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Research paper

Study on Monitoring Indonesia's Circular Economy: An Indicator System Proposal

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Abstract
Circular economy represents a fundamental departure from the traditional linear economic model. However, this transition poses a challenge and will inevitably have winners and losers. While the formalization of circular economy indicators may seem simple, its implications are profound and complex. Several countries, such as the EU, China, Japan, and Colombia, have already formalized their monitoring and evaluation framework; however, critical knowledge gaps persist due to the lack of universally recognized indicators. This study focuses on Indonesia, an emerging nation currently in the process of designing its circular economy monitoring framework. To achieve this, a triangulated methodology is employed, encompassing literature reviews, Economy-Wide Material Flow Analysis (EW-MFA), and expert interviews with the ministry and experts. Thirteen multidimensional indices, including common and custom indicators for Indonesia, are compiled. This study offers valuable insights and lesson learned to monitor and evaluate national and global transition towards circular economies.

Keywords: Circular Economy · Transition · Monitoring · Framework · Indicator System

1. INTRODUCTION

Conceptually, circular economy is a win-win solution that does not hinder both sustainability and economic growth since the successful implementation of a circular economy contributes to all three sustainable development dimensions (Korhonen et al., 2018). Circular economy is not limited to better waste management with end-of-pipe recycling solution but also aim to establish a safe and thriving natural environment as a basis of a thriving society and economy (Bappenas & UNDP, 2021). Circular Economy embraces a broad set of interventions along the lifecycle of a product (European Environmental Agency, EEA, 2016) across all relevant economic sectors and activities focusing on the 9Rs (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish/Remanufacture, Repurpose, Recycle, and Recover) which is fundamentally opposite from the business-as-usual, linear economy (Potting et al., 2017).

There are many pathways to achieve circular nation, from action plan, enacting new polcies, to evaluation and monitoring. The indicator formalization might sound simple, but the implication is enormous as well as challenging. Quantification through indicators could distribute attention, hold people together (Desrosières, 2015), inform decision-makers, allocate resources, and ultimately, be a basis for setting new priorities and driving actions (Rottenburg et al., 2015; European Commission, 2018a). Several nations have formulated indicator systems to monitor the circular economy and develop circularity strategies. European Commission 2018 developed the EU′s monitoring framework for the circular economy, complementing the existing Resource Efficiency and Raw Materials Scoreboards (European Commission, 2018a), followed by national monitoring frameworks. In Asia, well before tropic gained prominence, China adopted its first indicator system in 2007 and its most recent set of indicators in 2017 (National Development and Reform Commission, NDRC, 2017a), while Japan declared its first sound material-cycle economy in 2003 and the Fourth Plan in 2018 (Avdiushchenko & Zajac, 2019; PACE, 2019). In the American continent, Colombia also recently formalized in 2020; while Chile submitted its draft in 2019, and Canada has been conducting their survey data on circularity biannually (PACE, 2019). Further,

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several international organizations also brought indicator solutions on circular economy, such as World Business Council for Sustainable Development (WBCSD)'s Circular Transition Indicators, Ellen MacArthur Foundation's Circular Economy Indicators (European Academies Science Advisory Council, EASAC, 2016), and ISO Standard 59020 for measuring circularity framework.

While the need to measure circularity progress at national, regional, city, and business levels is growing, the knowledge base is fragmented (EEA, 2016), and no universally recognized indicators (European Commission, 2018a). Furthermore, it is impossible to accurately capture the complexities of the circular economy through a single measure or score. Accordingly, no country adopted a single indicator to assess circularity (European Commission, 2018a) and thus use an indicator system.

As the largest economy in Southeast Asia (ASEAN) and the 10th largest in the world in purchasing power parity (World Bank, 2022), Indonesia is now committed to shifting to circular economy to harmonize its economic and environmental goals and believed that circular economy could be a promising solution to strengthen their economy, creating new green jobs, lowering household expenditure, reducing household spending, and preserving the environment (Bappenas & UNDP, 2021).

Indonesia's government is currently developing a circular economy action plan, roadmap, platform development, and monitoring and evaluation system to achieve the target (at the second phase, Figure 1). However, despite the existing actions of developing the monitoring indicator system, we conducted this study from different angles, such as the MFA-based perspective.

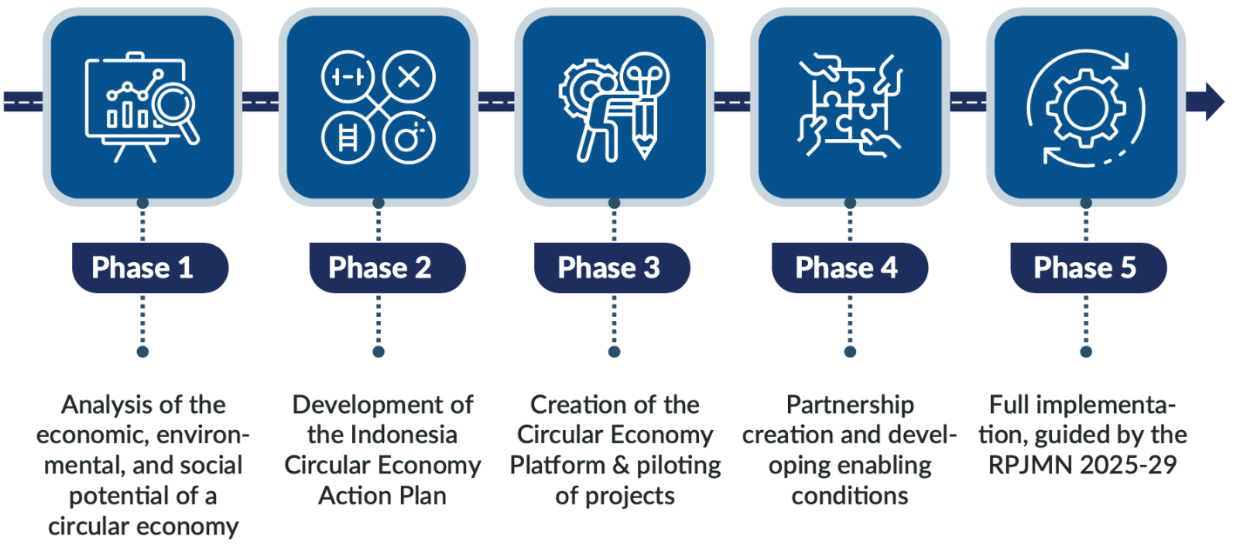


Figure 1. Timeline for National Circular Economy Roadmap: Indonesia Is Currently at Phase 2. Source: Bappenas & UNDP (2021)

This study was guided by the leading research question: 'What is a tailor-made macro-level indicator system for Indonesia's circular economy, which can assist a transition to the circular economy and can reflect, promote and capture the goals of circular economy?'. To systematically achieve the research objective, the research question is further elaborated into three sub-research questions:

1. What lessons, potential usage, scope, role, and rationales can be learned from EU's and other countries' existing circular economy indicators for Indonesia?
2. What are the strategic orientations and key priorities of Indonesia's circular economy?
3. What are the concepts, methodologies, most significant challenges, and critical requirements for further implementation of circular economy indicators for Indonesia?

This exploratory study aims to contribute to Indonesia's evolving Circular Economy development and offer a fresh perspective and a larger implication for developing nations.

2. CONCEPTUAL FRAMEWORK AND DEFINITIONS

2.1. Good Indicator: Definition, Function, and Criteria

The Organization for Economic Cooperation and Development (OECD) defines an indicator as "a quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention, or to help assess the performance of a development actor" (OECD, 2010). Indicators perform many functions, primarily by simplifying, clarifying, and providing aggregated information to decision-makers for better decisions and more effective actions.

A good indicator must be specific, measurable, attainable, relevant, time-bound (SMART), and concise (UNDP, 2009). The selection of good indicators must meet five criteria and standards: 1) Indicators are needed and practical; 2) Has technical value; 3) Fully defined conceptually; 4) Feasibility measurement of the indicators and 5) Field tested or put into use operationally (UNAIDS, 2010).

2.2. Circular Economy: Concept and Definition

There is no single or internationally agreed definition of a circular economy, which varies among countries and literatures (UN & OECD, 2024). Indonesia defines the circular economy as 'an economic model that optimizes the use of resources, designs products to be as efficient as possible, and returns the rest of the production and consumption processes into the production cycle' (Bappenas & UNDP, 2022).

2.2.1. Circular Economy Mechanism and R Framework

Circular and linear economies differ in how they create or maintain value. In a linear economy, materials are extracted, processed, used, and converted to waste at the end of their useful life (Bappenas & UNDP, 2022). The OECD and Bellagio principles (EEA & ISPRA, 2020) outlines mechanisms contributing to a circular economy, include : 1) Closing resource loops: Preventing waste by using secondary raw materials and extending the lifespan of products through reuse, repair, and remanufacturing ; 2) Slowing resource loops: Extending product lifespan through durable design and facilitating ownership changes, reducing demand for virgin materials ; 3) Narrowing resource flows: Increasing resource efficiency through technological innovation, better asset utilization, and shifts in consumption behavior, without necessarily creating circular loops (UN & OECD, 2024).

Indonesia presently adopts the 5Rs framework as part of its circular approach. The 5R framework utilized in this research has been derived from the three circular economy principles of the Ellen MacArthur Foundation and its ReSOLVE framework (Bappenas & UNDP, 2022). The 5Rs in this context encompass reducing, reusing, recycling, refurbishing, and renewing, as referenced in (Bappenas & UNDP, 2022).

2.2.2. The Building Blocks and Domains of Measuring Circular Economy

The Bellagio Declaration for Circular Economy Monitoring by European Economic Area (EEA) and Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) (2020); offers a framework for monitoring circular economy progress, encompassing: 1) material flows; 2) Environmental impacts; 3) Socio-economic impacts; and 4) Policy actions measuring policy, process, and behavioral change domains. The protocol calls for a holistic monitoring approach that considers social, economic, and environmental aspects of circular economy.

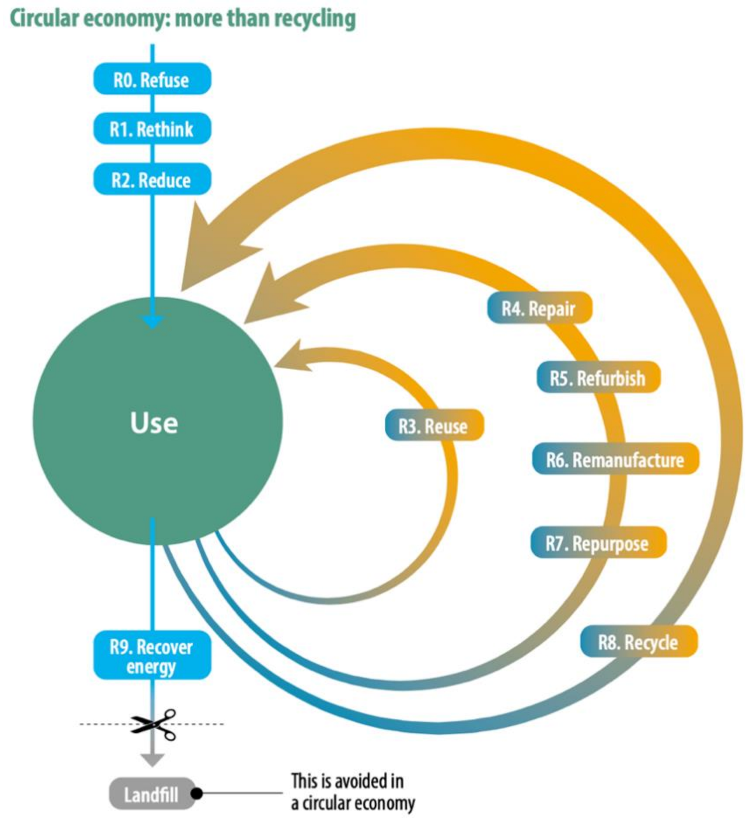


Figure 2. Circularity Ladder. Source: Potting et al., (2017, P. 5) as Cited in UN & OECD (2024)

2.3. Material Flow Analysis and Accounting

Material Flow Analysis (MFA) is an analytical method for measuring physical or energy materials or substances, processes, and inventories within well-defined system boundaries (time and area) over a periodic time frame (annual and monthly) (Brunner & Rechberger, 2016). MFA assesses how materials are used, leached, stored, and reused in society with the concept of pure flows and the principle of mass balance; therefore, all inputs will equal material outputs (UNEP, 2021). The core principles of MFA are based on a systems perspective, mass balance versus all flows from the cradle to grave, and annual flows versus geographic system boundaries. Applied extensively in the fields of industrial ecology and sustainable resource management, MFA serves as a valuable tool for assessing resource efficiency, pinpointing potential areas for improvement, and evaluating the environmental impacts associated with material flows.

EW-MFA can also focus on specific substances. For Europe, an emphasis has been taken on tracing Critical Raw Material (CRM). Thus, nations can utilize Substance Flow Analysis (SFA) to focus on a single or group of substances, which in this case, is relevant to analyze a specific product category under study.

Concerning circular economy, EW-MFA is a suitable approach for modelling waste management systems from a material recovery perspective and provides linkages for indicators for use. In waste management, the quantity and composition of waste are often unknown and must be collected empirically. MFA allows the calculation of the amount and composition of waste by balancing waste generation or waste treatment processes. Therefore, EW-MFA shows how a country handles and manages the flow of production, use, and disposal and how it contributes to environmental problems and how it contributes to environmental issues.

To fully capture the functions of EW-MFA, anthropogenic systems require a common language and indicator standardization. EW-MFA′s indicators are conceptually and globally accepted based on a simple environmental economic model in which the economic model is embedded in the environment (See Figure 3 and Table 1). It uses readily available production, consumption, and trade data combined with imports of unused domestic extracts, an indirect flow linked to imports of environmental statistics.

