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Review

Reforming MSWM in Sukunan (Yogjakarta, Indonesia): A case-study of applying a zero-waste approach based on circular economy paradigm

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ABSTRACT

Over the past years, Indonesia, the world's fourth most populous country, has confronted environmental problems due to uncontrolled generation of municipal solid waste (MSW). While the integrated solid waste management (ISWM) represents a critical strategy for Indonesia to control its production, it is also recognized that economic approaches also need to be promoted to address the waste problem concertedly. In this case study, empirical approaches are developed to understand how a volume-based waste fee could be incorporated into MSW collection services and how to apply a zero-waste approach in Indonesia by adapting resource recovery initiatives, adapted from Germany's mature experiences in integrating the CE paradigm into the latter's MSWM practices. Currently, Sukunan village (Yogyakarta, Indonesia) promotes waste reduction at sources in the framework of community-based solid waste management (CBSWM) by mobilizing the local community for waste separation (organic and non-organic) and waste recycling. As a result, about 0.2 million Mt of $CO_{2\text{-eq}}$ emissions was avoided annually from local landfills. The economic benefits of recycling activities by the village's community also resulted in 30% reduction of the waste generated. This CBSWM scheme not only saves the government budget on waste collection, transport and disposal, but also extends the lifetime of local landfills as the final disposal sites. By integrating the CE paradigm into its MSWM practices through the implementation of economic instruments and adherence to the rule of law in the same way as Germany does, Indonesia could make positive changes to its environmental policy and regulation of MSW. A sound MSWM in Indonesia could play important roles in promoting the effectiveness of urban development with resource recovery approaches to facilitate its transition towards a CE nationwide in the long-term.

Contents

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List of abbreviations

BW	Baden-Württemberg
BTP	Bandung Techno Park
CBSWM	community-based solid waste management
CE	circular economy
DRS	deposit refund system
DSD	duales system Deutschland (Dual system Germany)
EPR	extended product responsibility
ESBW	entsorgungsbettiebe der Stadt Baden-Württemberg (Waste disposal companies of the Baden-Württemberg state)
GDP	gross domestic product
GRDP	gross regional domestic product
GHG	greenhouse gases
GWP	global warming potential
ISWM	integrated solid waste management
LCA	life cycle analysis
MSWM	municipal solid waste management
MSW	municipal solid waste
MT	metric tonnes
NGO	non-governmental organizations
PAYT	pay-as-you-throw
SDGs	sustainable development goals
SMEs	small and medium enterprises
UNEP	United Nations environment program
USD	United States dollar
WTE	waste-to-energy
5R	reduce, reuse, recycle, recovery, and repair

1. Introduction

As one of the world's emerging market economies, Indonesia has confronted MSW problems over the past years. With an area of 1.9 million km^2, currently Indonesia is home to about 274 million of inhabitants in 2020, accounting for 3.5% of the world's population. Presently about 200,000 Mt of MSW is generated nationwide daily. On average, about 384 large cities in Indonesia generate about 2.2–2.7 kg of MSW per capita daily (Brotosusilo and Handayani, 2020). In Indonesia, the MSW mostly consists of organic waste, paper, and glass (Sudibyo et al., 2017). The refuse is classified either as residential or non-residential waste. Sixty percent of residential waste (by weight) consists of degradable organic materials, while their amount in non-residential waste varies depending on moisture content.

With an annual population growth of 1.4%, it is anticipated that by the end of 2020, the amount of MSW generation in Indonesia would reach 1.5 times more than that of the last decade (Gunawan et al., 2020). The increment in the magnitude and complexity of the MSW generated reflects the challenges that need to be tackled at local and national levels (Nzediegwu and Chang, 2020).

In recent years, MSWM has become the responsibility of local governments and communities. However, waste management is often handled in a fragmented and uncoordinated manner. Hence, there is a growing need for both integrated approaches and investment in the waste sector to address the uncontrolled generation of MSW. Harnessing investment capacity and technical know-how of private sectors such as manufacturers and recyclers are required if the government is determined to tackle waste management challenges by promoting a CE paradigm in the waste sector in the framework of resource recovery (Luttenberger, 2020). The phrase of CE itself refers to 'an economy in which resources are used for as long as possible, their maximum value is extracted whilst in use, and the materials are recovered at the end of each service's life cycle (Millete et al., 2020).

