

Circular impact compass: a monitoring and decision-support tool for evaluating community-based circular economy program

Anis Qomariah^{1,2*}, Bulan Prabawani^{1,2}, Sudharto P. Hadi¹, Ilham Ainuddin^{1,2}, and. Kadek Ardhika Widya Kresna³

¹Department of Business Administration, Faculty of Social and Political Sciences, Universitas Diponegoro, Semarang, Indonesia

²Inclusive Green Innovation, Transformation, and Entrepreneurship (IGNITE)

³PT Petrokimia Gresik

Abstract. Community-based sustainability programs increasingly adopt circular economy principles, yet their monitoring systems often remain linear: they report activity counts or diversion totals without showing how resources move across actors and how those movements translate into regenerative environmental outcomes. This paper presents the Circular Impact Compass (CIC), a compact monitoring and decision-support tool designed for routine use by program teams. Using a design-based research approach, the CIC was iteratively developed through (i) analysis of existing program records and reporting forms, (ii) field observations of material handling and decision points, and (iii) co-design discussions with program stakeholders. The CIC combines an actor-to-actor Circular Flow Map with a four-dimension scorecard that operationalizes circularity as environmental regeneration, resource utilization, socio-economic circulation, and community well-being. The Flow Map makes resource routing explicit, including quality constraints and alternative pathways (e.g., reuse, recycling, and energy recovery), so that leakage points can be located and discussed. An illustrative application in an industrial-community partnership shows how the CIC supports shared interpretation of circular progress and prioritization of adaptive actions. As a scope-oriented proceedings contribution, this paper clarifies CIC constructs, boundaries, and indicator options to support replication and future validation studies.

1 Introduction

Circular economy (CE) is increasingly positioned as a practical strategy to reduce pressure on virgin resources and to manage residuals through loop-based practices (e.g., reuse, recycling, recovery) that can be linked to broader ecological restoration ambitions [1,2]. Policy agendas such as the European Commission's Circular Economy Action Plan signal this shift by encouraging systemic interventions that extend product and material lifetimes and reduce waste generation [3]. At the community level, CE-inspired initiatives often take

* Corresponding author: anisqomariah@live.undip.ac.id

the form of reuse networks, upcycling, local repair services, and collaborative resource sharing.

However, monitoring arrangements for such programs frequently resemble conventional linear reporting: implementers count activities (trainings, campaigns) or summarize diverted mass, while the underlying circular logic remains implicit. In our document review and field observations, this limitation appeared in two ways: (i) reports did not consistently record the origin and destination of materials across multiple actors, and (ii) outcomes beyond diversion (e.g., local environmental risk reduction, community benefits, and durability of partnerships) were rarely monitored as part of a shared framework. Recent reviews highlight that many circularity indicators are tailored to products, firms, or national material accounts, and therefore require adaptation before they can guide community-based decision-making [4,5].

To address these gaps, we develop a Circular Impact Compass (CIC) as a monitoring and decision-support tool for community-based programs grounded in CE principles. The CIC is intentionally lightweight: it can be maintained by program teams using routine records, while still making circular resource flows and decision points visible. This proceedings paper provides the scoping foundation for the tool by clarifying constructs, boundaries, dimensions, and practical indicator options, complemented by an illustrative application.

2 Materials and methods

2.1 Design-based research approach

The CIC was developed using design-based research (DBR), an approach suited for producing usable artifacts through iterative cycles of analysis, prototyping, field use, and reflection in real settings [6,7]. In DBR, the aim is not only to produce a tool but also to articulate transferable design logic (e.g., what the tool must capture to support decisions) that can be adapted to similar programs. Development progressed through four stages. (A) Construct and needs analysis: existing program documents (objectives, activity logs, waste/resource records, partnership agreements, and reporting templates) were reviewed to identify decision needs and available evidence. (B) Field observation and preliminary flow mapping: walkthroughs and process tracing documented how materials moved among actors and where quality constraints influenced routing. (C) Stakeholder discussions: structured discussions with program managers, community representatives, and partners refined system boundaries, feasible data collection, and priority use cases. (D) Pilot refinement: the CIC was trialed in an anonymized industrial-community initiative to test usability and to revise indicator wording, evidence requirements, and scoring guidance.

