)	Not available – limited data	156 kt (8.5% of total plastic generated)	E (market dynamics)
Plastic waste imports (per year)	180 kt	Not available	E (market dynamics)

[1] Refers to England population in 2011 according to [9]; [2]Attributed to littering, dumping and open burning; 3 Attributed to littering and fly-tipping

The UNFC classification presented in Table 3 reflects the nature of plastics as anthropogenic resources embedded within waste management systems rather than resources recovered through conventional extraction activities. The classification therefore provides an indicative assessment of the maturity, feasibility and socio-economic viability of plastics resource recovery systems, rather than a quantification of recoverable volumes. Differences between Indonesia and the UK reflect variations in structures, values and enabling conditions within their respective plastics value chains.

Table 3. Indicative UNFC classification of plastics resource recovery systems in Indonesia and the UK using the CVORR+

Case	*Indicative UNFC Class*	*Justification*

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Indonesia plastics value chain	**E3 F3 G2**	- Socio-economic viability remains uncertain due to uneven policy implementation, limited market incentives for low-value plastics and strong reliance on informal recovery networks. - Technical feasibility is constrained by low collection coverage, uneven distribution of recycling infrastructure and limited capacity to process low-recyclability plastics. - Confidence in resource estimates is moderate due to limited national waste reporting systems and reliance on triangulation of literature, stakeholder consultations and indicative flow estimations.
UK plastics value chain	**E2 F2 G1-2**	- Socio-economic viability is supported by established regulatory frameworks, including EPR schemes and recycling targets that stimulate demand for recycled plastics. - Technical feasibility is demonstrated through established municipal collection systems, materials recovery facilities and recycling operations, although challenges remain related to contamination, sorting inefficiencies and reliance on export markets for certain plastic fractions. - Confidence in system knowledge is relatively high, supported by structured national waste reporting systems and comprehensive data on packaging flows.

UNRMS Integration

This case study represents a conceptual and analytical application of the UNRMS to anthropogenic resources within plastics value chains. Drawing on previously developed case studies in Indonesia and the UK, the study demonstrates how a systems-based approach such as CVORR+ can support integrated resource management and sustainable transitions. The analysis examines plastics value chains as resource recovery systems embedded within broader socio-economic, infrastructure, and governance contexts, illustrating the practical application of UNRMS principles in diverse settings.

The CVORR+ unpacks systemic inefficiencies and structural barriers across plastics value chains, thereby revealing leverage points that can improve retention of value, reduce material losses, and strengthen coordination across resource recovery systems [1]. By generating context-specific performance metrics, CVORR+ supports monitoring, evaluation and iterative assessment of resource recovery systems, enabling evidence-based transition strategies for sustainable transitions with minimal trade-offs [7]. Through comparative application in the UK and Indonesia, CVORR demonstrates how resource management strategies should be tailored to local socio-economic conditions, infrastructure availability and policy priorities [2]. In the UK, the focus is on optimising existing infrastructure and improving policy coordination. In Indonesia, priorities include strengthening collection coverage systems, integrating informal-formal stakeholders and enhancing institutional capacity for plastics resource recovery. This highlights the importance of context-sensitive strategies in implementing UNRMS principles.

The CVORR+ methodology is designed to be open, iterative and pluralistic [2]. **Open:** incorporates insights from diverse stakeholders and multiple data sources to promote transparency and inclusivity; **Iternative:** supports continuous learning and refinement through system reassessment and performance monitoring; **Pluralistic:** integrates multiple disciplinary perspectives and analytical methods to capture the multidimensional nature of resource recovery systems. By explicitly revealing data gaps, governance dynamics and systemic inefficiencies,

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CVORR+ strengthens transparency, system understanding and supports gradual transformation toward sustainable and integrated resource management.

Applying CVORR+ across two contrasting national contexts illustrates how systems-based approaches must be adopted to different governance, institutional and socio-economic structures. The analysis demonstrates that while the framework is transferable, strategic priorities vary with local conditions, providing practical guidance for designing context-sensitive resource management interventions consistent with UNRMS objectives.