For most cities in Indonesia, waste management is undertaken as a public service with high expenses that include labour, equipment, and infrastructure cost. Their expenditures range between 80% and 90% of the MSWM budget for collection costs alone (Melakessou et al., 2020). Therefore, most of the cities in developing countries could not manage (collection and disposal of MSW) properly with the limited resources they have (Mak et al., 2019).

In Yogyakarta, the provincial government spent US$105,000 for the MSW to be collected and transported to local landfills (Rusqiyati, 2015). In Jakarta, over 35% of the government budget has been allocated for MSWM, of which almost 90% is used to cover waste collection, while the rest of the expenditure is allocated for transportation and waste disposal (Kurniawan et al., 2013). However, there is still 40% of the waste uncollected and only 50% of the city's urban population is served by the collection service (Ruohoma and Ivanova, 2019). As a result, the rest is collected by scavengers for recovery and/or recycle. Subsequently, they trade the sorted waste to wholesalers.

While low budget allocations, less community participation, insufficient waste management from its collection to disposal, and the availability of empty land that can be used as disposal sites are

the main reasons of the local government to choose open dump, the lack of coordination among government institutions, insufficient regulation, and flexible implementation of the law represent structural problems in the country's MSWM system (Premakumara et al., 2014). Therefore, reformation of waste management policies in Indonesia is urgently required due to the continuous increase in waste generation annually.

The introduction of CE paradigm in recent years has facilitated MSW problems to be addressed using a variety of ways at local level to bring tangible impacts on a global scale. The novelty of the CE paradigm is underpinned by a school of thought that incorporating both engineering and economic approaches into waste management practice is required to address MSW problems concertedly (Khalil et al., 2019). Thus, economic instruments need to be applied to internalize the cost of waste management so that its generators bear it.

A preliminary study on MSWM in Jakarta undertaken by Machmud (2017) focused on the aspect of ISWM. Despite its novelty, the study did not directly address the economic aspects of the MSW. The work did not adequately integrate economic instruments as a part of sustainability solutions in the country's capital, while the important links between economy and environment in the policy sphere were not well established.

To reflect the novelty of this work, we investigate whether economic instruments are technically feasible and applicable to control MSW generation in Indonesia and how resource recovery approaches would improve local environmental protection through waste minimization in the framework of CE. Drawing from the successful experiences of the BW in implementing the CE through economic instruments, we evaluate the feasibility of introducing a volume-based waste fee to MSW collection services in Indonesia. Both positive and negative aspects of the adoption of economic instruments for controlling waste generation are also discussed.

For this purpose, the Sukunan neighbourhood, located in the Gamping sub-district, Sleman regency (Yogyakarta), was used as a model that started applying the CE. In 2004, the Sukunan's Eco-Edu Tourism project was recognized by the Indonesian government with a Green and Clean Award due to the innovative characters of the CE's implementation through waste recycling and other resource recovery initiatives.

2. Methodology

Waste management has been addressed by different nations and provincial governments through various policy and economic instruments (Boubellouta and Kusch-Brandt, 2020). The success and failure of such policy tools depend on the variety of factors, ranging from socio-cultural aspects and implementation strategies (Leclerc and Badami, 2020).

This case study addresses how economic instruments such as waste disposal fees and DRS, which control MSW generation in the BW (Germany), could be directly transferable and applicable to Indonesia. Although both Germany and Indonesia have various socio-economic levels and different living conditions, the case study of the MSWM in the BW (Germany) may apply to Jakarta (Indonesia) with respect to the implementation of public and economic policies.

Case-study was selected as the research methodology of this work because it provided the authors with a means of investigating a complex problem, consisting of multiple variables of importance in understanding the phenomena of waste management in both locations within its real-life context (Ragin and Becker, 2020). With respect to its advantages, a case study allowed the authors to collect vast information that would not be easily obtained by using other research methodologies. In addition, the data collected through a case study are of greater depth and richer than those obtained by using other research designs.

2.1. Study area

Situated in the south-western part of the country and to the east of the Upper Rhine (Fig. 1), BW is the third largest of the 16 states in Germany. With an area of 35,752 km^2 and a population of 11.19 million in 2020, BW was similar to Jakarta with respect to the population size between the two localities (Table 1). In addition, both BW and Jakarta have similar characteristics in terms of their share of GRDP and economic strength because of the presence of large and medium scale-industries such as electronics, automotive, chemicals, and mechanical engineering. Due to their respective roles as an economic powerhouse and because BW has successfully tackled its waste problems through environmentally acceptable solutions in the framework of CE, the German state represents an

Table 1
Characteristics of two localities in terms of population size and socio-economic statistics. **Source:** Statistics of Baden-Württemberg (2020) and Statistics of Jakarta (2020).