2.2 Boundary setting and life cycle considerations

Because CE interventions can shift burdens across the life cycle, boundary setting follows ISO 14040 principles for goal and scope definition [8–10]. The CIC does not replace LCA; instead, it uses life cycle considerations to decide which flows should be traced routinely (e.g., end-of-life materials, processing rejects, and secondary pathways such as recycling or energy recovery). The monitoring boundary is defined by (i) participating actors, (ii) tracked resource categories, and (iii) decision points where leakage or rerouting commonly occurs.

2.3 Data collection protocol and quality assurance

To keep the CIC feasible in community settings, the protocol distinguishes a minimum dataset from optional enhancements. The minimum dataset records: resource category; origin

actor; destination actor or pathway; quantity (mass, count, or volume); quality notes (e.g., contamination, damage, moisture); and evidence type (receipt, photo log, partner confirmation). Optional fields include economic values (costs/savings), energy yields, and selected environmental proxies (e.g., substitution of virgin inputs). Data quality is strengthened through simple triangulation (where feasible), periodic spot checks by a designated data steward, and transparent documentation of assumptions to support repeatability across monitoring cycles.

3 The circular impact compass framework

3.1 Design logic

The CIC integrates two complementary outputs. The Circular Flow Map visualizes actor-to-actor exchanges for defined resource categories and makes decision points explicit (collection, sorting, processing, offtake, and downstream routing). The Compass Profile is a compact scorecard that summarizes progress across four impact dimensions. This combination addresses a common trade-off noted in circularity measurement: aggregate scores can hide where circularity is gained or lost, while flow maps alone are difficult to compare over time or across interventions [4,5].

3.2 Four dimensions of circular impact

Circularity is operationalized through four interconnected dimensions as shown in Table 1. D1 Environmental regeneration captures outcomes that reflect reduced local environmental pressure and early restoration actions (e.g., reduced uncontrolled disposal and localized pollution risk). D2 Resource utilization captures loop-closing performance and efficiency (reuse, recycling, recovery, and substitution of virgin inputs). D3 Socio-economic circulation tracks how value is created and retained locally (livelihoods, enterprise participation, and distribution of benefits), consistent with the linkage between CE practices and sustainable development objectives [11]. D4 Community well-being captures tangible and perceived benefits experienced by residents, including environmental quality and social cohesion, drawing on multidimensional well-being measurement approaches [12,13].

Table 1. Circular Impact Compass dimensions and example indicators (adaptable by context)

Dimension	Monitoring intent	Illustrative indicators (examples)
D1 Environmental regeneration	Regenerative outcomes beyond diversion and compliance	Avoided uncontrolled dumping; reduced pollution risk; site greening/restoration actions; proxy GHG avoidance based on substitutions
D2 Resource utilization	Loop closure and resource efficiency across materials/energy	Share of materials reused/recycled; substitution ratio vs. virgin inputs; water reuse volume; residual routed to energy recovery where appropriate
D3 Socio-economic circulation	Local value creation and circulation across actors	Jobs and income created; local supplier/SME engagement; repair/refurbish micro-enterprises; skills and capacity building participation
D4 Community well-being	Human outcomes and perceived benefits of circular interventions	Perceived environmental cleanliness; safety and nuisance reduction; participation equity; community satisfaction and trust in program

3.3 Scoring, evidence, and repeatability

For routine monitoring, the CIC applies a 0-3 maturity scale to each indicator: 0 (absent), 1 (initiated), 2 (implemented), and 3 (institutionalized). To reduce ambiguity, each score must be supported by an evidence note (e.g., a log entry, invoice, mass record, partner confirmation, or structured stakeholder minutes). Where quantitative values exist (e.g., quantities routed to reuse/recycling, participation rates), they are recorded alongside the score to enable verification and trend interpretation. Results can be summarized at indicator level (for action planning) and at dimension level (for communication and reflection).