Organisational & Stakeholder Context: The Indonesia case study was conducted under the PISCES research partnership, enabling engagement with government agencies, NGOs, community initiatives and private-sector actors involved in the plastics value chain. The UK case study was undertaken in collaboration with DEFRA, industry and academic partners, providing insights into national plastics policy frameworks and packaging recovery systems. Within the CVORR+ approach, stakeholders are analysed as structural components of resource recovery systems, revealing their relationships, power dynamics and governance arrangements that influence system performance. In line with the open and pluralistic principles of CVORR+, stakeholder engagement incorporates diverse institutional perspectives and data sources, capturing complex governance arrangements and value priorities across the value chain. Stakeholders in CVORR+ are categorised between internal stakeholders, who directly influence the operational processes and material flows, and external stakeholders, who influence system performance indirectly through policy, regulation, market incentives or societal behaviour [4, 6, 10].

Internal Stakeholders

- **Indonesia:** packaging manufacturers, FMCGs, retailers, distributors and households generating post-consumer plastic waste. Informal recycling sector (i.e., waste pickers (pemulung), waste traders (rosokan), community collectors (rukun tetangga and rukun warga), and waste aggregators (pengepul)) form the backbone of plastic material recovery. Semi-formal stakeholders such as community-based waste banks (bank sampah), facilitate waste collection and aggregation of recyclable materials at the neighbourhood level [6]. Formal stakeholders have a limited role in plastic waste recovery. Recyclers
- **UK:** regulated waste management companies, closely linked to FMCGs, plastic manufacturers, and retailers. Waste collection and management are largely organised through local authorities, who own regulatory oversight of the collection, sorting and processing within formal infrastructure [3, 10].

External Stakeholders

- **Indonesia:** national ministries, local governments, non-governmental organisations and community initiatives working on plastic pollution and waste reduction, as well as international development partners and industry platforms supporting circular economy initiatives [4].
- **UK:** regulatory institutions, EPR coordinators, NGOs, associations and large market actors, including FMCG producers and retailers advocates who shape material flows, and policy compliance.

Power dynamics differ across contexts: in Indonesia, informal recycling stakeholders often operate with limited institutional recognition, while large FMCG producers, packaging manufacturers and recycling industries dominate governance. In the UK, regulatory institutions and formal market stakeholders drive system decisions, with local authorities acting as key intermediaries.

Sustainable Development & Just Transition Alignment: CVORR+ integrates insights from both case studies to support evidence-based decision-making in complex resource recovery systems. These insights provide a

diagnosis of the system performance, identify interventions and inform the design of context-specific performance metrics for monitoring circular economy objectives [7]. The comparative application demonstrates how CVORR+ can support the development of strategies that: 1) reduce environmental pollution and improve resource efficiency; 2) enhance economic activity in recycling sectors; 3) promote inclusive participation of all stakeholders, including informal recycling stakeholders, within resource recovery systems; and 4) identify trade-offs and governance dynamics that affect sustainability outcomes.

Planning & Management: CVORR+ supports planning across short-, medium- and long-term horizons by linking identified points of intervention to the infrastructural, technological, socio-cultural, policy and economic conditions required for implementation. These intervention points enable the evaluation of the scope and feasibility of solutions within context-specific contexts and can support the planning of critical control points and define review triggers for assessing progress and adapting strategies over time. The iterative refinement of these planning processes evolves through stakeholder feedback, allowing strategies and interventions to be progressively refined and institutionalised as system knowledge improves.

Capacity Building: CVORR+ emphasises transparent information systems, stakeholder engagement and knowledge integration. By combining multiple data sources, participatory workshops and collaborative research initiatives, the methodology enhances system understanding, identifies data gaps, and strengthens communication between policymakers, industry actors, researchers and civil society organisations. The CVORR+ framework and toolkit can also serve as a practical training tool for practitioners, fostering systems-thinking capabilities and supporting knowledge exchange. Stakeholders across different governance and socio-economic contexts can use CVORR+ or apply CVORR+'s insights to improve resource recovery performance and adopt evidence-based, context-sensitive strategies.

Operations and Risk Management: CVORR+ supports risk-aware decision-making by linking the system-wide assessment (e.g., inefficiencies, drivers and leverage points) to policy and operational strategies. This ensures realistic target setting and mitigates ineffective or overly ambitious interventions. By revealing trade-offs across environmental, economic, social and technical dimensions, CVORR+ allows stakeholders to anticipate and address potential risks and align with broader sustainability goals.