	Jakarta	BW
Inhabitants (million people)	10.77	11.19
Population density (people/km^2)	14,464	310
Area (km^2)	661.50	35,752
GDP per capita (USD)	3871	49,400
GRDP (%)	17.12	15. 21

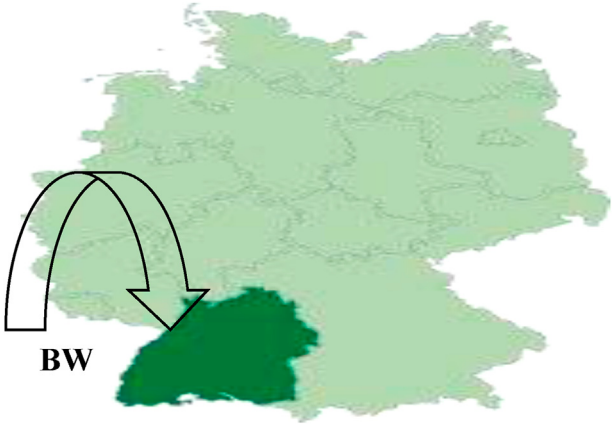

Fig. 1. Geographical location of BW in Germany.

Table 2
Physico-chemical properties of MSW in Indonesia. **Source:** Machmud (2017).

Properties	Average
Moisture (%)	49.42
Density (kg/m^3)	239.32
Ash (%)	29.27
Combustibles (%)	33.43
Volatile matter (%)	83.19
Carbon (%)	53.02
Hydrogen (%)	7.21
Nitrogen (%)	1.14
Low heating value (MJ/kg)	0.53
High heating value (MJ/kg)	0.60
Pb (ppm)	1.23
Cd (ppm)	0.09
Hg (ppm)	0.01

Table 3
Information on respondents in BW (Germany) and Sukunan (Indonesia).

	BW	Sukunan	Remarks
Total respondents	30	30	Respondents have been residing in BW or Sukunan. Through social networks, they were recruited based on knowledge and experience of the selected individuals with economic instruments and CE paradigm, representing the population.
Breakdown of respondents' occupation (number of persons)			
- Government officials	2	3	Working for government
- Professionals	22	9	Working in a private sector
- Self-employed	4	12	
- Community Leaders*	2	6	*Defined as leading figures in a community, who take responsibility for the well-being and improvement of their local community
Duration of the interview (min)	55–65	45–75	Average of the duration: 60 min

appropriate case study for Jakarta to draw valuable lessons from the former's successful experiences in MSWM over the past decades.

Jakarta is a miniature of Indonesia with complex socio-economic and environmental problems, particularly due to an uncontrolled generation of MSW. Its characteristics are presented in Table 2. The MSW's moisture content in Indonesia is higher than that in developed region, while its heating value is lower.

If the MSW problem in Jakarta could be effectively tackled using economic instruments based on the CE model in the framework of resource recovery, the same approach may be directly transferable and applicable to other regions nationwide as long as their stakeholders implement good governance and adhere to the rule of the law (Billi et al., 2021).

2.2. Data acquisition and analysis

To carry out this study, the data were obtained from both primary and secondary sources. Initially, a literature survey was carried out to analyse official documents on Germany's pre-existing environmental regulations on its MSWM. The secondary information on the German Statistics of MSW was complementary.

The primary data were derived from our semi-structured interviews with relevant stakeholders, such as government officials, operators of local landfills, and community leaders (Table 3). This method was an effective way to understand what happened by asking critical questions and evaluate events with relevant stakeholders.

The interviews took about 1 h on average for each respondent in both places. When necessary, interviewees were contacted again to address further questions. The questions asked to the respondents in the interview were closely related to the application of CE for resource recovery of the sorted waste and good governance practices implemented by their stakeholders. Important quotes from the respondents during the interview and the differences of their opinions on the CE paradigm are presented in Tables S1 and S2, respectively, while Table S3 lists the advantages and bottlenecks of the CE implementation in BW and Sukunan that could be learned by other stakeholders in both locations and/or abroad. The respondents' answers were also screened to identify the most commonly discussed points. Their replies were recorded to detect key differences based on earlier surveys. As the data used in this research were mostly qualitative, they should be perceived as indicators only.