3.4 Circular flow map: tracing multi-actor loops

The Circular Flow Map traces key resource categories through participating actors (e.g., industry, community groups, SMEs, local government units, recyclers, and recovery operators). For each exchange, the map records origin conditions (including quality constraints), processing or transformation steps, ownership and decision authority, and the final pathway. This approach is consistent with industrial symbiosis logic, where by-products are exchanged to generate environmental and economic co-benefits across a network [14]. In the CIC, the map is used to locate leakage (where materials exit intended routes) and to identify where additional partners, storage, or processing capacity are needed.

3.5 Decision-support use cases

The CIC supports common operational decisions in community programs: (i) pathway selection when multiple options exist (reuse, recycle, refurbish, recovery), (ii) partner coordination and accountability by clarifying who controls key handover points, (iii) adaptive resource allocation across sorting, training, storage, and market development, and (iv) communication to funders and partners without reducing performance to a single diversion metric.

4 Illustrative application

4.1 Case setting and boundary

The CIC was piloted in the Tawangargo Smart-Eco Farming Village (TAMENG) social innovation program, an industrial-community partnership led by PT Petrokimia Gresik and community groups in Desa Tawangargo, Indonesia. The program was selected because internal life cycle considerations flagged the grave (end-of-life) phase as a hotspot, driven by unmanaged end-of-life materials such as used fertilizer bags, silo drums, scrap iron, and wooden pallets. Accordingly, the CIC boundary covered (i) transfer of selected end-of-life materials from the company to community actors; (ii) community utilization and repurposing processes; and (iii) downstream handling of residual fractions (reuse and further recovery routes where available). Evidence sources combined program inventories and handover records, field observations, and stakeholder discussion notes.

4.2 Compass outputs

The CIC was piloted in the Tawangargo Smart-Eco Farming Village (TAMENG) social innovation program, an industrial-community partnership led by PT Petrokimia Gresik and community groups in Desa Tawangargo, Indonesia. The program was selected because

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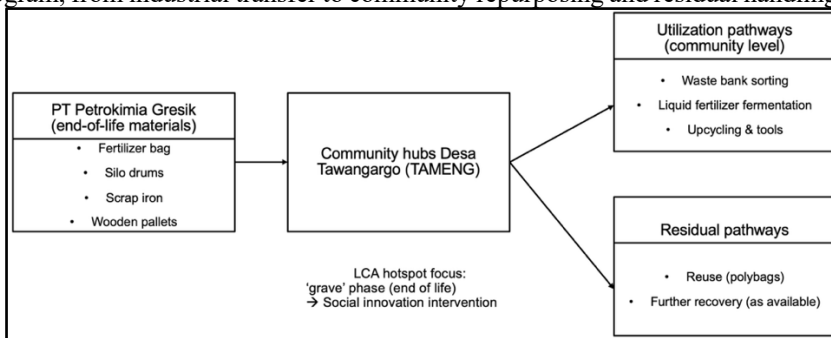


Fig 1. Simplified circular flow map for Program TAMENG (PT Petrokimia Gresik-Desa Tawangargo) used to trace end-of-life materials, community utilization, and residual pathways

4.3 Leakage detection and adaptive actions

Flow mapping and stakeholder review highlighted three practical leakage risks. (1) Supply dependence: several utilization routes relied on continued provision of industrial end-of-life materials; this was mitigated through planned transfer of operational roles to local institutions and diversification of supply partnerships. (2) Process inconsistency: utilization processes (sorting, cleaning, fabrication, fermentation) were vulnerable to quality variation and person-dependence; actions included standardizing operating procedures and evidence documentation, and strengthening skills through hands-on training. (3) Institutional and market anchoring: long-term loop closure required local governance support and stable demand for products; the program integrated source segregation into village governance and strengthened the economic value of outputs such as licensed liquid organic fertilizer.