Continual Improvement/Feedback: The iterative design of CVORR+ enables adaptive management and continual improvement. CVORR+ provides a basis for monitoring system performance and evaluating progress toward sustainability objectives. This supports policymakers and stakeholders to refine strategies over time, supporting more adaptive and context-sensitive resource management practices.

Social, Environmental and Just Transition Considerations

CVORR+ integrates environmental, social and equity considerations through its Five Levels of Information framework (5LoI) (Step 5 of Figure 1) [1]. The **Natural environment level (1st LoI)** focuses on the impacts on ecosystem services, capturing ecological interactions and environmental externalities associated with the production, consumption and (mis)management of MCPs and degradation pathways, which can affect environmental quality, ecosystem resilience and human well-being [5]. The **Human behaviour, needs, and practices level (5th LoI)** captures consumer/user behaviour, needs, habits, perceptions of plastics and practices (e.g. participation in waste-management services and access to information and infrastructure), workforce inclusion and cultural norms that shape plastics consumption and management [5]. The framework explicitly supports just

transition principles, ensuring that interventions generate equitable social outcomes, strengthening community resilience and long-term environmental stewardship. By linking cause-and-effect relationships across plastics value chains, CVORR+ identifies technical, infrastructural, economic and communication-based interventions (Step 6 of Figure 1), and supports the development of multidimensional metrics (Step 7 of Figure 1) that can be used to monitor transition pathways and assess system performance over time [7].

Economic Analysis & Value Creation Pathways

CVORR+ evaluates economic and technical enabling conditions through its Five Levels of Information framework (5LoI) (Step 5 of Figure 1) [1]. Through the **Technologies, infrastructure and innovation level (2nd LoI)**, it assesses the physical and operational systems that enable the collection, sorting, treatment and reintegration of plastics within the economy, identifying opportunities for technological improvements and system innovation that can improve material recovery and efficiency [5]. The **Business dynamics and market conditions level (4th LoI)** examines market dynamics, financial incentives, market stability, trade relationships and business models for value retention and creation. This enables identification of circularity opportunities, private-sector mobilisation, public–private collaboration and local economic development linked to resource recovery [5]. These analyses reveal value creation pathways that enhance resource circularity and improve economic viability across contrasting governance settings.

Policy, Governance & Legal Considerations

CVORR+ examines **Governance, regulatory framework and political landscape (3rd LoI)** through the Five Levels of Information framework (5LoI) (Step 5 of Figure 1) [1]. This includes the evaluation of policy frameworks, regulatory instruments and enforcement mechanisms, including EPR schemes, recycling targets, tax instruments and other policy tools, and incentives [1]. Governance considerations include the effectiveness of regulatory enforcement, transparency and reporting mechanisms, and the institutional capacity required to ensure compliance with environmental and waste management regulations [5]. This level is linked to the coordination between governmental bodies and stakeholder roles in shaping policy outcomes, including industry actors, civil society organisations and community groups. By situating governance within environmental, technical, economic, and social enabling conditions, CVORR+ supports context-specific interventions aligned with UNRMS and UNECE/EGRM principles.

Key Findings, Lessons Learned and Recommendations

Plastics resource systems are inherently complex and cannot be effectively captured by single performance indicators [1]. CVORR+ effectively maps interactions across environmental, economic, social and technical value domains, while incorporating governance structures and stakeholder influence [2]. Stakeholder relationships play a critical role in shaping system outcomes, indicating that collaboration is essential for improving the effectiveness and legitimacy of resource management interventions [4, 6, 10]. The indicative UNFC classification reflects these systemic conditions.

Indonesia: the plastics value chain is characterised by E3–F3–G3, reflecting emerging policy frameworks, limited infrastructure capacity and greater uncertainty in data related to plastics flows and recovery activities.

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UK: the plastics value chain aligns more closely with E2–F2–G2, reflecting established regulatory frameworks, structured waste reporting systems and mature recycling infrastructure, though operational inefficiencies and market limitations remain.