The same method was also used for data collection in Sukunan (Yogyakarta) to explore the applicability of the local resource recovery initiatives to control MSW generation in the context of CBSWM. Sukunan, situated in a peri-urban area, approximately 5 Km west of the city's centre, has a population of 1.5 million, while about 4 million of inhabitants lived in the province in 2020.

3. Results and discussion

3.1. MSWM practices in BW: a case study

In the framework of the CE paradigm, we create value from waste for the economy, while reducing resource use and environmental impacts through the 5R scheme. This work highlights the implementation of the CE model based on Germany's experiences in integrating economic instruments into MSWM practices in the framework of resource recovery approach (Table 4).

As a key location of climate protection and adaptation to climate change, Germany aims at attaining a closed-loop economy that conserves resources and minimizes impacts on the environment by optimizing an efficient consumption of raw materials, enhancing recovery rates and removing any residual trash, which cannot be recycled. Therefore, in recent decades, Germany has been a role model of circular economy for best-practiced MSWM worldwide (Kaza et al., 2018).

Energy conservation, GHG emissions reduction from MSW, and sustainable development are huge challenges for developing countries like Indonesia. Hence, learning from Germany on how to apply a sound MSWM is a good approach for Indonesia to improve its own. Indonesia could draw and apply the valuable lessons from the country's mature experiences in MSWM. Among the 16 German States, BW was selected as an example due to certain peculiarities of its economy, as indicated by the State's extensive industrialization and rapid development that resembles aspects of emerging economies like Indonesia.

The complexity of waste management in Germany has facilitated the development of seminal policies when the country

Table 4
Potential economic instruments for controlling waste generation. **Source**: Mont et al. (2020).

Economic instruments	Type	Applicability
For increasing revenue	Tax system	Pollution charge Pollution taxes
	Charge system	Waste collection and disposal services Waste generation
For providing revenue	Fiscal tax	Duty on waste treatment
	Financial instrument	Incentive for pollution control technology

promoted a sustainable production and consumption paradigm in dealing with its MSW problem. Before enacting the 2010 Closed Substance Cycle and Waste Management Act for Prevention and Recovery of MSW based on the EU Waste Framework Directive, a new era began in the country's MSWM practices following the introduction of the DSD in 1990 due to the Packaging Act (Saez and Osmani, 2019). The Act, which promotes waste avoidance and recycling, shifts the responsibility towards industries and businesses by encouraging them to design not only packaging that facilitates waste avoidance, but also production systems and products to reduce waste and enable recovery (recycling or reuse) and eco-friendly safe disposal. It is mandatory for the manufacturers and consumers of packaging materials to follow the requirements of extended product responsibility (EPR), of which industry has to be responsible for the recovery and the recycle of their waste. Any manufacturer, which uses packaging materials into circulation, is required to minimize its ecological impacts on the environment. To meet this requirement, the Act sets an ambitious recycling target for any packaging waste through eco-fee regulation (Kumar, 2020).

For this reason, from the beginning, the implementation of the DSD program in BW involved stakeholders from public and private sectors in the framework of public-private partnerships to provide this service on their behalf (Bueno and Valente, 2019). The state provided waste collection and processing services for green bins, distributed to each household for individual collection of the light portion of packaging waste, while the private companies provided environmental services to business enterprises. The state also collaborated with private companies in transferring bulky waste to drop-off facilities (Martinez-Sanchez et al., 2015).

To comply with the DSD requirements, manufacturers are required to recycle a certain quantity of their packaging materials. Instead of returning each bottle to its manufacturer, an association of local waste management companies, called DSD, has been involved in waste collection for recycling in exchange for cash payments from the DSD scheme. Through "green dot", the DSD charges the manufacturers or users of the packaging based on the type and quantity of the packaging used. The levy represent a marginal cost imposed by the DSD to collect and sort individual materials (Dunkelberg et al., 2019). A mandatory deposit of €uro 0.25 on non-recycled packaging has been introduced. The deposit is imposed on all non eco-friendly packaging that contains mineral water, soft drinks, etc. In addition, €uro 0.80 will be charged as an additional tax to every kg of non-recycled plastic waste from 2021 onwards (Kumar, 2020)).

Germany recognizes the potential of waste as a resource and tackles it at source to the end of life cycle to interrupt and reverse its unwanted growth. For this purpose, waste minimization is conducted through the EPR, which require manufacturers to develop products that have the longest possible service life and to apply production techniques, which produces the least volume of the waste. Therefore, they need to take into account in advance the environmental impacts and any risks of their products throughout the entire life cycle (Paes et al., 2020).