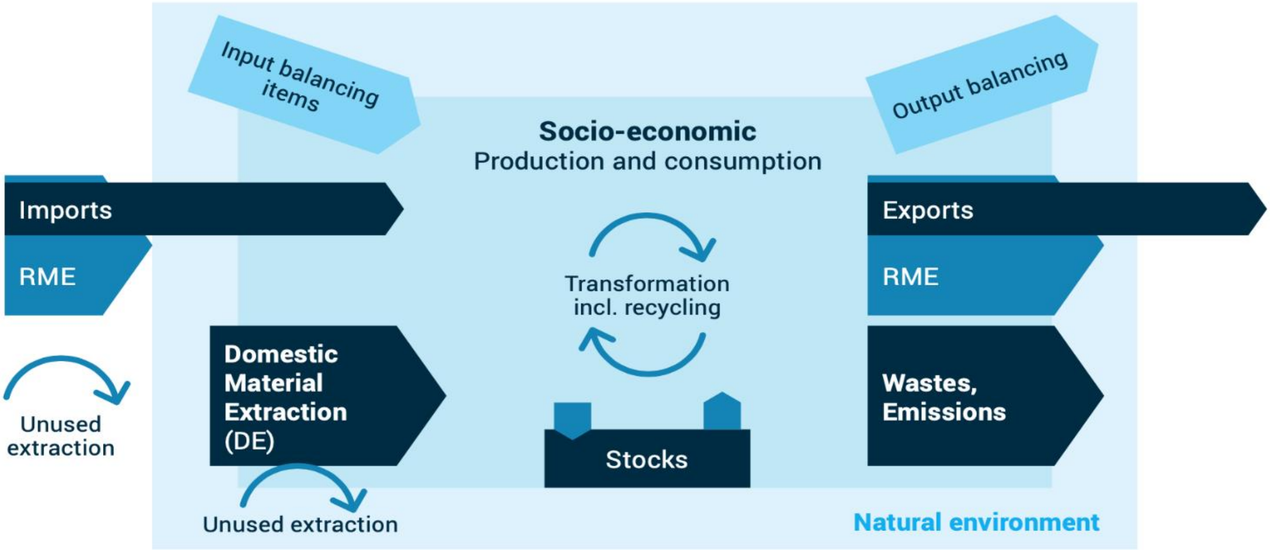


Figure 3. Schematic Representation of EW-MFA and Society Metabolism. Source: (UNEP, 2021)

Global Material Flows Database by the United Nations Environmental Program (UNEP) and International Resource Panel (IRP) is an essential step toward global accounting standards. Deforestation exacerbates soil erosion, habitat destruction, biodiversity loss, and contributes to global warming by depleting carbon sinks. Therefore, the Ew-MFA in practice usually breaks down each flow and indicators based on the material or product category or translated into sectors.

Table 1. EW-MFA Indicators. Note: HF: hidden flows; IF indirect flows. Source: (Eurostat 2018)

Indicator Classes	Indicators or aggregates	Accounting rules
Input	Domestic Extraction (DE)	Flow
	Direct Material Input	DMI = DE+Imports
	Total Material Requirement	TMR = DMI+HF(unused extraction and IF)
Output	Domestic Processed Output	DPO = emissions+waste+dissipative flows
	Direct Material Output	DMO = DPO+Exports
Consumption	Domestic Material Consumption	DMC = DMI-Exports or DE + Import
	Total Material Consumption	TMC = TMR-Exports-hidden or indirect material flows of exports
Balance	Net Additions to Stock	NAS = DMI-DPO-Exports
	Physical Trade Balance	PTB = Imports-Exports
Efficiency	Material productivity of GDP	GDP/Input or Output indicator = GDP divided by indicators values (per mt)
	Resource-efficiency of materials extraction	Unused/Used = Ratio of unused (hidden or indirect) to used (DMI) materials

3. RESEARCH METHODOLOGY

3.1. Literature Review

This study examines the rationales, purposes, relevance, role, and scope behind each indicator adopted from other nations for potential uses in Indonesia and the recent academic development of the circular economy. The European Commission's monitoring framework and indicator taxonomy are mainly derived from the updated Eurostat, Circular Economy Action Plan, EU law from EUR-Lex, and relevant data with citation followed. Eurostat provides a detailed overview of methodology, relevance, and comparison among EU Member States. Furthermore, this study further adopted a developing nation and a net exporter as a means to gain a deeper understanding of different trade and industrialization situations: China. China has been revising China's 2008 first evaluation and updated its 2017's Circular Economy Development Evaluation Index System (NDRC, 2017a).

Reviews of the nation′s National Medium-Term Development Plan (RPJMN), Waste Sector Act No. 18/2008 regarding Solid Waste Management, Government Regulation No. 81/2012 regarding Management of Domestic Solid Waste, Law on Environmental Protection and Management, overall waste management, waste trade, international trade on primary materials, and significant initiatives contributing to a circular economy are critiqued.

3.2. Economy-Wide Material Flow Accounts

We extended the economy-wide assessment based on ew-MFA from Global Material Flows Database by the UNEP's IRP by linking national statistics, waste production, and trade consumption to establish Indonesia′s socioeconomic system using official national data sources. This study uses Global Manual on Economy-Wide Material Flow Accounting by UNEP (2021). The initial exploration focuses on the main indicator classes and the practices of global ew-MFA. It has outlined the need for detailed product type flow, especially in recycling or reuse, End-of-Life, and DPO. Thus, we explored Indonesia's waste field-level data collection and assesses via different authorities with different methodologies, namely Indonesian Statistics (BPS) and National Waste Management Information System (Sistem Informasi Pengelolaan Sampah Nasional (SIPSN). Further, the European Union's waste data collection from Waste Framework Directive is assessed to compare the waste data practices.

3.3. Expert Interviews

The experts provided noteworthy contributions throughout the development of this research, primarily on Indonesia's circular economy outlook, insider's perspective, obstacles, and national priority. The main goal of indicator formalization is to monitor change toward the intended result (MDF, 2015); thus, the literature review and ew-MFA alone are insufficient to deliver circular economy indicators proposal for use. As the means and ends of this study, the potential indicators must incorporate the policy makers' opinion to reflect and to align with Indonesia's government focus, priority, and challenges.

The primary official publication UNDP & Bappenas (2021) on 'The economic, social, and environmental benefits of a circular economy in Indonesia' is the flagship document on analyzing Indonesia's critical priorities of circular economy deployment and interviews with the authors and coordinators, and the EEA experts tremendously enrich the development of this research. The interview resulted in an ongoing and follow-up discussion using virtual meetings, e-mail, and private messaging (See Annex 1) The interview was recorded upon the informants' permission and conducted flexibly and casually in English and Bahasa Indonesia. We used mixed language to immerse deeply in the informant's mind to investigate Indonesia′s cultural and political significance and particular practices. The semi-structured interview was done in a brainstorming style rather than a one-way directional.

4. RESULTS AND DISCUSSIONS

"You cannot manage what you cannot measure" is famously quoted to show the substance of monitoring and evaluating progress towards desirable futures (World Bank, 2014). The transition to a circular society and economy is transformative, systemic, profound, and sometimes disruptive (European Commission, 2020). Therefore, the transition must be fair; measures must be regularly updated, evolved, and transparent to achieve circular ambitions.

4.1. Indicator System Proposal for Indonesia

Used in combination as a system, this indicator system proposal comprised of common and specific indicators can provide policymakers, businesses, and civil society organizations with valuable information and guidance to track Indonesia's progress towards a circular economy. The proposed indicators are categorized based on four domains, similar to Bellagio Declaration′s circular economy groupings.

'Conceptual clarity' refers to the clarity of definitions and methodology in practice. A high rating indicates that the indicator (equation, formula, and definition) is clear and well-understood. Low rating suggests that conceptual gaps is huge and defition or methodological consensus has not been reached. The 'Measurability' index has been introduced to reflect the indicator's statistical simplicity, and data accessibility, mobilisation and collection to yield high quality and validity of result. High rating signifies ability to measure in the short term, with basic data available along with a well-defined indicator methodology with reliable information. Low rating suggests significant methodological or data gaps requiring sustained data collection and conceptual improvements. Finally, a remark on 'Adoption' shows whether the chosen indicator is common, newly made for Indonesia, or adopted.

4.2. Common Indicators: Total and Five Sectoral Focus

Based on a review of the existing list of indicators, a similar pattern of common indicators selected by countries was recognized. The EU, Japan and China adopted resource productivity, waste generation and recycling rates for the material and waste flows (production and consumption) domain. The European Union does not include resource productivity in EU's monitoring framework but conducts separate monitoring annually to track decoupling progress.

4.2.1. Resource Productivity and Recycling Rate: Scope and Definition

From the point of view of the physical world, indicators ID1 to ID4 are recurrent and widely adopted by other nations and academia, such as resource productivity, waste generated, recycling rate, and cyclical use rate. These material flow indicators (in tonnes) should measure both the total amount and each sectoral focus. Learning from EU, breaking down circularity per category is essential, especially C&D, whose weight severity may result in an inaccurate representation of totals. This representation in (%) and its evolution of sectoral monitoring should induce substantial resource recycling, environmental footprint savings, and reductions in material extractions. Material flow indicators are necessary to compute ew-MFA illustrated in the Sankey diagram for circular economy and resource efficiency agenda, which can be extended further for a more sophisticated analysis to evaluate certain purposes and policies.

Table 2. Circular economy indicator system proposal for Indonesia

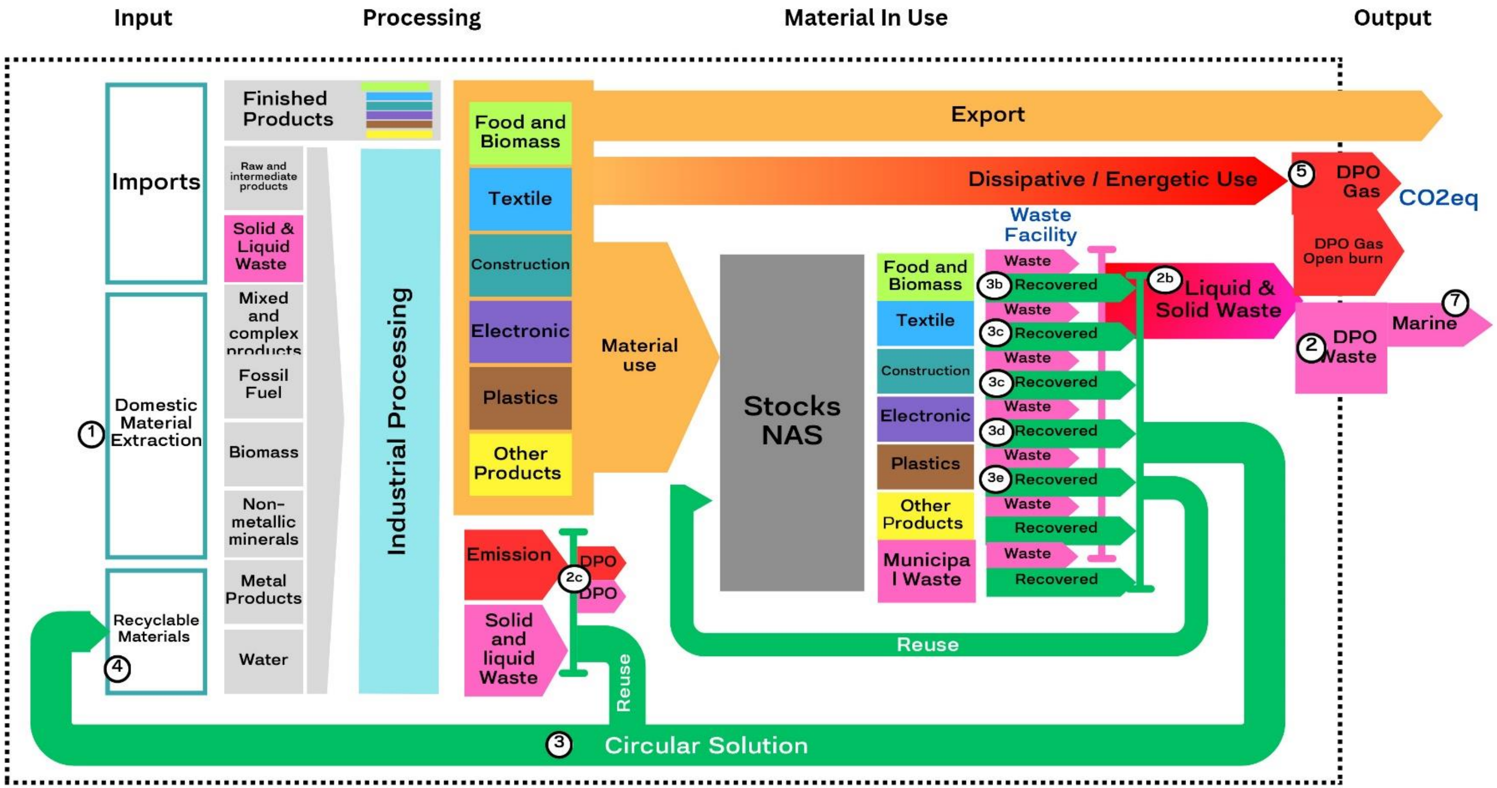
No	Indicator	Definition	Concept clarity	Measurability	Adoption remarks
Material flow (production and consumption) (4): flow of materials through the economy, including extraction, production, consumption, and disposal, which can help to identify material losses and potential areas for improvement					
ID1	Resource productivity = GDP / TMR	Measuring the economic output per unit of resources consumed, indicating the efficiency of resource use in the production and consumption of goods and services.	High	High	Common
ID2	Waste generation	The amount of waste generated by households and businesses, as well as the amount of waste category.	High	Medium	Common
ID2a	Total (ton annually and ton per capita) = Total waste generated / Total population	The amount of waste generated annually per type category.	High	Medium	Common
ID2b	Municipal Solid Waste (ton annually and ton per capita) = Total MSW generated / Total population (and can be downscaled to municipal level)	The amount of waste generated annually originated from residents per capita.	High	Medium	Common
ID2c	Industry (ton annually) = Total waste generated from industrial activities	The amount of waste generated annually originated from industrial activities.	High	Low	Common
ID3	Recycling rate	The amount of recycled material over the waste generated throughout the supply chain instead of being sent to landfill or incineration.	High	Medium	Adopted from EU
ID3a	Total (%) = Recycled Material / Waste Generated	The amount of waste generated annually per type category.	High	Medium	Adopted from EU
ID3b	Food loss and waste (%) = (Total biogas generated + Total compost + digested organic municipal waste) / Total food and loss waste	The amount of food waste recycled, recovered, reused, or composted annually throughout the supply chain, from cultivation, logistics, market, to consumption.	High	Medium	Modified from EU, (include biogas)
ID3c	Textile (%) = (Total textile reused + total textile recycled) / Total textile waste generated	The amount of textile waste recycled and reused annually throughout the supply chain in the reference year.	High	Low	Adopted from EU