CVORR+ demonstrates strengths in integrated, multi-dimensional assessment, systemic inefficiencies identification and intervention design. Challenges include uneven data availability, institutional coordination gaps, and uneven infrastructural capacity, highlighting the need for adaptive governance, transparency, improved data systems and cross-sector collaboration to support integrated resource management.

Social, environmental, economic outcomes and trade-offs: Environmental benefits arise from reducing plastic leakage, improving recycling performance and strengthening waste-management infrastructure. At the same time, economic opportunities exist through improved value retention, increased circular material flows and the development of recycling and secondary materials markets. Social considerations remain critical, particularly in systems where informal actors play a central role in material recovery or where consumer behaviour significantly influences recycling outcomes.

The CVORR+ approach highlights that addressing trade-offs across these dimensions requires coordinated interventions across policy, infrastructure, markets and behavioural change mechanisms. Table 4 summarises the key insights emerging from the comparative CVORR+ analysis of the plastics value chains in the UK and Indonesia, highlighting system inefficiencies, governance dynamics, enabling conditions across the Five Levels of Information (5LoIs), and key intervention points identified in each context

Table 4. Comparative insights from the CVORR+ analysis of plastics value chains in the UK and Indonesia

CVORR+ components	*UK[3]*	*Indonesia[4-6]*	*Cross-case insight*
Key system inefficiencies	Material losses during sorting, contamination in recycling streams, inconsistent collection systems, reliance on export markets	High consumption of low-value plastics (sachets), limited collection coverage, uneven infrastructure, reliance on informal sector, weak law enforcement, leakage to environment	System inefficiencies vary across contexts, reflecting differences in institutional capacity, infrastructure availability and market conditions
Stakeholder power dynamics	More institutionalised governance (local authorities, producers, waste firms), though still influenced by market actors and policy frameworks.	Fragmented governance, strong role of the informal sector, and influence of FMCG producers, NGOs and international initiatives.	Power dynamics shape material and monetary flows and influence how value and responsibilities are distributed across the value chain
Data availability	Relatively high data transparency and reporting systems	Fragmented data due to informal sector activities and uneven monitoring	Systems methodologies are particularly valuable where data uncertainty exists
Environmental conditions (1st LoI)	Environmental challenges from loss of material value due to contamination, inefficient sorting and	High environmental pressure from widespread use of low-value plastics, limited collection coverage and disposal practices	Environmental impacts depend on both material design and waste-

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	limited recyclability of some packaging formats, alongside externalities linked to plastic waste exports	leading to marine pollution, ecosystem degradation and drainage blockages	management capacity across systems
Technical and infrastructural conditions (2nd LoI)	Advanced collection, sorting and recycling infrastructure, though long-term contracts, market conditions and sorting inefficiencies create technological lock-in and limit system flexibility	Rapidly developing but uneven waste-management infrastructure, with outdated upstream production technologies, limited recycling capacity and inconsistent feedstock supply constraining recovery systems	Infrastructure maturity shapes recovery efficiency but does not eliminate systemic inefficiencies
Governance and regulatory conditions (3rd LoI)	Mature regulatory framework with landfill taxes, EPR reforms and voluntary initiatives, prioritising recyclability, higher recycled content and improved collection systems, though policy design and market instruments can shift costs to local authorities and create system lock-ins	Expanding regulatory framework targeting plastic reduction and circularity, prioritising marine plastic reduction, improved waste collection and circular economy development, but implementation remains constrained by weak enforcement, institutional and technical capacity gaps within government, and fragmented governance	Policy frameworks shape system direction, but effectiveness depends on enforcement capacity, institutional coordination and alignment of economic incentives
Economic enabling conditions (4th LoI)	Volatile PRN markets, weak incentives for design-for-recycling, dependence on exports and uncertain returns on reprocessing infrastructure constrain long-term investment	Sachet-driven market growth, dependence on imported raw materials, unstable recycled-plastic markets and inadequate financing for collection and recycling infrastructure constrain circularity	Market volatility, weak investment signals and misaligned financial incentives limit circularity in both contexts, despite different levels of market maturity
Social and behavioural conditions (5th LoI)	Consumer confusion, asymmetric information and inconsistent collection rules undermine sorting behaviour and reduce the quantity and quality of recyclables collected	Affordability, convenience, limited access to waste management services, entrenched disposal practices and limited awareness reinforce sachet consumption, open burning and low participation in formal waste-management services	Consumer behaviour and social norms strongly influence system performance, but behavioural change depends on clear information, accessible services and sustained communication-based interventions
Key interventions	Upstream packaging redesign, clearer source segregation, reform of EPR/PRN incentives, greater collection	Upstream reduction of sachet-based packaging, expansion of collection and sorting systems, stronger integration of informal actors, improved financing and	Effective intervention points span multiple levels of the system and must combine technical, infrastructural, economic,