By implementing the DSD, Germany changed the waste management approach towards a resource conservation paradigm based on the "5R" concept (reduction, recovery, recycle, reuse, and repair) (Saez and Osmani, 2019). The 5R concept reduces operational costs related to waste disposal and secures resource supplies by maximizing the life cycle of the waste materials, paving the way forward for Germany to a sustainable path (Mont et al., 2020).

All of the states in Germany have been required to institute MSWM system that identifies how, where, and by whom MSW is treated or recycled. The level of government, type of institution, and mechanisms for enforcement involved depend on the type of policy instruments. The Law requires households to separate their MSW for recycling and reuse. While the MSW could have a second life, it is possible to have certain materials left until the end of its life cycle. Therefore, the waste has to be reduced at source by compressing it for volume or weight reduction.

Like other states in Germany, BW has an integrated waste management system in place that includes waste reduction, recycling, composting, and landfills. The major components of the MSWM system in BW state include drop-off bins for separating paper and glass, and bulky waste; material collection; and WTE facilities for composting and local landfills. The state also has developed a waste composting and source separation, while incinerating its biodegradable waste for generating power.

In addition, the BW's waste collection and disposal services were integrated into a separate entity that consisted of various departments within the state's administration. The entity, called the ESBW, has been involved in the collection of household waste and packaging materials. Presently the facility is used to treat and screen sortable waste such as domestic refuse. After treatments, the rest is transferred to the WTE facilities for combustion for energy recovery.

By integrating collection, separation, and composting, in recent years BW has significantly increased the recycling rate to 50% (about 45,359 Mt) of useful materials annually, while creating job opportunities for local community. The materials include recyclable items such as plastics, glass, wood, and metals recovered from various waste streams and compost, originating from organic waste. The State has increased the number of collection bins to facilitate source separation of organic refuse. Ultimately, this improves the quality of compost as an end product generated by the WTE facilities.

Apart from the implementation of ISWM facilities, waste avoidance is another key element in the education campaign in BW. Local organizations have been involved in promoting reuse of bulky materials like furniture and e-waste. A separate pick-up program has been organized for bulky items. Other novel aspects of the MSWM in BW include: (1) the presence of extensive networks of drop-off boxes and curbside collection of paper waste in various areas in each city; (2) the establishment of a separate corporate entity to address its own waste management needs; and (3) the implementation of economic instruments for MSW disposal fee based on the volume of the refuse generated.

According to Burchart-Korol et al. (2019), environmental charges such as waste disposal fees and DRS are commonly used to influence people's behaviours. The German systems have adopted the unit-charge to fund MSW collection at source. Accordingly, waste generators are incrementally charged based on the PAYT policies for their waste disposal. The policy ties waste charge to the cost of collection and disposal, providing incentives on waste generators to reduce waste through changes in purchasing styles and reuse of containers. Based on the BW's experiences in MSWM, it is obvious that the use of economic instruments for environmental protection provides a way to save cost, while achieving environmental objectives simultaneously (Table 5) (Lu et al., 2020).

As reflected by Table 5, the economic instruments shift costs away from the poor to the richer ones, who usually generate more waste (Botello-Álvarez et al., 2018). The poor groups are the most vulnerable to the implications of weak waste management because they cannot afford to pay waste management services. Therefore, we argued that economic instruments would encourage waste generators (households) to alter their behaviour on waste. As the economic instruments could reflect the "polluter pays" principle, they could consolidate the cost of environmental damages due to the waste into a full fee. As a result, a waste disposal fee could set a price tag for the negative implications of environmental pollution and enforce waste generators to pay their price fully (Huang et al.,

Table 5
Comparison of economic instruments and resource recovery approaches.

Type	Purposes	Advantages	Drawbacks
Economic instruments	To raise revenue from excessive waste disposal; to encourage efficient use of resources.	Discouraging environmental pollution; providing households incentives for 5R	Revenue is not used to manage the environment due to its low tariff; waste disposal fee is not calculated based on proper formula/standard
Resource recovery	To address climate change concern; to promote local needs of development	Creating job opportunity such as waste composting at a local level	Not mandatory

2020). The implementation of such a policy is fair, justifiable, effective, and efficient, as this provides society with economic incentives to generate less waste. Consequently, it is no longer necessary for the government to spend its public budget on waste management, unlike common practices in Indonesia.