4.4 Example of compass profile summary

Table 2 provides an indicative Compass Profile derived from the maturity rubric and evidence compiled during the pilot. Resource utilization (D2) scored highest because multiple reuse and upcycling routes were established for bags, drums, scrap iron, and pallets, alongside organic waste processing into liquid organic fertilizer. Environmental regeneration (D1) and socio-economic circulation (D3) were rated as emerging and strengthening; the LCA documentation used for program scoping reported reductions in acidification potential (0.3483%) and eutrophication potential (0.0164%) through direct practice changes, and reductions in global warming potential (0.0163%) and ozone depletion potential (1.4439%) through compensatory actions. Community well-being (D4) benefits were observed through participation and cleanliness improvements, but systematic well-being measurement should be institutionalized for longitudinal monitoring.

Table 2. Compass Profile summary for Program TAMENG

Dimension	Illustrative score*	Interpretation (example)
D1 Environmental regeneration	2	Mitigation actions linked to reduced open burning and higher organic fertilizer use; regeneration evidence is still proxy-based and should be tracked routinely.
D2 Resource utilization	3	Multiple reuse/upcycling routes established for bags, drums, scrap iron, and pallets; organics processed into liquid organic fertilizer; residual handling still depends on partner availability.
D3 Socio-economic circulation	2	Emerging value circulation through community production (POC), shared facilities, and local partnerships; market scaling and revenue tracking still developing.
D4 Community well-being	2	Participation and cleanliness benefits reported; source segregation supported by local governance; well-being indicators not yet measured systematically.

*indicative scores; 0-3 maturity scale

5 Discussion

The CIC addresses limitations of linear evaluation by connecting reported outputs to observable circular flows and by integrating environmental and social lenses. Unlike product-centric circularity indicators, the CIC is designed for programs where circularity depends on coordination across heterogeneous actors and where outcomes include livelihoods and community benefits. The four-dimension structure encourages balance: high performance on loop closure (D2) is treated as insufficient if it is not accompanied by regeneration outcomes (D1) and fair value circulation and well-being outcomes (D3, D4).

Life cycle considerations help reduce the risk of burden shifting. ISO 14040 emphasizes clear goal and scope definition and interpretation relative to system boundaries [8–10]. The CIC uses this logic to decide which flows must be traced routinely (e.g., end-of-life materials and secondary pathways) while keeping data requirements feasible for community teams. A tiered approach is recommended: use the CIC for routine monitoring and learning, then formulate targeted LCA questions when deeper quantification is required.

Finally, the CIC complements evaluation approaches that emphasize relevance, effectiveness, and sustainability because it makes the meaning of ‘impact’ operational in circular programs and links it to evidence that can be reviewed in partner meetings [15]. The Compass Profile supports concise communication to funders, while the Flow Map supports coordination across actors—an essential feature in industrial-community circular partnerships [7].

5.1 Limitation and future work

This proceedings paper focuses on scoping and design with an illustrative pilot; it does not claim net environmental benefit estimates. First, maturity scoring involves judgment; reliability should be improved through rater training and inter-rater agreement testing. Second, program boundaries can change as partners enter or exit; versioning of flow maps and consistent definitions are required for trend interpretation. Third, some regeneration outcomes manifest over longer time horizons and require complementary environmental monitoring. Future journal work should validate the CIC across multiple sites, test reliability

and construct validity, and assess how CIC-informed decisions influence environmental and socio-economic outcomes over time.

6 Conclusion

This paper presented the Circular Impact Compass (CIC) as a practical monitoring and decision-support tool for evaluating community-based sustainability programs grounded in circular economy principles. Developed through design-based research, the CIC combines circular flow mapping with a four-dimension scorecard (environmental regeneration, resource utilization, socio-economic circulation, and community well-being) to capture multi-actor routing and to make leakage points actionable. The illustrative application shows how the CIC can support shared interpretation and adaptive management. The CIC provides a scope-oriented foundation for future empirical validation and wider deployment.

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