ID3d	Recovery rate of Construction and demolition (%) = C&D waste that is ready for reuse, recycling, or material recovery (including through backfill) / C&D waste generated	The amount of construction and demolition waste reused, recovered, or recycled during construction and from End-of-Life in the reference year	Medium	Low	Adopted from EU
ID3e	Plastic (%) = Total plastic packaging waste recycled / Total plastic packaging sold	The amount of plastic waste recycled in the reference year.	High	Medium	Adopted from EU
ID3f	Recycling rate and reuse rate WEEE (%) = Total weight of the WEEE entering the recovery to reuse facility / Average of WEEE placed in the market in the five conservative years	The amount of WEEE recycled and reused divided by the average of three conservative years EEE placed in the market.	Medium	Medium	Modified from EU (to 5 years)
ID4	Circular use rate (DMC + U) (%) = U / (DMC + U)	Or cyclical use is the share of cyclical use (amount reused/recycled) to total input in the economy and society.	High	High	Adopted from EU
Environmental footprint (3): assess the environmental performance and progress towards decoupling resource use from environmental degradation					
ID5	*Carbon emissions avoided (CO2eq annually) = total amount of CO2eq avoided	The amount of carbon dioxide equivalent avoided by shifting to circular economy.	Medium	Low	Tailor-made
ID6	- Water consumption (bcm) = Total water consumption in the reference year - Water discharge by main pollutants (mgBOD/L, mgNH4-N/mL, P/L) = Average discharge per liter exceeding predetermined threshold	The amount of water consumed each year and the average water quality discharge. This metric can further be analyzed for water productivity (a measure of water use efficiency: consumption / GDP)	High	High	Modified from China
ID7	*Marine debris : multimethod	The amount of waste disposed of or abandoned into the natural waterbodies (marine, river, and lake).	Low	Low	Tailor-made
Socioeconomic impacts (3): assess the social and economic impacts of circular economy practices and policies					
ID8	Circular Gross Value Added (% GDP) = Gross value added within selected sectors / GDP	Total sector's contribution to GDP net of input costs, expresses gross value added as a percentage of GDP, to measure the circular economy size.	High	High	Modified from Colombia
ID9	*Circular MSMEs (number) = Total MSMEs adopting circular economy or 5Rs solution	The number of MSMEs that have adopted circular business models	High	Low	Tailor-made

ID10	- Circular job employment (%) = Total employment in circular economy sector / Total Employment *100% - Women circular employment (% and number) = Total women work in circular economy sector	The number of jobs created in circular economy industry. This indicator is suggested to be broken down into five sectoral focus and gender details.	Medium	Low	Common
Policy, process, and behavioral change (3): assess the effectiveness, efficiency, and coherence of circular economy policies and strategies					
ID11	Investment and capital mobilization				
ID11a	Circular or green government spending (million IDR) = Government spending in circular economy sector and development	Total government spending in circular economy incentives (tax saving and subsidy), education or training, business model or asset; as the primary inhibitor of circular and sustainable business model adoption and large scale expansion.	Medium	Medium	Adopted from EU
ID11b	Circular or green investment (million IDR) = Gross capital investment in circular economy sector	Gross investment by private sectors in circular economy sector, business model or asset; as the primary inhibitor of circular and sustainable business model adoption and large scale expansion.	Medium	Medium	Adopted from EU
ID12	Procurement, investment, and certification				
ID12a	- Circular or Green Public Procurement (GPP) (number and %) = Number of public procurement contracts awarded to circular businesses and activities - GPP coverage (number) = number of regulated product group within the year	Percentage of public procurement contracts that are awarded to circular businesses or for circular and environment criteria and threshold.	High	High	Adopted from EU and tailor-made for coverage
ID12b	- Circular Ecolabelling (number) = Total Ecolabel granted for circular economy - Ecolabeling coverage (number) = number of regulated product group within the year - Ecolabeling market adoption (million IDR) = the market size of ecolabel product sold in the market within the year	The number of Ecolabel granted for environmentally-friendly technologies and products designed with the principles of the circular economy, such as prolong durability, repairability, and recyclability. The sub-indicators aim to monitor the government efforts to cover as many products as possible, how the market shift and adopt circular products.	Medium	High	Adopted from EU and tailor-made for coverage
ID13	Zero Open Burn = number of individuals burn trash	The number of cases and DPO as resulted in combined governmental and policy effort to shift the open burn practices through strict penalty and monitoring, agricultural and rural area waste collection, improved cookstove distribution, composting, community engagement and education.	High	Low	Tailor-made

* Signifies indicators are under development: the methodology needs to be developed to obtain sufficient data quality in the upcoming years

A. Material flow: (in tons annually)



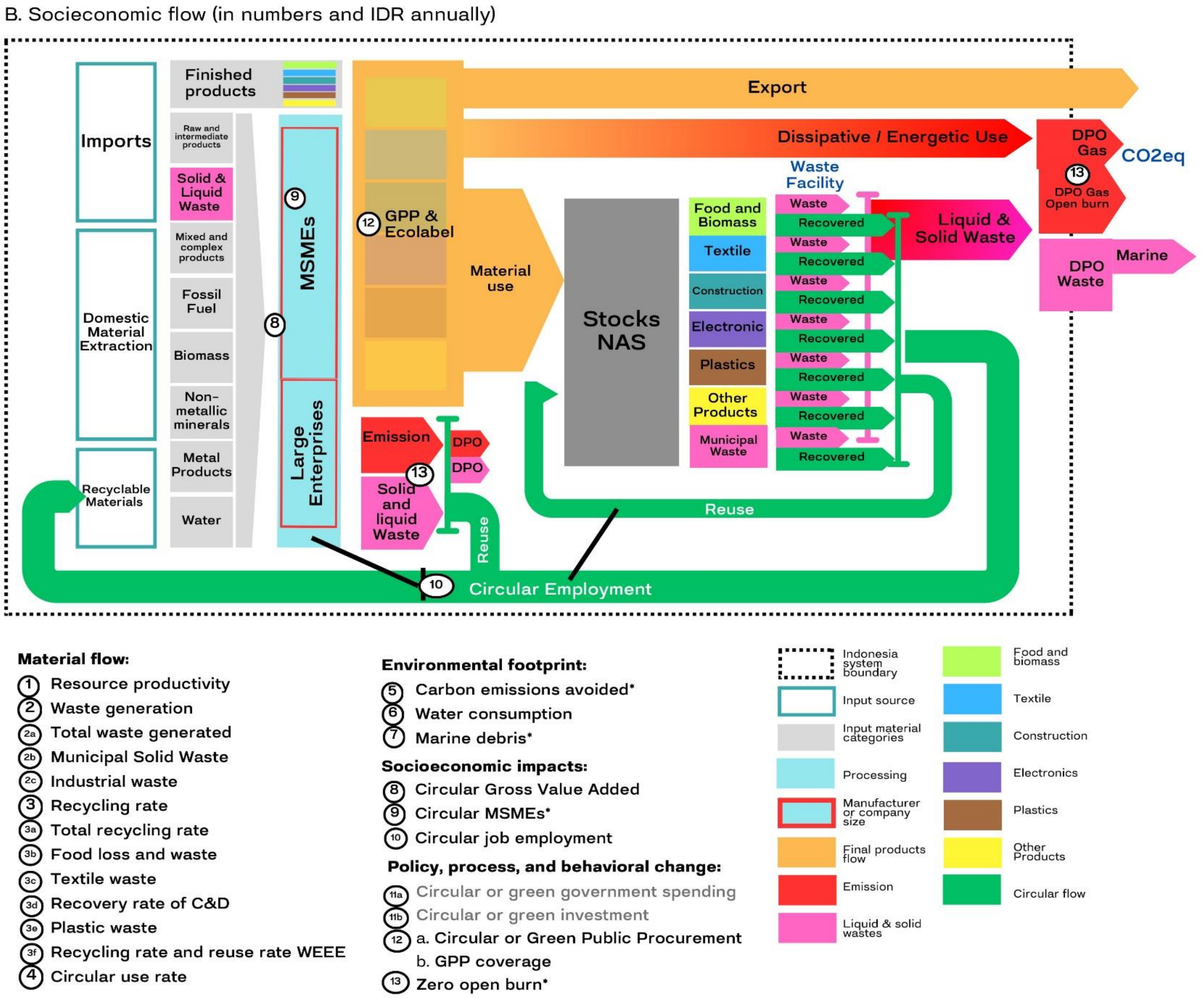


Figure 4. Circular Economy Indicator System Proposal Displayed in Indonesia's Society Metabolism. Source: Own Illustration, Adapted from Institute of Circular Economy, Tsinghua University (n.d.). Note: Size and Length Do Not Show the Magnitude

EU and Indonesia both use the direct method to collect waste data. However, gaps in solid waste data in Indonesia need to be adjusted, integrated, and harmonized. This redundancy and overlapping of responsibilities between several official agencies have the potential to save statistical budgets. While this incongruity posed a challenge in data collection, this presents an opportunity for Indonesia to start to collect MFA data which might be helpful in circular economy and other agenda monitoring.

4.2.2. Circular Economy Business Classification Sectoral Code Determinations

It is important to note that the industries analyzed on the competitiveness and innovation domain (EU9) represent only a portion of the broader economic impact since the circular economy on other industries is more diffuse and difficult to isolate. Recycling, repair and reuse are good proxies for mainstreaming the circular economy into other sectors. EU uses 24 business categories listed in Nomenclature of Economic Activities (NACE) codes to define circular economy sectors as in recycle, repair, and reuse classes (See Annex 3), an efficient and straightforward way of measuring business progress is by observing a circular sector.

The current Standard Classification of Indonesian Business Fields (KBLI) 2020 by the Investment Ministry of Republic Indonesia's Online Single Submission (OSS, 2020) has a specific category E for ‘Water Treatment, Wastewater Treatment, Waste Material Treatment and Recovery, and Remediation Activities’ sectors. However, Indonesia needs to link the circular economy activities which are not listed within E category but signify circular economy attainment in the 5Rs philosophy (See Annex 5). Therefore, to reduce the statistical burden for socioeconomic monitoring, Indonesia is suggested to use the KBLI approach on circular economy or 5Rs business to measure Ecolabeling, investment, MSMSE, job creation, and household saving indicators. Although the 5R categories are spread across different category pedigrees, this sector code provides an immediate and direct measure for selected sectors of all listed legal businesses.

4.2.3. Environmental Footprint: Solid, Liquid, Gas

From the China’s evaluation framework, China is concerned about resource productivity with a specific focus on water, energy, and land and the recycling rate of main wastes (European Commission, 2018b). For EU, Industrial waste and liability are addressed indirectly, as measured by competitiveness and innovation (indicators EU9-EU10). Nevertheless, the EU’s EW-MFA detailed the emissions of DPO to 15 gaseous and PM group, the 64 emissions from industries and the water discharge profile parameters are recorded (Eurostat, 2018a). These parameters are necessary to be listed on Indonesia’s ew-MFA.

The implementation of a circular economy in Indonesia has the potential to cut down CO2 emissions by 126 million tons and reduce water consumption by 6.3 billion cubic meters by the year 2030 (Bappenas & UNDP, 2022). From the interview, the UNDP and Bapennas agreed that all economic activity footprints shall be translated into CO2 equivalent to support ENDC and the net zero emission goal in 2060. Currently, the water footprint is not the priority concern for national circular economy monitoring; however, we strongly believe it is important to focus on water and its discharge to strengthen the water security. It is estimated that the area of critical waters will increase from 6% in 2000 to 9.6% in 2045 (Bappenas, 2019b). To complete the assessment, the parameters needed for Indonesia to harness the water footprints is at least: total P, total NH3-N and total COD (or BOD) discharges.

4.2.4. Waste Hierarchy and Circular Solution Categorization

The waste hierarchy is a prioritization model that outlines the preferred methods for managing waste, intending to promote resource efficiency and reduce environmental impacts. At the top of the hierarchy are waste prevention and minimization, followed by reuse, recycling, recovery, and, as a last resort, disposal (European Commission, 2017b). The waste hierarchy, as defined in the EU's Waste Framework Directive (2008/98/EC), promotes waste prevention as the most preferred option. The next level is reuse, which encourages the use of products and materials multiple times before they become waste.

Waste-to-energy processes encompass a wide range of waste treatment operations, spanning from what can be categorized as 'disposal' and 'recovery' to 'recycling.' For instance, operations like anaerobic digestion, which yields both biogas and digestate for fertilizer, are considered recycling, while waste incineration with limited energy recovery is classified as disposal and not yet a circular solution (European Commission, 2017b) (See Figure 5). For Indonesia, the government has invested three Pembangkit Listrik Tenaga Sampah (PLTSA, or WtE) for biogas as a recovery solution. This will lead to an increase of total recycled in food waste and loss (ID3b) to include the biogas recovered. The reasoning is biogas recovery decreases greenhouse gas emissions compared to landfilling and recovers energy from waste that would otherwise go to waste and met the renewable energy targets by promoting resource recovery from waste streams, as stated by the Ministry of Energy and Mineral Resources of Indonesia.