The incentive of the waste disposal fee may attract and persuade waste generators to reduce the amount of waste they generated through recycling. Setting the right price for products that have the potential to end up as waste and pricing waste management services are essential to promote market instruments as a part of reforming waste management policy in Indonesia. A higher price per unit of waste could reduce the demand for waste collection service. With the incentives of a lower waste disposal fee, households would decide to reduce the waste they generate. This leads to changes in their consumption of packaged products. Such instruments could promote manufacturers to alter their production patterns, reducing MSW generation in the long-term.

The state of BW charges households a waste fee according to the number and size of their trash bins, and the frequency of their waste collection service. Instead of paying a fixed monthly fee for collection, residents have to pay an amount in proportion to the quantity of the MSW they generated. The fee charged to households in Germany varies from one state to another, depending on the size of the waste container. In BW, the annual basic charge for one 40 L of the trash bin is €uro 49.0 with an additional €uro 0.16 per kg of extra waste generated (Nelles et al., 2016). A fixed fee is charged on every reusable trash container, while a higher charge is applied to each non-reusable trash container collected. If the prices of waste management were imposed on waste generators, this would promote environmental awareness for responsible waste management, while people have incentives to modify their behaviours, thus increasing public participation in the 5R campaign.

Due to the implementation of economic instruments and adherence to the rule of law, the BW state has made a substantial achievement in waste management. The MSW generation in BW has decreased by 62% from 3.12 Mt in 1996 to 1.18 Mt in 2018 (Federal Environmental Agency of Germany, 2018). This was attainable because the waste prevention system in BW was effective in facilitating the transfer of MSW for recycling and reuse. Consequently, the proportion of MSW recovered and recycled escalated and less MSW was disposed of in local landfills. The recovery rate of the MSW in BW improved from 50% in 2000 to 70% in 2007 (Fig. 2). Due to the high requirements for waste recovery, the sorting is performed technologically by using a detector with near infrared spectrography to separate various types of waste automatically with a high level of accuracy.

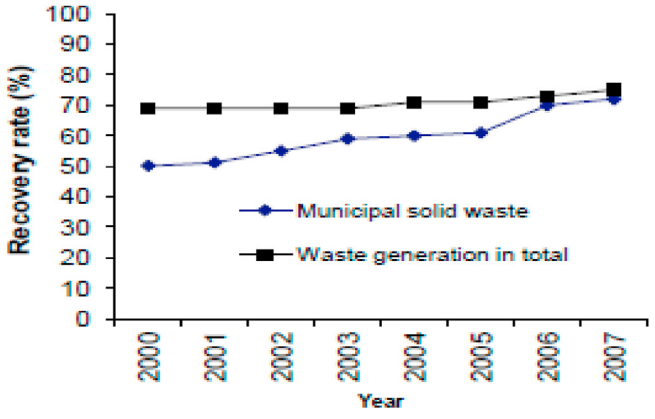

Fig. 2. Recovery rate of MSW in Baden-Württemberg (2000–2007). Source: Federal Environmental Agency of Germany (2018).

Recently, the recycling industry has employed over 200,000 staffs with an annual turnover of €uro 40 billion. The Germany's mature experiences teach other countries that cooperation and coordination among authorities, companies and public are required to enhance MSWM. Therefore, if Indonesia switched from current waste disposal practices to an integrated approach like the same system in BW, it would address the country's major problems associated with its waste management.

As evidenced by this case study, the state has emphasized avoidance and recovery of resources from trash to balance between economic growth and environmental protection. In BW, environmental protection is not regarded as an obstacle, but a tangible contribution to sustainable development. This case study does not supply information that represents the overall situation in Germany as a pioneer of sustainable waste management, but rather presents materials relevant to BW. Therefore, the State does not represent entire Germany.

3.2. Promoting economic instruments for waste management in Indonesia

The successful implementation of economic instruments in the BW state has stood for a good target-of-learning for Indonesia that today's trash could be turned into tomorrow's trove. However, economic instruments are difficult to apply for some waste streams like the waste generated at public venues, which could not be charged accordingly. In Indonesia, MSW does not carry a price tag that corresponds to the marginal cost of waste collection and disposal. Therefore, the cost of waste disposal is low and reflects the under-pricing of its capacity service to the environment. We suggest the need of economic instruments such as unit-pricing or volume-based waste disposal fees to address the problem. If applied properly, the instruments would increase the prices for environmentally damaging goods, altering people's consumption-oriented lifestyles (He et al., 2020a).