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consistency and stronger domestic reprocessing capacity	enforcement, and communication-based behaviour change	policy and communication-based measures

Overall, the findings demonstrate that plastics resource recovery systems are shaped by complex interactions between governance structures, infrastructure availability, market dynamics and social behaviour.

- **The UK context:** operates within a relatively mature institutional and infrastructural environment, challenges persist due to market volatility, technological lock-ins and behavioural barriers.
- **Indonesia context:** faces structural constraints related to infrastructure coverage, regulatory enforcement, and the widespread use of low-value plastics, while also relying heavily on informal recycling systems.

Despite these contextual differences, both systems exhibit common barriers to circularity, including misaligned economic incentives, fragmented governance and behavioural challenges. Addressing these requires coordinated system-level interventions that align policy frameworks, infrastructure investments, market incentives and social engagement strategies.

The CVORR+ toolkit provides a structured methodology for identifying these intervention points and understanding how value flows across plastics value chains, enabling policymakers and stakeholders to design more effective strategies for improving plastics resource recovery and advancing circular economy objectives.

Recommendations for resource management, policy, governance, replicability, and scaling

Recommendations are grounded in a systems-based understanding of how processes, structures, values and enabling conditions interact across the value chain. In this respect, CVORR+ supports the identification of context-specific intervention points and the development of multidimensional metrics for assessing progress and monitoring transition pathways over time. Future strategic priorities include:

i. adopt systems-based approaches for plastics management;
ii. improve data collection, transparency and reporting across resource recovery systems;
iii. promote stakeholder collaboration across value chains; and
iv. integrate social considerations and just-transition principles into circular economy strategies.

UK-specific priorities: move beyond recycling-rate targets alone and adopt a broader set of context-appropriate metrics capable of capturing environmental, economic, social and technical performance. Improve source segregation, reduce losses at sorting facilities, strengthen domestic reprocessing capacity, and reform producer responsibility mechanisms so that costs and responsibilities are distributed more equitably across the system. Increase transparency in PRN/PERN revenues, exports and infrastructure investments, with granularity in monitoring different plastic packaging formats and their lifecycle fate. These steps would help the UK monitor progress more effectively, confront existing lock-ins, and align future policy reforms with tangible long-term impacts [3].

Indonesia-specific priorities: strengthen implementation capacity and develop integrated, location-specific strategies [8]. Expand waste collection coverage and sorting infrastructure, strengthen law enforcement, clarify governance roles, and create stronger financing mechanisms for waste management and recycling systems. A further priority is to formally integrate the informal recycling sector through training, fair compensation, personal

protection equipment access and social protection. Given the critical role of behaviour, social norms and sachet-based consumption, communication-based interventions, such as community engagement and awareness-raising, must complement technical and policy reforms. More broadly, Indonesia would benefit from measurable multidimensional metrics that can track environmental, economic, social and technical progress over time and support adaptive governance. These recommendations highlight the value of CVORR+ not only as a diagnostic tool but also as a framework for designing, implementing and monitoring context-sensitive interventions across diverse governance settings.

Relevance to EGRM / UNECE Community and Knowledge Sharing

This comparative case study demonstrates how CVORR+ supports integrated resource management of anthropogenic materials by identifying systemic inefficiencies, governance dynamics and intervention points across complex resource recovery systems, providing multidimensional metrics and strengthening coordination across value chains. In this respect, the case contributes to UNECE knowledge sharing by demonstrating how systems-based approaches aligned with UNRMS principles can inform decision-making, facilitate international learning and support the scaling of integrated resource management practices across regions.

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