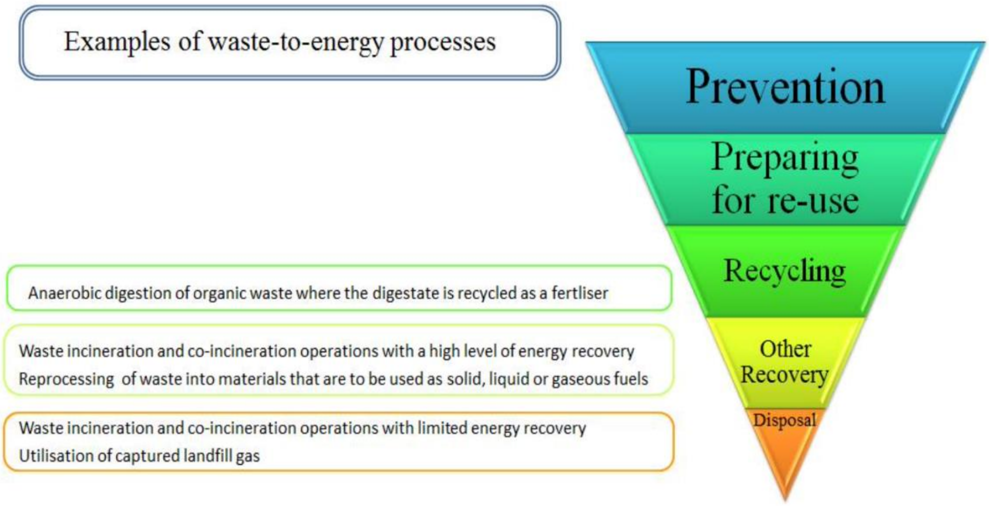


Figure 5. Types of Waste-to-Energy in EU Waste Hierarchy. Source: European Commission (2017b)

The waste hierarchy is needed to provide a structured approach to waste management, and Indonesia is required to create and improve the waste classification with sufficient arguments and reasoning. The approach will enable organizations and municipalities to prioritize efficient and responsible waste management, and ultimately derive greater waste recovery and value maximization.

4.3. Tailor-Made Indicators for Indonesia

The specific theme of Indonesia's economy is MSMEs and middle-class boom (as an emerging nation), marine debris (as a maritime nation), and capital mobilization to MSMEs and informal sectors.

4.3.1. Marine Debris

Marine debris is not easy to measure, and there is a strong and shared monitoring demand for marine litter by diverse stakeholders, such as UNEP IRP, G7, G20, UNESCO, and WMO; thus, they formed Global Ocean Observing System (GOOS) and Global Partnership for Marine Litter (GPML). Marine Plastics Debris Essential Ocean Variable is now an emerging indicator under the cross-disciplinary (including human impact) category. International cooperation and joint research like GPAP and GPML will realize marine debris monitoring and reduce marine debris by 70% in 2025. A collective effort and a multidiscipline approach employing observation and meteorological satellites, litter movement modeling, sensor (Kershaw et al., 2019), and debris density using the semantic segmentation model and high-resolution satellite (Sekine et al., 2022). Measurement must also cover origin of debris entry points, the types of debris (rubber, cloth, paper cardboard, plastics, micro-plastics, and nano-plastics), movement of patterns, accumulation zone, land- and sea-based anthropogenic pollutions, fragmentation, and degradation patterns, which then serve as a foundation to set geopolitical mitigation measures (Omeyer, et al., 2022).

In March 2019, Southeast Asia adopted Regional Action Plan for Combating Marine Debris in the ASEAN Member States (2021–2025) on marine plastic pollution transboundary cooperation (ASEAN Secretariat, 2021). Therefore, joining forces is highly suggested to fully capture the marine debris data, and ultimately create mitigation plans and circular solutions.

4.3.2. MSMEs: Backbone of Indonesia's Economic Advancement

MSMEs accounted for 90% of employment and nearly 90% of the GDP in Indonesia in 2019 (Bappenas & UNDP, 2021) with 15,69% export contribution in 2021 (Coordinating Ministry for Economic Affairs, 2022), MSMEs are the key to achieving inclusive growth (ADB, 2021) and are referred to as the 'critical engine 'of the Indonesia economy and many national programs have been targeted towards this avenue, especially on financing and leverage (Coordinating Ministry for Economic Affairs, 2022). Thus, ensuring that MSMEs are at the heart of Indonesia's circular economy priority is crucial.

Despite the statistical obstacle in measuring MSME, attempting to collect MSME data periodically (such as monthly) will be costly yet useful. The accounting might involve National Bank data, while the savvier tangible product MSMEs might be easily calculated via digitally enabled marketplaces. Indonesia's e-commerce sectors ranked ninth in the world, valued at USD43 billion in 2021, grew sixfold from 2018 due to Covid-19, dominated by 4.5 million active MSMEs (International Trade Administration, 2022). The five largest e-commerce in Indonesia are Shopee, Tokopedia, Bukalapak, Lazada, and Blibli, and via social commerce, such as through Facebook, Instagram, Line, and WhatsApp (McKinsey, 2018). Products listed within circular keywords (e.g. rental, sharing economy, recycling, upcycling, repair cafés, etc) and partnering with digital providers can help Indonesia quantify and accelerate circular MSMEs adoption. The database can improve MSMEs government programs and benefits.

4.3.3. Mobilize Investment: Bridging the Capital and Infrastructure Gap

"Not making a profit" ranked eighth among the biggest barriers for Indonesian businesses to adopt a circular economy. For MSMEs, these barriers include skills gaps, lack of information, and funding shortages. MSMEs benefit the most if these challenges are overcome. Indonesia, without capital investment, is evidently lagging on concrete action to attain circular economy success.

The circular/green government spending (ID11a) shows how governments allocate efforts and resources to shift business-as-usual ways of doing business. The indicator complements the GPP indicator (ID12a) further to capture the municipal and educational and incentive efforts since subsidy and tax saving may help to reduce the barrier of higher investment cost for circular business model adoption. Circular/green investment (ID11b) indicator is used as a proxy to monitor the shift of shareholders' and investors' measurement of returns. The main disadvantages of circular and sustainable business are the lack of internalizing social and environmental benefits and cost measurement (BMK, 2022). The metric reflects changing decision-making by commercial banks, stock markets, and investment firms, which have begun incorporating ESG into their investment plans, loans, and other instruments for more responsible integrated reporting, and have developed the concept of true value. These indicators aim to advance MSMEs and informal sector to compete with linear players.

4.3.4. Mitigating Open Burn

Open burn is an economical means to get rid of household waste and clear land for the cultivation of crops, and frequently employed by residents of rural areas and small-scale farmers. Efforts to address open burning in Indonesia have been hindered by several factors, including the lack of law enforcement, waste collection investment, and the involvement of vested interests. In addition to regulatory and enforcement measures, there is a growing interest in using remote sensing technologies to monitor and combat open burning. Satellite-based tools and data analysis have proven effective in tracking fire hotspots and assisting authorities in responding to outbreaks more swiftly (Potter et al., 2023).

Regulatory challenges, vested interests, and complex land tenure issues make addressing this problem a multifaceted challenge. Thus, we include the 'zero open burn' indicator (ID13) as part of the governmental and policy effort to shift the open burn practices through various ways, such as strict penalty and monitoring, agricultural and rural area waste collection and composting promotion. Community engagement and education play a vital role in changing open burning practices and reduce the reliance on open burning for land clearance.

4.3.5. Process and Policy: The Essence of Circular Economy Transition as a 'Degree', Not a Black-And-White Concept

Inducing behavioral change is, in nature, qualitative, challenging to measure accurately, and prone to subjectivity assessment, leading to low internal validity. The indicator must be designed carefully to steer private business processes socially, and ways of working and government policy could then socially steer society behaviors. The fourth category, process, and policy domain, is one of the most crucial indicators to measure the learning process and the direction of transition, as quoted from Peder Jensen from EEA and Bellagio Declaration:

> Nothing is 100% circular, and nothing is 100%. Most things are somewhere in between, so if you could start looking at different sectors of the economy and the statistics and say, things are doing circular activities. The activities have circular too, 20, 30, 40% or to the degree that is like that… But circularity by being an element of everything that we do and is something that cannot be measured in black and white.

Therefore, utilizing business sectoral code (NACE or KBLI) to measure circularity has a limitation to limit the scope of circular economy and label a business as circular versus not circular. In this case, the fourth domain attempt to 'give an early signal that something is working or is not working.'

GPP (ID12a) aims to induce green purchasing with benefits associated with conscious decisions and not limited to the environmental impact but also social, health, economic, and political benefits. Government possesses the power to set the market and technical conditions and shift direction via GPP, energy-intensive products, and ecolabeling. In Indonesia, GPP is one of the existing indicators; however, GPP only covers the six regulated product groups (BSILHK, n.d). Complementing the Eco-label, the energy is regulated under the Energy Star program for electronic products and home appliances according to the energy efficiency industry standard. To fully tap the potential of the GPP indicator, the GPP and Ecolabel must regularly update the criteria and aim for better coverage of all products. GPP and Ecolabel metrics can be monitored beyond the limitation on KBLI sectors, and the efforts must focus on the quality of the impact of policy.

Therefore, the indicator of ID11 and ID12 within the process and policy shall capture how production and consumption have been shifted after a circular policy is enacted. The coverage of GPP and Ecolabel is evidently lacking. These indicators reflect the evolution of change and the quality of the new policy rather than enforcing a target to the municipal and governing bodies.

5. CONCLUSION

Countries interpret differently and vary in their approaches to circular economy objectives and policies. In practice, circular economy policies address environmental concerns across multiple domains tackling broader environmental issues like climate change, energy efficiency, and material supply security, and promote resource efficiency in production and consumption. While environmental goals are predominant, social, and economic considerations are also significant, as outlined on The Bellagio principles and UN and OECD's framework to holistically assess the economic and environmental system.

The material flow analysis domain includes evaluating the flow of materials throughout the economy, from extraction to production, consumption, and disposal. The second domain focuses on environmental footprints, to assess progress towards decoupling resource use from environmental degradation. Circular economy could also solve multi-environmental problems, including the social dimension of sustainability. Thus, third domain evaluates the socioeconomic impacts to understand the shifting effects on society and the economy. Lastly, measuring the quality of transitions through policy, process, and behavioral change domain helps assess the effectiveness, efficiency, and coherence of circular economy efforts, policies, and strategies. First, circular or green government spending reflects the government efforts targeting circular economy adoption.

5.1. Closing Reflections

5.1.1. Quality and Reliability of Data: Measurability and Conceptual Clarity

This study underscores the importance of addressing both conceptual clarity and measurability to ensure that indicators accurately capture the complexities of the circular economy and provide meaningful insights for policy formulation and decision-making. Rating on measurability and conceptual clarity can assist Indonesia's statistical bodies to identify areas for improvement.

When an indicator lacks in both conceptual and methodological clarity, such as the case of the Marine Debris definition (ID7), it poses significant challenges in accurately defining and understanding the phenomenon under consideration. Oftentimes, the methodology and concept are clear in dedicated study and smaller system boundary, such as Carbon emissions avoided (ID5), but substantial gap exists to measure in macro, nationwide scale. While indicators like Circular MSMEs (ID9) and Zero open burn (ID13) are conceptually well-understood, yet their measurability remains low, resulting in questionable quality and reliability.

5.1.2. The Caution of Using Indirect 'Proxy' to Measure Complex System

Despite the practical, fast, and alignment with the current statistical system measurement, using indirect proxies has shortcomings by labelling circular economy as a binary concept. The 100% accurate measurement of circular economy transitions is difficult and nearly impossible — the reasons are at least twofold.

First, we use a quantitative indicator as a proxy to measure qualitative progress. Quantifying nationwide perception, culture, lifestyle, and psychology toward circularity is challenging statistically. We adopt an indirect quantifiable' proxy 'to measure change; for example, government spending and investment in circular businesses indicators may depict the efforts of a municipal to steer behavior further socially, which in turn influences purchasing behavior and educate society. These efforts converted into indicators assume a positive correlation.

Second, the main advantage to use Indonesia's KBLI or EU's NACE is the efficiency, directness, and alignment with the available data, including the stressors linked. However, this approach may limit the definition and scope of circular economy to companies solely focusing on the circular economy sectors only, which may undermine and discourage the efforts done by businesses in different industries to shift to a circular solution.

5.1.3. Indicators Can Be Anti-circular and 'Antagonist' to Other Circular Objectives

The users of these indicators will translate these metrics into monthly or yearly targets to evaluate their performance. The ultimate 'ends' of the circular economy are to achieve sustainable development by improving environmental performance, eliminating the concept of waste, and extending product lifespan — and the 'means' are through high-quality 9R implementation. However, current circular economy monitoring fails to reflect the quality of transitions and efficiency of recycling and reuse. For example, Ecolabel coverage may reflect the number of innovative technologies implementing the 5Rs to 9Rs, but not necessarily the quality and quantity of environmental footprint reduction; increasing recycling rates may reflect waste management success but is counterproductive to the goal of lifespan extension. Therefore, it must be kept in mind that the priority of the circular economy is to retain a material's value during the use phase, rather than recycling. Thus, we hope the users will not replace the means as the ends.