A pragmatic approach is to charge a disposal fee according to the quantity of the total waste a household generates (Paes et al., 2019). Since the cost of waste management is accompanied by economic benefits either savings through waste minimization or resource recovery through recycling, the unit-pricing approach represents an ideal option to charge waste generators for collection and disposal services based on its volume. Through two-tier pricing (Alzamora and Barros, 2020), two types of fees could be charged to

households. The flat fee covers a minimum degree of services such as the disposal of one bag weekly, while the unit-based price varies, depending on the number of additional bags collected weekly from households. While setting a threshold limit below, of which charging households for the disposal of domestic waste could be waived, the fees on a volume-based system should be set at an affordable level for every household.

Unlike the flat fee, the unit-pricing provides households with direct incentives to minimize waste generation and encourage waste-reduction behaviours such as purchasing style toward products with less packaging or with recyclable packaging on one hand. On the other hand, companies in the production sectors may consider redesigning their product's packaging if there is a good return for their efforts. For example, a product based on an eco-design perspective can be sold at a higher rate in the market. Principally, a unit-pricing system may increase the marginal cost for waste generators, which reflects the real cost of waste management services such as processing, storing, and setting out the waste for collection (Zhou et al., 2020). We argue that charging households a full fee, which reflects the costs of collection and disposal, would reduce the quantity of MSW generated at source.

If implemented in Jakarta, the unit-pricing programs are likely to be successful. In the capital, residential MSW is regularly picked up curbside. As households commonly dwell in multi-family buildings, the normal practice is to share the total cost of waste disposal among them equally. This program would facilitate changes in their behaviours towards waste reduction. To a certain extent, Zhang et al. (2019) argued that this weight-based waste disposal fee generates economic incentives among the households and contributes to local economic development by supplying waste services. Therefore, an efficient, reliable and low-cost MSW service is essential to the development of an urban economy, not only for creating jobs and generating incomes in waste industry, but also for providing the public with better environmental services.

To attract the involvement of households in waste reduction, unit-pricing could be integrated with the recycling program (He et al., 2020b). This would not entail charging a fee for the collection of recyclable materials if the households separate useful materials from the other streams. In recycling, a potential trade-off may occur when we encourage reduction and materials diversion at source.

Unlike recycling, unit-pricing facilitates source reduction and waste diversion. The higher the unit price is, the stronger the public participation in source reduction and recycling will be. If the unit price is set too high, waste generators may respond to it by disposing of their waste illegally. In BW, the fines for illegal activities on waste are high to protect the safety of workers and the health of the community. The authors argue that charging for waste generation through unit-pricing would improve people's awareness of the economic costs of the waste they generate. To what extent waste generators respond to a higher unit pricing with source reduction depends on the degree of substitutability between high garbage- and low garbage-generating products. Without substitutability, source reduction still occurs due to the monetary implications of accruing a higher charge of the waste services. Therefore, consumers require goods that generate the same level of consumption utility, but produce less garbage.

The economic instruments, whether price- or quantity-based, would not eliminate waste generation activities, but may change people's behaviour concerning the waste they generate. To promote public participation and to enhance their environmental awareness, people's behaviour may be influenced through massive campaigns and information dissemination through media or social networks. However, it may be easier to start changing people's behaviour with their employers, as lowering taxes financially is beneficial to them.

Another option is to charge a tax or levy on certain products, which represent major problems in a waste stream, during its sale through special arrangements. If the price for the waste disposal is zero, a deposit-refund per tonne of MSW required to meet a certain target of reduction would be the marginal cost of the waste reduction (Shi et al., 2019). As the fee represents a charge on waste disposal, waste generators need to adjust their behaviour to enable the charge to equal the marginal cost in the reduction of the waste disposal.

Compared to the unit-pricing, the DRS, which can generate funds for reuse and recycling purposes, is less costly to facilitate source reduction (Zhou et al., 2020). The DRS also involves market mechanisms. The market-generated system could not work efficiently if the refund level was higher than its net reuse value for certain goods. This indicates that Germany's successful experiments with economic instruments in CE provide valuable lessons for Indonesia on the need for monitoring and enforcement through a command and control approach (Di Foggia and Beccarello, 2020).