5.1.4. Definition Clarity, Dissemination, and Evolution

Measuring is always about creating a definition acting as a boundary between contexts. The structure of EW-MFA and the material flow indicators (ID1-ID4), the circular sectors as needed for socioeconomic impacts and business model indicators (ID8-ID10) and financing mobilization (ID11) require a rigid and clear definition and classification, but cannot be built overnight, and involve many data personnel. These definitions must be clarified and understood easily in layman's terms with a dedicated platform to publish and notice updated changes. The EU has been developing for over 15 years, yet still evolving, redefining, and clarifying definitions. Publishing transparently and publicly and incorporating the data collector's feedback can allow the government to improve the data quality. Participative and adaptive users and proactive statistical bodies are the prerequisites for a successful circular economy monitoring framework.

5.2. Limitation of Study

This study has at least two limitations. First, the study is highly dependent on access to people and data from the government. Due to the limited access, we conducted self-reported available data from government publications. Second, this study is far from perfection and seeks to utilize existing data as of 2024 to help Indonesia save time and make use of available resources without exhaustive efforts. Monitoring framework serves as a basis for action plan. Since the prior study is a knowledge gap, hopefully, this study can serve as a starting point to develop Indonesia's circular economy monitoring framework.

5.3. Future Research Direction

Future research is expected to design the applied EW-MFA methodology of Indonesia using national statistics, refine the formula listed in this study, and statistical authority where the data is derived, calibrated, and implemented. Moreover, forthcoming research is anticipated to extensively examine and establish guidelines and clarify responsibilities to mitigate overlapping, redundancy, and inconsistent data collection practices of Indonesia's data collection entities. Additionally, it will explore methods for effectively disseminating data and providing decision-making support for data operators and calibrators.

We acknowledge that the development of a statistical classification or nomenclature entails considerable and exhaustive efforts. Tolerable and small inaccuracies may deem acceptable as long as they fulfill their purposes and could reflect the prevailing progress and could guide appropriate government responses. The objective of the monitoring framework is the means to support the effective transitions of circular economy initiatives, not the ends, per se. Nevertheless, circular economy is a cross-cutting disciplines, and the development of indicators is fruitful not only for circular economy transitions, but also to track Indonesia's sustainable and national development.

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AUTHOR CONTRIBUTIONS

Yulia Ratnasari: main author and researcher

Dr. Ralf Aschemann: conceptualization, supervision and advising

DECLARATIONS

Competing interests The authors declare no competing interests.

APPENDIX

1. ANNEX 1: INFORMANTS AND DATE OF INTERVIEWS

No	Informants	Departments	Date and Time
1	Adhitya Pratama Yusuf Team: Verania Andria, Diah Ratna Pratiwi, Made Dwi Rani Dian Septarianti, Sitti Azzahra	Circular Economy, UNDP collaborating with Bappenas to develop Indonesia's circular economy masterplan	January 18, 2023 (online) April 14, 2023 (online) August 30, 2023 (in person) continued with direct message and call
2	Julie Bülow Appelqvist	Head of Environment and Water of the Embassy of Denmark in Indonesia	January 14, 2023, continued with email
3	Peder Jensen	Circular Economy and Resource Efficiency Expert, EEA and Bellagio Declaration	May 24, 2023 May 30, 2023
4	Zulfan Zul	Analyst, Ministry of Energy and Mineral Resources of the Republic of Indonesia	July 22, 2023 continued with direct message and call

Source: Researcher (2023)

2. ANNEX 2

2.1 Analysis of EU's Monitoring Indicators for the Circular Economy, Methodology, Relevance, and Potential Use for Indonesia

No	Indicators, Methodology and Calculation	Definition and Global Relevance for the Circular Economy	Relevance to EU (European Commission, 2018)	Relevance to Indonesia
Production and consumption				
EU1	EU self-sufficiency for raw materials Import Reliance (IR) = (Net Import)/(Apparent Consumption) IR = (Import – Export)/(Domestic production + Import – Export)	Raw materials are essential for the functioning of a country's economy. Reducing the risk of supply of raw materials through recycling, especially for CRM. Many industrial sectors depend on the secure supply of raw materials, particularly for various	Apart from indium and limestone (as net exporters), the EU lacks the other non-metallic mineral resources necessary for the economy to function. This risk is mainly related to geopolitical relations with several countries and supply disruptions.	Indonesian economy requires a wide variety of raw materials, semi-finished materials and final products to function; not everything is produced domestically, with a trade surplus of USD12.13 billion, mainly in palm oil, coal and gold. In addition, ferronickel is listed as one

		domestic extraction, recycling and imports. This indicator should be considered in a broader context given the potential for supply disruptions in economically sensitive areas.	For some bulk materials such as aluminum, copper or iron ore, self-sufficiency in the EU is between 15% and 40%; for some, recycling contributes between 20% and 30% of total material demand (see Indicator 7a) (European Commission, 2018).	of the CRMs. In 2019, Indonesia imported petroleum communications electrical components, petroleum and petroleum-based oils, spelled wheat, common wheat and soybean meal (WITS World Bank, 2021). Indonesia has been a net importer of rice and soybeans in the food sector, relying on rice as a staple food and soybeans as protein. Even though Indonesia is an agricultural country, it has witnessed high volatility in the prices of agricultural products, which affect Indonesian society, economy and politics (WITS World Bank, 2021).
EU2*	Green Public Procurement = The total share (%) of public tenders and procurement procedures above the EU thresholds EU minimum criteria: the documents incorporated technical specification, targeted actions, and performance conditions to reduce environmental impact; as well as compulsory reporting to monitor compliance. However, concept of 'green procurement' is a complex, multi-interpretative, and multi-faceted issue and to find an accurate legal or environmental definition may not be possible among all authorities; which could lead to overly positive GPP tenders value.	Promoting SDG 12.7 by incorporating environmental and Rs (especially repairability, recyclability, and durability) standards in public contracts will further enhance the circular economy across all sectors and in both production and consumption. GPP incorporates large shares of consumption which can drive circular economy by ensuring consumer to receive trustworthy and relevant informations on the market, and EU further protect customers from greenwashing and premature obsolescence (European Commission, 2020). Monitor and encourage institutions, companies and public to carry out the GPP to produce environmentally friendly goods and services to reach balance between cost considerations,	Public procurement accounts for EUR1.8 trillion (14% of EU GDP) around 150,000 procurement procedures annually. GPP is a voluntary instrument in Europe, and EC currently propose minimum mandatory criteria for environment standards (European Commission, 2020). Further instrument, Ecodesign and Energy Labelling Working Plan 2020-2024, which is not monitored under circular economy framework: - Ecodesign Directive: manages to regulate energy efficiency and several circular features of energy-related products. - Eco labeling: EU have been awarding 87,485 products, 2,270	To promote National Medium-Term Development Plan, the indicator has been evaluated since 2019 under Ministerial Regulation No. 5 or the Procedure for Application of Eco-friendly Labels for Green Public Procurement. In 2019, Green Industry through green productivity model has been implemented attempting on the standardization of communicating environmental impacts in Indonesia through 15 products category for Eco-Label and six product classes for GPP. Data availability: yes In 2020, GPP registered in Indonesia was six products (BPS, 2020).

		environmental performance, market availability..	company licenses since 1992 for environmental excellence currently dealing with 24 products (EU Ecolabel, 2022). The majority of products are awarded in Spain (21%), Italy (14%), Germany (12%) and France (11%) (EU Ecolabel, 2022).	
	Waste generation	Waste generation is a central theme in the circular economy and is a macroeconomic indicator, but can be narrowed down to municipal waste, waste generation based on economic activity, enterprise level, waste stream or product category.		
EU3a	Generation of municipal waste per capita (kg per capita) = Total amount of municipal waste collected/total municipal population It consists primarily of household waste, but can also include waste from sources such as businesses, offices and public institutions origins.	In circular economy, waste generation must be minimized. The municipal waste generated includes waste collected by or on behalf of municipalities and disposed of through waste management systems. Its evolution provides insight into citizen engagement, the effectiveness of waste prevention measures, and behavior and consumption patterns.	Municipal waste fell from 255 million tonnes to 245 million tonnes between 2005-2016, accounts for 10% of the total weight of waste generated in 2015 (European Commission, 2018). Each EU citizen generated an annual average of 480 kg of municipal solid waste in 2016 (down from 6.8% in 2005 to 515 kg), which varies widely between countries: 762 kg/capita in Denmark compared to 247 kg/capita in Romania.	An accurate estimation of waste generation is necessary to monitor and manage waste across the 38 provinces. Hitherto, there's an overlapped waste generation data published by Indonesian authorities, and the result uses different unit (volume and mass). Waste generation data is a huge challenge since open burn and water disposal are still in practice. The estimates done World Bank, Deltares, Royal Haskoning DHV, and Coordinating Ministry for Maritime Affairs and Investment (2021) estimates 42.123 million tonnes annually (160 kg/capita) assessed from five big cities. While UNDP (2017) has higher estimates of 64 million tonnes per year (0.70 kg/day/capita).

EU3b	Generation of waste, excluding significant mineral waste per GDP unit (kg per 1000 EUR) = All waste generated in a country excluding major mineral wastes/GDP	Comparing the waste generated to GDP reflects the waste intensity of an economy and provides a measure of "eco-efficiency". Disposal of large amounts of mineral waste is required for the disposal of heavy materials from C&D and mining activities. It is important to note that the head-to-head comparison are still challenging due to: different waste classification, purchasing power are not fully reflected in exchange rates, and GDP is based on material-intensive industry vs service industry nations; making compatibility even more difficult.	In 2014, the EU produced 66 kg of waste per thousand units of GDP, which accounted for 30% of total waste generated, excluding mineral waste. From 2006 to 2014, the amount of waste generated per unit of EU GDP decreased by 11%, indicating an improvement in the eco-efficiency of economic activities (European Commission, 2018). Across member countries, there is significant gap: six countries produce less than 50 kg of waste per euro of GDP, whereas Estonia and a few others produce over 400 kg, mainly due to their reliance on oil shale for energy production (European Commission, 2018).	For mining, it is relevant and quite measurable. Measuring indicator EU3a and EU3b are both relevant; however, C&D data of Indonesia is a challenging data gap, since C&D generally are reused and downcycled in-situ and nearby the area without entering the municipal waste management facility where the data is being collected.
EU3c	Generation of waste, excluding significant mineral waste per domestic material consumption unit (%) = All waste generated in a country excluding major mineral wastes / DMC The DMC does not include upstream "hidden" traffic associated with the import and export of raw materials and products.	Also known as 'material efficiency metric' that compares the amount of waste generated to the DMC; showing how many kg per DMC become waste. A significant advantage of this indicator is the high comparability across countries, which is less affected by differences in the structure of economic production, especially for service nations.	In 2014, the EU generated an average of 0.13 kg of waste per kg of DMC (excluding essential mineral wastes), meaning that 13% of domestic material consumption ended up as waste. Waste generation per DMC in the EU increased by 11% between 2006 and 2014, due to a decrease in waste production by 8%, and DMC decreased at higher rate by 19%.This indicator shows large gap between Member States: range from less than 5% in Romania and Latvia to 25% in the Netherlands and Italy, reaching 34% in Estonia (due to the use of oil shale for energy production).	Relevant, by incorporating UNEP IRP (2019) data on DMC, and major waste allowing comparability among countries.

EU4*	Food waste (million tonnes) = Total annual volume of food waste generated across the food value chain (from agriculture, processing and manufacturing, shops, restaurants and canteens, and households). New reporting obligations for Member States (in the Commission's proposal to revise the Waste Framework Guidelines - Article 9.3).	Reduce Sustainable Development Goal 12.3: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food loss in production and supply chains, including post-harvest losses". Food waste is related to pressure on limited natural resources, the environment and climate change.	Based on EU Action Plan for Sustainable Food Systems Food waste is a significant problem in Europe, estimated at around 20% of all food production. The food waste in the EU reached 81 million tonnes in 2012 (with an underlying financial cost, estimated at EUR143 billion in the EU in 2012), and the total food waste was 76 million tonnes in 2014, representing a 7% reduction from 161 kg to 149 kg per capita annnually (European Commission, 2018).	Food and organic waste is a serious problem in Indonesia, UNDP (2017) estimated to be 38.4 million tonnes per year (60% of total MSW) or at around 0.14kg per capita annually (Bappenas & UNDP, 2021). Despite the small amount of waste in comparison to other nations, the organic waste has an untapped potential for biogas, composting, and livestock feed which can promote society welfare once utilized.
Waste Management				
EU5	Recycling rates			
EU5a	The recycling rate of municipal waste (%) = Total recycled municipal waste/Total amount of municipal waste generated Waste recycled excludes energy recovery and backfilling. Countries measure recycling in different ways, such as waste collected instead of generated, and before or after sorting, which has large implications for accuracy and comparability.	With a focus on waste management in urban areas, the objective is to track advancements towards achieving SDG11, which aims to create inclusive, safe, resilient, and sustainable cities and human settlements. SDG11 seeks to enhance urban areas and other human settlements to ensure equitable access to essential services, energy, housing, transportation, green spaces, and more, while concurrently optimizing resource utilization and minimizing environmental harm. SDG Indicator 11.6.1 measures the proportion of urban solid waste that is consistently collected and disposed of appropriately relative to the total waste generated within cities.	Represents approximately 10% by weight of the total waste generated in the EU (30%, excluding important mineral waste) (European Commission, 2018). During the period 1995-2016, the recycling rate of municipal waste in the EU continued to increase, reaching 45.6% of the total amount processed (equivalent to 140 kg per capita) (European Commission, 2018). Recycling rates in EU cities have been higher than landfill and incineration rates since 2014. In 2016, only Germany met its recycling target, followed by Slovenia and Austria. Malta,	A successful shift toward a circular economy has the potential to diminish the generation of waste at its origin and elevate rates of waste recycling. It is projected that the adoption of a circular economy could lead to a 50% reduction in Indonesia's waste by 2030 compared to a business-as-usual (BAU) scenario, while simultaneously boosting recovery rates by 4-17% relative to BAU projections (Bappenas & UNDP, 2021). Data: the current recycling rate use local data, local proxy (Vietnam and Malaysia), and international proxy.

			Romania, Greece and Cyprus have recycling rates of less than 20% (European Commission, 2018).	SISPN collects data empirically but not yet cover the whole Indonesia.
EU5b	The recycling rate of all waste, excluding significant mineral waste (%) = RVR /TRT Recycling of Various Residue (RVR) = all waste disposed and treated of in a country excluding from mining and C&D Total Recycling Treated (TRT) = waste collected in domestic plants + waste sent out of the country for recycling - (waste imported and treated in domestic recycling plants)	Indicates the level to which essential waste materials are reintegrated into the economic cycle. It introduces a production component alongside the final consumption stage, as seen in municipal waste recycling, and encompasses the recycling patterns of generated waste. Indicator EU5b differs from EU5a by modifying the denominator to account for trade.	The EU recycling rate for waste (excluding major mineral waste) was 55% in 2014, and was 53% in 2010 (European Commission, 2018). Recycling rates vary greatly among member nations: some countries have rates exceeding 70%, such as Belgium at 78%, Slovenia at 75%, and the Netherlands at 72%, while others, like Estonia, Bulgaria, and Greece, have rates below 20%.	Relevant to compare all waste, excluding heavy materials arises from C&D and mining; complementing the comparison for indicator EU5a. Furthermore, Indonesia imports waste which may enter the NAS, or domestic recycling plant or marine bodies.
EU6	Recycling or recovery for specific waste streams, excludes export and include import	One of the core pillars of the circular economy is maximizing material value, including cascading use and multiple cycles of reuse; while minimizing losses by feeding materials back to the economy and avoiding sending waste to landfill or incineration.		
6a	The recycling rate of overall packaging waste (%) = Total packaging waste / Total packaging material throughout the supply chain Most cases Member States assume that the waste generated equals the amount of packaging marketed in that country in a given year, which may bubble the recycling rates.	Packaging waste defined as 'containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer, excluding production residues'. Packaging waste includes all packaging material waste from raw materials to processed products, from producers to users or consumers, excluding production residue.	Packaging constitutes 9.3% of the total waste generated and typically consists of mono-materials suitable for recycling (European Commission, 2018). Between 2009 and 2020, "paper and cardboard" emerged as the primary packaging waste in the EU, totaling 32.7 million tons in 2020, followed by plastic and glass (Eurostat, 2022a). In 2015, EU recycled 65.7% of all packaging waste, showed more than 10% increase from 2008 (54.6%) (European Commission, 2018). Member States with recycling rates surpassing 70% include Belgium (81.5%), Czech Republic (74.3%), Netherlands, and	Currently, circular focus in the five focus sector of Indonesia only limited to plastic packaging. The data of packaging is not available. SIPSN collects waste data based on compositions; while for functional use (in this case, packaging), is unmonitored.

			Sweden (both nearing 72%) (European Commission, 2018). Packaging recycling target: 55% (2008) and the proposed 65% (2025) and 70% (2030)	
EU6b	The recycling rate of plastic packaging waste (%) = Total plastic packaging waste recycled /Total plastic packaging The recycling rate for plastic packaging waste only considers the material that is recycled and used back specifically for plastic production.	A large amount of plastic, including packaging, also ends up in the ocean and is a major contributor to marine debris.	Around 60% of plastic waste in the EU is attributed to plastic packaging (European Commission, 2018). In 2020, the average person in the EU generated 34.6 kg of plastic packaging waste, but only 13.0 kg of it was recycled (Eurostat, 2022a). Between 2005 and 2015, plastic packaging waste generated in the EU increased by nearly 12% to reach 15.8 million tons, with one-third of it ending up in landfills. As of 2022, the total recycling rate for plastic packaging waste across the EU stands at 38%. Regarding targets, all Member States except France (21.4%) and Malta (10.2%) met the 22.5% target for recycling plastic packaging waste by 2020 (Eurostat, 2022a). The target for 2025 is set at 55%.	Under BAU scenario, plastic packaging waste is projected to increase by 2.2 million tonnes by 2030, representing a 40% growth with a compound annual growth rate (CAGR) of 3.1%, driven by an additional 90 million individuals entering the middle class and 35 million people migrating to urban areas (Bappenas & UNDP, 2021). In 2019, the total amount of plastic packaging waste was 5.4 million tons. Only 0.6 million tons (12%) of this waste was recycled, while 0.5 million tons (0.5%) found its way into water bodies, and 3.3 million tons (62%, with 78% of this openly burnt) was mismanaged (World Economic Forum, 2019 as cited in Bappenas & UNDP, 2021). It's estimated that 10% of global marine plastic leakage originates from Indonesia (Jambeck et al., 2015). A circular solution could potentially reduce and recycle 2.7 million tonnes (36%) of total packaging waste (Bappenas & UNDP, 2021). The target and legal framework for addressing this issue are outlined in

				Presidential Decree No. 83/2018, which aims to decrease plastic waste by 70% by the year 2025.
EU6c	The recycling rate of wooden packaging (%) = (Total recycling + repair of wooden packaging waste) / (generation + repair of wooden packaging waste)	For wood packaging, reuse and repair are often the right solution. When reuse is no longer feasible, recycling emerges as the most feasible option to promote the principles of the circular economy.	Recycling rates of wooden packaging have been increase from 36.5% to 39.8% between 2005 and 2015 in EU. The data shows that some Member States are not progressing, especially in countries where this waste is subject to energy recovery. Target: EU-wide 2030 target of 75% for reuse and recycling	Beyond the scope of the packaging priority of Indonesia circularity strategy. Wood is more addressed for sustainable alternatives for construction sector (8.7 million tons in 2019).
EU6d	The recycling rate of electrical and electronic waste (e-waste) (%) = Collection rate * Reuse and recycling rate Where specified in the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU: - Collection rate = Total WEEE collected in the reference year / average number of electrical and electronic equipment (EEE) placed on the market in the past three years - Reuse and recycling rate = Total weight of the WEEE entering the recovery to reuse facility / Total weight of all the WEEE collected separately	EEE includes items such as used computers, televisions, refrigerators and cell phones, is one of the fastest growing waste streams globally. Although recycling of WEEE may be insignificant in terms of weight compared to biomass and C&D and poses a risk to the environment (hazardous components), it contains untapped potential for recovering valuable raw materials, and estimated 60 of the 118 chemical elements on the periodic table are found in complex electronics, which potentially are recyclable (Eurostat, 2022b). Can be downscaled to meso-level indicator: WEEE can vary widely in the complexity of material composition in different product classification	In 2012 the European Union produced 7.6 million tonnes WEEE and evolved to reach peak of 12.4 million tonnes in 2020 (grew by 62.2%). The EU WEEE recycling rate increased from 28.8% in 2012 to 32.2% in 2014. In 2020, 4.7 million tonnes were collected; with recovered WEEE is 4.3 million tonnes and the recycled and prepared for reuse was 3.9 tonnes in 2020 (grew by +57.8%, 65.1% and 61.7% since 2012, respectively) (Eurostat, 2022b). Primary raw materials like gallium, germanium, indium, and dysprosium are predominantly utilized in EEE. The collection, reuse and recycling rates of WEEE vary widely across member countries, indicating the potential for greater resource efficiency.	The annual value of WEEE in Indonesia was close to IDR26 trillion (USD1.8 billion) in 2019 (11% of the GDP contribution from EEE). Indonesia has high import dependence for machinery and computers and electronic equipment (25% of Indonesia's imports), and potentially, Indonesia can reduce WEEE by 13% and recycle 16% of the remaining WEEE by 2030 (Bappenas & UNDP, 2021). In Indonesia, around 90% of WEEE is processed informally by people working in the informal sector, who face the greatest health risks from potentially dangerous lead, cadmium, mercury and beryllium if incinerated or recycled improperly (Bappenas & UNDP, 2021).The standardized formalization and recycling sector will generate greater

			Malta is on one side of the scale with 11.5% recycling rate, while Bulgaria is the best performing member country with 96.5% in 2015.	economic, social and environmental benefits. Data: WEEE estimated from Mairizal et al. (forthcoming) as cited in Bappenas & UNDP (2021)
EU6e	Recycling of biowaste per capita (Kg per capita) = Composted and digested municipal waste / Total population Note that comparability may be weakened because most countries only count separately collected waste as recycled compost; and others may include organic matter obtained by mechanical biological treatment.	Biotic resources must be returned to the economy or the natural environment in a profitable manner, in form of livestock feed, fertilizer, and biogas. However, some of biowaste fraction ends in mixed municipal waste with other waste and landfilled, making a significant contribution to climate change.	Biowaste composting or anaerobic digestion contributes around 17% of total municipal solid waste recycled (in mass). In 2016, every EU citizen recycled an average of 79 kg of municipal biowaste, an increase of more than 23% compared to 2007. Biowaste recycling per capita varies between member states, with some under 10kg per capita (Malta) and over 120kg per capita (Austria). Furthermore, Phosphorous and Phosphate rocks have been listed as CRM since 2017 (RMIS, 2022), and separation technology to generate biowaste free from impurities is necessary to obtain a high-quality compost that is environmentally safe for use for agriculture (RMIS, 2022).	Food waste represents 44% of the total waste, amounted for 29.5 million tonnes in 2019 (Bappenas & UNDP, 2021). The biowaste in Indonesia prioritize 2Rs of reduce throughout the supply chain (post-harvest, loss, and consumer waste) and recycle (energy, composting, and nutrient extraction). Data: Ministry of Environment & Forestry (2020) and WRI (2019).
EU6f	The recovery rate of construction and demolition waste (%) = C&D waste that is ready for reuse, recycling, or material recovery (including through backfill operations) / C&D waste treated and collected. The recovery rate includes backfilling since backfill (energy recovery and	Most of the materials contained in C&D waste can be easily recovered; thus, these waste streams are a valuable source of secondary raw materials, particularly in in-situ recycling. Fundamental to returning these materials to the economy and retaining their value as much as possible is the design of building materials and	Construction and demolition is Europe's largest source of waste: in 2014, construction accounted for 33.5% (871 million tons) of total waste in EU-28 (European Commission, 2018). In 2014, the EU recovered approximately 88% of its C&D waste, a significant increase of 10% since 2010 (European Commission, 2018).	C&D waste is estimated to reach 29 million tons in 2019 and 52.8 million tons in 2030. By optimizing the use and design of buildings and building more resource-efficient buildings (Bappenas & UNDP, 2021). The circular opportunity can reduce emissions by 44.8 million tons of CO_2e and save 300 million meters

	landfill) is lower hierarchy than recycling. The recycling rate excludes backfill.	structures, the selective demolition of structures, allowing the segregation of recyclable parts and hazardous materials, and a quality assurance program in recycled C&D materials.	Only seven member countries had not met the mandatory recovery target (70% by 2020) of the Waste Framework Directive. There are major differences between member countries, with 11 member countries having a share of more than 95% and 2 member countries having a share of less than 40% in 2014.	cubic water relative to BAU in 2030 (Bappenas & UNDP, 2021). Data: not available, which is a major data gap due to the reuse and recycling in-situ and surrounding area. Current data: C&D uses Vietnam data as proxy adjusted with Gross Value Added (GVA) to construction sector with 5.6% estimated growth.
Secondary raw materials:				
EU7	Contribution of recycled materials to raw materials demand	Unlike indicators that focus on the collection or recycling rates of specific waste streams (EU6), this indicator measures the contribution of recycling to material demand for each material type. Method: Material System Analysis (MSA), the key materials are tracked in detailed flow.		
EU7a	End-of-life recycling input rates, EOL-RIR (%) = Total secondary material production / (Total primary material production + Total material import + Total secondary material production) Total secondary material production = Total production of secondary material from post-consumer functional recycling in EU sent to processing in EU+ sent to manufacturing in EU Total primary material production = Production of primary material as main product + as byproduct in EU sent to processing in EU	End-of-life recycling input rate' (EOL-RIR) measures how much of the total material fed into a production system comes from recycling, showing the efficiency, quality, and effort of waste collection and recycling reintroduced as new raw material. Recycling serves as a significant reservoir of secondary raw materials, aiding in ensuring supply stability and facilitating the shift towards a circular economy; and also economically advantageous. However, for most materials and almost all critical raw materials, recycled materials make a small to negligible contribution and not feasible to meet the growing demand, especially for materials for low carbon technologies, batteries or electrical or electronic equipment.	EOL-RIR is available for the share of secondary raw materials in total demand is more than 50% for only handful of raw materials. For lead (75%), mainly because there is a strictly regulated closed-loop recycling system for lead batteries (European Commission, 2018). The high rates on copper and silver can be explained by the high intrinsic economic value of these materials (European Commission, 2018). For many bulk materials, such as certain metals, secondary raw materials account for 30% to 40% of the total material demand (European Commission, 2018). While many of these materials have EOL-RIR in excess of 50%, primarily	Relevant if Indonesia put a particular interest in specific materials, such as in this case the five focus sectors or CRM. Indonesia also imports recyclable waste and do not possess handful of CRM; making EOL-RIR necessary to measure and be linked with the trade statistics.

	Total Imports to EU = Import of (primary material + secondary material + processed material) EOL-RIR only considers 'old waste', i.e. at the end of their useful life, and exclude waste from the manufacturing process ('new scrap' and 'process scrap'), used in closed-loop industrial symbiosis.	EOL-RIR is determined by several factors: increasing demand for raw materials, amount of recycled materials and life span of materials. Attempt to prolong lifespan could reduce the EOL-RIR, which could contradict to retaining value philosophy.	because they are used in sufficient quantities in easily recyclable applications such as automotive steel, their end-of-life recycling input rates are much lower due to the need for these materials (European Commission, 2018). The EOL-RIR for Beryllium, Dysprosium, Erbium, Gallium, Indium, Lithium, Natural rubber, Niobium, and Silicon are less than 1%, indicating that the demand is higher than what recycling can provide (European Commission, 2018).	
EU7b	Circular material use rate (%) (DMC + U): CMU = U / (DMC + U) (DMC + U) measures the ratio of the amount of secondary raw materials (U) to the overall material consumption demand (DMC) U = Total recycled waste = waste processed by domestic recycling plants - imported waste for recycling + export waste for recycling abroad	The CMU level represents the the ratio between closed loops and material reused in the economy, shown in the MFA Sankey diagram. A higher ratio means more secondary recycled material in the economy relative to overall material use. Substitution of primary raw materials with secondary raw materials reduce waste generation, and limit the extraction of virgin raw materials, which are the theme of circular economy. The CMU Indicator complements EOL-RIR (EU7a) which focuses on a specific raw material, especially CRM. Meanwhile, (CMU +U) measures the overall use of secondary raw materials in the economy with four important categories of materials aligned with MFA (biomass, metal, fossil-fuel, and non-metallic minerals).	Recycled materials were estimated to account for 11.4% of EU material demand in 2014, with a steady increase since 2004 due to rising material consumption while the amount of waste recycled was stable (European Commission, 2018). Between 2010 and 2014, CMU levels increased, especially for non-metallic minerals, from 13.9% to 15.2%, and for fossil energy materials, from a much lower baseline of 2.1% to 2.5% (European Commission, 2018). The very important metal ore category showed some volatility, increasing from 28.0% in 2010, to 30.4% in 2012; then declined to 28.4% in 2014, but overall, the trend is positive. For the biomass category, the CMU decreased from 8.9% to 8.1% from 2010 to 2014 (European Commission, 2018).	Highly relevant, as part of the ew-MFA circularity within Indonesia economy. The details on MFA important categories must be displayed on the MFA Sankey Diagram; as a flow from 'waste' to DMC account.

			The value suggested by Member States ranges between: Netherlands (26.7%), Italy (18.5%) and France (17.8%) as the top ranks; while Greece (1.4%), Romania (1.7%) and Ireland (1.9%) had the lowest rates (European Commission, 2018).	
EU8	Trade in recyclable raw materials: total mass of waste and by-products transported within, and across internal and external EU borders.	This metric precisely outlines the trade patterns of various waste streams that are capable of being recycled into secondary raw materials. The movement of waste is governed by the Basel Convention on the control of transboundary hazardous waste movement and disposal, which was enforced in 1992. This metric exclusively encompasses the lawful exportation of used goods.	An active domestic market and efficient utilization of the EU's recycling capabilities can support the effective generation of secondary raw materials. Consequently, monitoring the origin, trajectory, and transfer of these secondary raw materials within European borders, including their utilization within EU industries, imports, exports, and intra-EU trade, can provide a precise insight necessary for waste management and recovery efforts. Legislation: Regulation (EC) No 1013/2006 (the Waste Shipment Regulation – WSR)	Relevant since Indonesia allows waste trade, as regulated on Law on Waste Management, Law on Environmental Protection and Management, and Regulation of the Minister of Trade of the Republic of Indonesia (Permendagri) UU no 25/2022 (BPK, 2018) for paper, logam, plastic, rubber, glass, and textile as long as it is non-hazardous, and not from landfill, and from a valid exporter and importer.
EU8a	Imports from non-EU countries (tonnes) = Total mass of waste and by-products imported across internal and external EU borders	Import on recyclable waste materials can enhance the input for nation’s recycling when domestic urban mining is inadequate. Further, recycling can support multilateral, regional and bilateral between nations, especially when the import partners do not have sufficient recycling technology and capacity.	In 2020, imports of recycled raw materials from non-EU sources rose slightly to reach 44.7 million tons, marking a 7% uptick since 2004. The primary import partners include Brazil (8.6 million tonnes), Argentina (7.3 million tonnes), and Russia (4.7 million tonnes) (Eurostat, 2021a).	Relevant since Indonesia allows waste import from worldwide: Indonesia allowing 57 industry recyclable waste types from WEEE, biowaste, liquid, polymer, mining, pharmaceutical, sludge, cleaning agent, oil, wood-based, chemical, C&D to gas. (BPK, n.d)

EU8b	Exports to non-EU countries (tonnes) = Total mass of waste and by-products exported across internal and external EU borders	Exporting recyclable waste is economically viable if the secondary market value worth less domestically. There is ample evidence that large amounts of waste are being exported illegally; which an accurate picture of this indicator is challenging since illegal waste shipments are not tracked in the official reporting system, especially end-of-life vehicles or WEEE.	In 2020, exports of recyclable raw materials from the EU to non-EU destinations totaled 38.4 million tonnes, marking a 70% surge compared to 2004. Turkey emerged as the top exporter with 14.4 million tonnes, followed by the UK with 4.6 million tonnes, and India with 2.9 million tonnes. Indonesia ranked fifth among the larger exporters of recyclable raw materials from the EU, shipping 1.4 million tonnes (Eurostat, 2021a).	Legally, Indonesia have been importing recyclable waste, amplified after China limit its recyclable waste import in 2017, which before imported 50% of total global plastic and paper waste. In 2018, Indonesia imported 320,000 tons of waste from 42 nations, doubled from 2017 (Dermawan, 2020). Indonesia has been the desitnation of illegal waste, which in this case is undocumented.
EU8c	Intra-EU trade (tonnes) = Total mass of waste and by-products exported between EU borders	Specialization among nations to recycle waste is economically and diplomatically useful to achieve synergy and economies of scale.	The trade within EU increased sixfold since 2004 to 0.12 million tons in 2016 (Eurostat, 2021a). The trade in plastic waste is the only one where exports to non-EU countries were consistently higher than intra-EU trade in the period 2004-2016.	
Competitiveness and innovation				
EU9	Private investments, jobs, and gross value added related to circular economy sectors (in million EUR)	Looking at employment and growth in the relevant sectors shows whether the transition to a circular economy is producing the desired results. Industries closely linked to the circular economy, such as recycling, repair and reuse, are highly labor intensive and contribute to local employment.	In 2014, private investment in the circular economy sector within the EU was approximated at about EUR15 billion, equivalent to 0.1% of GDP, showcasing a 3% rise from 2013 (European Commission, 2018). The proportion of private investment allocated to the circular economy sector displays considerable variability among members, spanning from 0.04% in Greece to 0.27% in Latvia, with Estonia (0.25%) and Slovakia (0.21%) following closely (European Commission, 2018).	The transitions from linear economy requires investment mobilizations towards circular business model and solutions. As mentioned conscientiously in the UNDP and Bappenas (2021) impact assessment, jobs, GVA, and investments are the economic opportunities and enabler to tap circular economy potential.

EU9a	Gross investment in tangible goods (% of GDP at current prices) = Total investment in tangible goods in the recycling, repair and reuse sector / GDP Tangible goods is defined as new and existing tangible capital goods, whether purchased from third parties or produced for own use (i.e. capitalized production of tangible capital goods) with a useful life of more than one year, including leasing and reuse; while exclude unmanufactured tangible goods such as land and financial assets.	Lack of funding and financial incentives are main company's challenge to adopt circular opportunities, and to compete with the well established infrastructure and BAU, linear economy firms. Significant investment is needed for economy transition, fill infrastructure gaps, and create business models that can unlock circular economy opportunities.	In 2014, private investment in the circular economy was estimated at around EUR15 billion (0.1% of GDP) with an increase of 3% over 2013 (European Commission, 2018). The share of private investment in the circular economy sector varies significantly across member states, ranging from 0.04% (Greece) to 0.27% (Latvia). Seven member states (Belgium, Croatia, United Kingdom, Bulgaria, Poland, Slovenia and Romania) have high shares between 0.15% and 0.20%. The Member States with the largest increases in private investment in the circular economy over the period 2008-2015 were Hungary (+40%), France (+33%) and Germany (+26%) (European Commission, 2018).	Relevant to capture and enable circular opportunities and business models, requiring estimated IDR308 trillion (USD21.6 billion) annually across the five focus sectors. The biggest share, around 50% for construction is needed to develop energy-efficient and distribution infrastructures (Bappenas & UNDP, 2021). The key is to create value to investors especially on circular models and its returns beyond profitability. Supply chain models, green bonds, sustainability-linked loans, impact investing, and blended finance are the key innovative financing approach which could support and unlock circular economy, especially for MSMEs.
EU9b	Number of persons employed (% of total employment) = Total employment in the recycling sector; and repair and reuse sector / Total employment Employment is defined as the total number of people working within the observed unit, i.e. the firm (including owners, partners who regularly work and unpaid family workers), as well as including those working outside the unit and paid by them (e.g. sales representatives, delivery personnel, repair and maintenance teams). This does not include human resources provided to the unit by other	Circularity is expected to have a positive impact on job creation if workers acquire the skills needed for a green transition (European Commission, 2020). Circular jobs could further improve competitiveness, especially in technological innovations dimension.	Nearly 4.0 million people (1.7% of all employment) were employed in the circular economy sector in the EU in between 2012 and 2018 (European Commission, 2020b). Despite the financial and economic crisis, employment in the circular economy increased in most member states in both absolute and relative terms during the period 2008-2015 (European Commission, 2020b). Between 2020 and 2030, potential job creation will be 700,000 new jobs (European Commission, 2020b). Lithuania and Latvia have	Highly relevant, and women inclusion is also a key priority within circular job indicator for the five focus sectors. Bappenas and UNDP aim to monitor the green jobs creation benefit from the circular economy, and Indonesia potentially create 4.4 million green jobs from circular economy implementation by 2030. For instance, circular construction sector could create 1.6 million net jobs (90% could be for women) by 2030 (Bappenas & UNDP, 2021). Due to the potential socioeconomic risks and job losses in the transition,

	companies, and personnel currently serving in the military.		the highest circular job achievement, with more than 2.5% of total economy employment. In absolute terms, however, Germany has the highest number of people working in the circular economy (over 616,000), followed by Italy and the UK (around 500,000 each) (European Commission, 2018).	Indonesia will prepare Industry Transformation Maps (ITMs), including occupations, and reskilling options, educating businesses to invest in training programs (Bappenas & UNDP, 2021).
EU9c	Value added at factor cost (% of GDP at current prices) = (Sum of increase amount of turnover + capitalized production + other operating income + decreases of stocks) - (purchases of goods and services + other taxes on products related to turnover but not deductible + duties and taxes related to production) / GDP. Value adjustments (such as depreciation) are not deducted.	Value added to factor costs is gross income from operating activities adjusted for operating subsidies and indirect taxes. The gross value added (% of GDP) expresses gross value added as a percentage of GDP to facilitate comparisons among countries.	In 2014, the gross value added generated by the circular economy sector in the EU amounted to approximately EUR141 billion, equivalent to around 1% of the total EU GDP. It is projected that there will be a 0.5% increase in GDP attributable to the circular economy sector between 2020 and 2030 (European Commission, 2020b). From 2008 to 2015, there was a notable growth in the gross value added of the circular economy sector, with a 46% increase in the UK and nearly 30% in Austria. Slovenia witnessed the highest rise in gross value added (as a percentage of GDP) within the circular economy sector, exceeding 19%, followed by Finland, Austria, and the United Kingdom, exceeding 10%.	HIghly relevant: Indonesia is in urgent needs to recreate and rethink circular value to generate economic growth by maintaining the value of resources in economy as long as possible and reducing social and environmental impacts and risks. Bappenas & UNDP (2021) estimated additional IDR593 trillion to 638 trillion economy wide GDP will be generated, and the direct GDP impact from the five focus sectors will vary from -IDR1,563 trillion to 312 trillion IDR by 2030.
EU10	Number of patents related to recycling and secondary raw materials = Total patented innovation relating to recycling and secondary raw materials treatment using the	The term "patent" encompasses a collection of legally recognized documents concerning various inventions, including applications	In the EU, the number of patents related to recycling and secondary raw materials increased from 270 to 364 (+35%) between years 2000	Somewhat relevant to encourage innovation and competitiveness. Patents application and approval concerning recycling technologies can be traced monthly under

	relevant codes from the Cooperative Patent Classification This does not encompass all industry technologies associated with waste management, waste services and business models.	submitted by different entities, thus preventing duplication in counting. Patent statistics serve as indicators for evaluating technological advancement and innovation. Innovation is crucial for enhancing competitiveness and facilitating the transition to a circular economy. This involves the development of innovative technologies for waste management and recycling, as well as the introduction of new technologies, processes, services, and circular business models.	and 2013 (European Commission, 2018). The Member States performance varied between 8.3% and 10.4%, with the highest number of patents per million population in 2013 was Luxembourg, followed by Finland, Latvia, Denmark, Belgium, Austria and Germany (European Commission, 2018).	Directorate General of Intellectual Property of Indonesia (DGIP). Legal basis: Patent Law 13/2016

Source: own compilation

2.2 Synthesis of Existing Circular Economy Indicators of China and Japan

The structured overview of various circular economy indicators adopted by China and Japan are outlined in the table below, including their key metrics, data sources, and the methodologies involved in their calculation.

Country / Member States and references	Domain	Sub-domain	Indicators
China's Evaluation Index System for the Development of Circular Economy (2017 Edition)	**Comprehensive indicators (2)**	**CN1. Resource prodoductivity**	Resource productivity (yuan/ton) = GDP (100 million yuan, constant price) ÷ DMC (100 million tons) Physical consumption of main resources = fossil energy + iron and steel resources + non-ferrous metal resources + non-metal resources + biomass resources.
		CN2. Recycling rate of main wastes	*Recycling rate of main waste (%) = comprehensive utilization rate of crop straw (%) × 1/5 + comprehensive utilization rate of general industrial solid waste (%) × 1/5 + recovery rate of main renewable resources (%) × 1/5 + urban buildings Waste resource treatment rate (%) × 1/5 + Urban kitchen waste resource treatment rate (%) × 1/5* Recycling rate of agricultural waste Recycling rate of industrial waste Recycling rate of urban construction waste Recycling rate of urban food waste
	Work Indicator (11)	**CN3. Productivity of resources**	Energy productivity (10,000 yuan/ton of standard coal) = GDP (100 million yuan, constant price) ÷ energy consumption (10,000 tons of standard coal) Water productivity (yuan/ton) = GDP (100 million yuan, constant price) ÷ total water consumption (100 million tons) Construction land productivity (10,000 yuan/ha) = GDP (100 million yuan, constant price) ÷ construction land area (10,000 hectares)

		CN4. Resource recycling and reuse (or comprehensive utilization)	Comprehensive utilization rate of straw stalk (%) = Weight ÷ total weight of straw produced × 100% Comprehensive utilization rate of industrial solid waste = Comprehensive utilization of industrial solid waste ÷ (production of industrial solid waste in the current year + comprehensive utilization of storage in previous years) × 100% Reuse rate of industrial water = Reused water consumption of industrial enterprises above designated size ÷ (Reused water consumption of industrial enterprises above designated size + new water consumption) × 100% Recycling rate of renewable resources (%) = recovery of various types of renewable resources ÷ production of various types of renewable resources (the weight is 1/7) × 100% Utilization rate of kitchen waste (%) = total food waste resource treatment ÷ kitchen waste generation x 100% The amount of kitchen waste generated can be estimated by the resident population of the urban built-up area × 0.14 kg/day. Utilization rate of building material waste (%) = construction waste recycling amount ÷ total construction waste generation × 100% The amount of construction waste generated can be expressed by the statistics generated at the source or the amount of construction waste removed and transported; or by estimation. Utilization rate of urban water (%) = urban recycled water utilization amount ÷ urban sewage treatment amount × 100%
	Reference indicator (4)	**CN5. Resource recycling industry**	Gross output value of recycling industries (%) = the total output value generated by resource recycling activities.
		CN6. Waste discharges	Disposal of industrial solid waste: incinerate industrial solid waste and use other methods to change the physical, chemical and biological characteristics of industrial solid waste to reduce or eliminate its hazardous components, or to place industrial solid waste in final Discharge of industrial sewage: the amount of industrial wastewater discharged to the outside of the enterprise through all discharge outlets in the enterprise factory area. Municipal solid waste landfill: The total amount of domestic waste is disposed of by sanitary landfill. Discharge of main pollutants (by categories): COD, ammonia nitrogen, sulfur dioxide, nitrogen oxides, and other discharge exceeding environmental threshold
Japan's Sound Material-cycle Society, Fourth Fundamental Plan	**Overall picture of a sound material-cycle society (13)**	**JP1. Material flow indicators**	Resource productivity = GDP/DMI Cyclical use rate at inlet = amount of cyclical use / (DMI + amount of cyclical use) *Cyclical use* = share of cyclical use (amount reused/recycled) to total input in the economy and society. Cyclical use rate at outlet = amount of cyclical use/generation of waste, etc. Cyclical use rate at outlet represents the share of cyclical use (amount reused/recycled) to generation of waste, etc. Final disposal amount = Amount of landfill disposal waste. This indicator is directly linked to the issue of securing final disposal (landfill) sites for waste.

		JP2. Material flow indicator by objective (primary indicator) regarding the integration of efforts toward environmental and economic considerations and its numerical target	Resource productivity by industry (in terms of primary resources converted) Market size of business related to Almost double FY2025 sound material-cycle society business Generation of household food loss Generation of commercial food loss
		JP3. Material flow indicators by objective (primary indicators) regarding the integration of efforts toward cyclical use and low-carbon and their numerical targets	Emission of greenhouse gas from the waste sector Reduction of greenhouse gas emissions from other sectors through the utilization of waste as raw material and fuel as well as a source of power generation Average power generation efficiency of garbage incineration facilities constructed or improved during the specified period
		JP4. Material flow indicator by objective (primary indicator) regarding the integration of efforts toward cyclical use and harmony with nature and its numerical target	Ratio of domestically-produced biomass resources to total natural resources input Area of forests for which specific forest management plans are formulated
	Indicators regarding regional revitalization through the formation of diverse regional circulating and ecological sphere (3)	JP5. Material flow indicators regarding regional revitalization through the formation of diverse regional circulating and ecological spher	Per-capita waste generation per day Per-capita household waste generation per day Business waste generation
		JP6. Effort indicator by objective regarding regional revitalization through the formation of diverse regional circulating and ecological sphere	Number of local governments working on the formation of local recycling networks
	Indicators regarding thorough circulation of resources throughout the lifecycle of goods and services (10)	JP7. Material flow indicators by objective egarding the thorough circulation of resources throughout the lifecycle of goods and service	Per-capita consumption of natural resources in terms of primary resources converted = RMC / population Cyclical use rate at outlet
		JP8. Effort indicators by objective regarding the thorough circulation of resources throughout the lifecycle of goods and services	Market size of reuse Market size of sharing (car sharing, etc.) Development of guidelines for product asessment (design for environment) by industries
		JP9. Material flow indicators by objective regarding the thorough recycling of materials throughout the lifecycle of goods and services	Cyclical use rate at inlet for each of the four types of resources (biomass, metals, non-metallic minerals) Cyclical use rate at outlet by type of waste, etc. (plastic waste, biomass, metals, non-metallic minerals) Final disposal amount by type of waste, etc. (plastic waste, biomass, metals, non-metallic minerals) Implementation rate of recycling of cyclical food resources - Generation of household food loss - Generation of commercial food los
		JP10. Effort indicator by objective regarding the thorough recycling of materials throughout the lifecycle of goods and services	Establishment rate of life extension plans for individual facilities (individual facility plan)

	Indicators regarding continued promotion of proper waste treatment and environmental restoration (7)	JP11. Material flow indicators by objective regarding the continued promotion of proper waste treatment and environmental restoration	Amount of illegal dumping Amount of waste treated improperly
		JP12. Effort indicators by objective regarding the continued promotion of proper waste treatment and environmental restoration	Number of illegal dumping cases Number of improper waste treatment cases Diffusion rate of electronic manifests Number of remaining sustainable years of municipal waste final disposal sites Number of remaining sustainable years of industrial waste final disposal sites
	Indicators regarding the development of well-planned framework for disaster waste management (1)	JP13. Effort indicators	Ratio of local governments with a disaster waste management plan in place = number of prefectural governments that conduct training regarding disaster waste/total number of prefectural governments *or municipal
	Indicators regarding the development of proper international framework for circulation of resources and overseas expansion of waste management and recycling industries (2)	JP14. Effort indicators	Number of nations with which a memorandum of understanding or other agreement on environmental cooperation (including that for resource circulation) is signed Number of projects of overseas expansion of waste management and recycling industries
	Indicators regarding the development of infrastructure in the area of recycling (4)	JP15. Effort indicators on development of information infrastructure in the area of recycling	Diffusion rate of electronic manifests
		JP16. Effort indicators on technological development and utilization and application of the latest technologies in the area of recycling and its numerical target	Ratio of research projects with the result of ex-post evaluation being S or A in the Environment Research and Technology Development Fund (ERTDF) program (sound material- cycle field)
		JP17. Effort indicators on regarding the development of human resources as well as dissemination and enlightenment in the area of recycling and their numerical targets	Reduction of waste generation and awareness for cyclical use and green purchase Implementation rate of specific 3R actions

Source: NDRC (2017a) and Ministry of the Environment Government of Japan (2018)

3. ANNEX 3: COUNTRY OVERVIEW: INDONESIA

	Population	Employment	Unemployment	Household	Export	Import
	Thousands people	Thousands people	Thousands people	Thousands people	USD Billion	USD Billion
2011	241,991	117,370	7,700	62,630	200,788	190,948
2012	245,425	118,053	7,245	63,097	207,073	207,621
2013	248,818	118,193	7,389	63,938	197,060	200,548
2014	252,165	121,873	7,245	64,767	175,981	178,179
2015	255,462	114,819	7,561	65,582	150,366	142,695
2016	258,705	118,412	7,032	66,385	145,186	135,653

2017	261,891	121,022	7,040	67,173	168,828	156,986
2018	265,015	126,282	7,073	67,945	180,215	188,711
2019	268,075	128,755	7104	68,701	167,683	171,276
2020	271,066	128,454	9,768	69,439	163,306	141,569
2021	272,683	131,051	9,102	70,048	231,522	196,190

Source: BPS (2021) as cited in ESDM (2022)

4. ANNEX 4: CIRCULAR ECONOMY SECTOR BASED ON EU'S NACE

NACE Code	Proxy NACE Codes Rev 2 codes for recycling
E 38.11	Collection of non-hazardous waste
E 38.12	Collection of hazardous waste
E 38.31	Dismantling of wrecks
E 38.32	Recovery of sorted materials
G 46.77	Wholesale of waste and scrap
G 47.79	Retail sale of second-hand goods in stores
NACE Code	**Proxy NACE Rev 2 codes for repair and reuse**
C 33.11	Repair of fabricated metal products
C 33.12	Repair of machinery
C 33.13	Repair of electronic and optical equipment
C 33.14	Repair of electrical equipment
C 33.15	Repair and maintenance of ships and boats
C 33.16	Repair and maintenance of aircraft and spacecraft
C 33.17	Repair and maintenance of other transport equipment
C 33.19	Repair of other equipment
G 45.20	Maintenance and repair of motor vehicles
G 45.40	Sale, maintenance and repair of motorcycles and related parts and accessories
S 95.11	Repair of computers and peripheral equipment
S 95.12	Repair of communication equipment
S 95.21	Repair of consumer electronics
S 95.22	Repair of household appliances and home and garden equipment

S 95.23	Repair of footwear and leather goods
S 95.24	Repair of furniture and home furnishings
S 95.25	Repair of watches
S 95.29	Repair of other personal and household goods

Table 10. Statistical Classification of Economic Activities in the European Community (NACE)

Source: European Commission (2018)

The NACE (Nomenclature statistique des activités économiques dans la Communauté européenne), or Statistical Classification of Economic Activities in the European Community, is a classification system used to categorize economic activities within the European Union (EU). The NACE system is designed to provide a standardized framework for collecting and presenting statistical data on economic activities across EU member states.

5. ANNEX 5: STANDARD CLASSIFICATION OF INDONESIAN BUSINESS FIELDS BUSINESS CODE, WHICH MIGHT BE RELEVANT FOR 5RS

KBLI category	Relevant Business Code	Remarks
E. Water Treatment, Wastewater Treatment, Waste Material Treatment and Recovery, and Remediation Activities	370. Wastewater treatment -3701. Wastewater Collection -3702. Wastewater Treatment and Disposal	Operation of wastewater disposal systems or wastewater treatment facilities, including the collection and transportation of wastewater through sewer networks and transport facilities. This division also includes desludging and cleaning of wastewater storage facilities, service and treatment of wastewater through biological, chemical and physical processes, as well as maintenance and cleaning of waterways and sewers.
	38. Waste Material Treatment and Recovery 381. Collection of waste 382. Waste Treatment and Disposal -3821. Treatment and disposal of non-hazardous waste; Treatment of organic waste for disposal; Retrieval of energy from incineration of non-hazardous waste -3822. Disposal of waste materials such as refrigerators to eliminate hazardous waste; Treatment and disposal of transitional radioactive waste from hospitals; Management and disposal of toxic waste and contaminated, 383. Material recovery	Activities of collecting, processing and disposing of waste and garbage from the local collection of waste and waste to the operation of recycling facilities (eg selection of recyclable waste from waste and waste collections), organic waste, waste containing poisons, living or dead animals, waste from hospitals, used goods and other polluted waste which is harmful to human health and the environment by operating hazardous waste treatment facilities, landfills, incinerators and other means.

KBLI category	Relevant Business Code	Remarks
	-38301. Metal Material Recovery -38302. Non-metal Material Recovery	
	39000. Remediation and Management of Waste and Other Garbage Activities	Provision of environmental recovery services from pollution (remediation), for example services for the restoration of sites or places and buildings, soil, groundwater or surface water that has been polluted; decontamination of industrial places or factories, including nuclear sites and plants; decontamination and cleaning of surface water due to pollution, cleaning up spilled oil (oil spill) and other pollution on land, surface water, in the oceans and seas, including coastal areas; reduction of asbestos, paint and other toxic materials; other special pollution control activities.
C. Industry	222. Manufacture of plastic goods (includes recycled plastic) 2410. Remelting of waste and metal scrap	This group covers the manufacture of new final products from secondary raw materials (raw materials originating from recycling), in the processing industries.
F. Construction	4220. Construction of Irrigation, Communication and Waste Networks	The construction, maintenance and/or rebuilding of solid, liquid and gas waste processing buildings, waste reservoirs, sewage pipelines, inner city wastewater network buildings (domestic/human waste water collection networks and industrial waste water), buildings for waste disposal and incineration (incinerator), services for installing septic systems, construction of waste treatment units generated from thermal, hydro, heat generators earth, other new and renewable energy (EBT).
G. Wholesale	46696. Wholesaling of Used Goods and Unused Remains (Scrap)	Wholesale business of used goods and unused scraps and scrap metal and non-metallic materials for recycling, including collecting, sorting, segregating, releasing goods that are still useful, and buying and selling of used goods that still have value.
S. Service*	95421. Repair and maintenance of consumer electronics 95422. Repair and maintenance of household appliances and garden and home equipment 95423. Repair and maintenance of footwear and leather goods 95424. Repair and maintenance of Furniture and Home Appliances	This class excludes: repair of rifles for sport and recreation (3311), repair of power driven hand tools (3312), repair of time lock devices, time/date stamps and recording equipment other times (3313)

KBLI category	Relevant Business Code	Remarks
	95425. Repair and maintenance of Personal Needs And Other Household Supplies	

Source: own interpretation and translation collected from OSS (2020)

* Better definition shall include what is listed under circular economy, for instance, OEM, e.g. electronic and automotive spare parts provided by the car repairs, do not postpone material loss or prolong the estimated lifetime

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