As the approach of MSWM has changed in Indonesia in recent years from 'end-of-pipe' (management of the disposed waste) to 'reduction of waste at source' (waste generated by household), the government may consider setting the annual basic charge for one 40 L of the trash bin to be IDR 0.6 million (approximately €40) with an additional IDR 1000 (about € 0.07) per kg of extra waste generated. The charges are intentionally kept minimum to be affordable to households as the main waste generators. To pay the entire cost, the rest of expenditure would be covered by the allocated budget provided by local municipality. As the world's 10th largest economy in terms of purchasing power parity, Indonesia has made a sustainable progress in poverty reduction, reducing the poverty rate to 9.4% in 2019. However, there is no official policy in place to increase the charge to the waste generators (Sambodo and Novandra, 2019).

Although economic instruments have been successfully implemented in Germany over the past decades to control MSW generation, the same model of their implementation would not automatically bring the same favourable results for Indonesia due to different socio-economic levels of inhabitants. For Indonesians, having a job stability first that allows them to survive is preferable to paying an additional tax for generating waste. Therefore, it is important to regionalize the economic instruments based on the inhabitants' socio-economic conditions. It is easier to implement economic instruments in Jakarta, where its population density is high and supporting infrastructures are available, than outside the country's capital.

In addition to economic incentives, adherence to the rule of law is another pillar of good governance for a successful implementation of economic instruments. People's adherence to the rule of law in the developing world is not the same level as their counterparts in developed countries due to the different levels of educational background and their awareness. With law enforcement, the law will be equally interpreted by the rich and the poor so that none feels that they are above the law. In addition, compliance with the law not only keeps public authorities credible and accountable, but also promotes transparency and integrity among the stakeholders, leading to good governance (Billi et al., 2021). Good governance is never optional to address the gap of policy implementation in waste management at all levels of stakeholders in Indonesia.

There are pros and cons to promote economic instruments for MSWM in Indonesia. Machmud (2017) argued that a disposal fee, collected from waste generators, can be invested to improve the current system, increasing the government's pressure on capital shortage concerning MSWM. As waste disposal fee contributes to government revenue, the implementation of economic

instruments can improve the economic and environmental situation in Indonesia in the long-term. Depending on the level of public participation and their environmental awareness, we are cautiously optimistic that at least five years of their implementation are required to obtain environmentally favourable results.

It is anticipated that such an economic instrument would help decrease waste disposal in local landfills because households as waste generators would act to minimize MSW and maximize materials diversion through recycling and recovery schemes. Through materials and energy recovery from the unused MSW, the ISWM at the household level can reduce GHG emissions significantly from local landfills. The recent experiences of the Sukunan village (Yogyakarta) has demonstrated the effectiveness of the CE paradigm to control MSW generation at source in the framework of resource recovery.

Despite its potentials, the introduction of waste disposal fees to waste generators may not automatically give the expected outcomes. According to Wang and You (2019), this could be due to the inability to monetize a suitable price tag for the total costs attributed to environmental damage. Although prices indicate the full costs of consumption and production, they do not reflect factors of negative externalities such as pollution due to the waste generated. Both producers and consumers need to feel the negative implications of the products that result in pollution through price indicators by increasing their price. This approach provides incentives for any production processes that promote environmental sustainability.

In practice, it is difficult to charge households with the waste disposal fee efficiently and effectively. Unlike other goods, environmental damage does not have a fixed price tag. There is no single calculation that could determine the entire cost of environmental damage caused by waste disposal. If the fee for waste disposal is low, households do not have any proper incentives to alter their behaviour. In contrast, a higher fee could lead to illegal waste disposal elsewhere. Therefore, economic mechanisms need to facilitate recycling program and address environmental externalities simultaneously (Bui et al., 2020).

Apart from the positive aspects, there is a criticism towards introducing economic instruments for the MSW collection services. As an opponent of economic instruments, Zhou et al. (2020) argued that this instrument could encourage negative waste disposal through illegal dumping. Since unit-pricing encourages households to reduce the burden of waste disposal through recycling, the balance between monetary and household's collection time and costs should be taken into account. Other difficulties in applying this unit-pricing option include the absence of any complete analyses of its effects on the environment, costs, and revenues, which can be unpredictable, since they depend on the response level by an individual household to waste disposal fees. In spite of those drawbacks, ideally economic instruments have to remain a fundamental part of reforming the MSWM in Indonesia in its transition towards a circular economy.

3.3. Policy implications of introducing economic instruments in Indonesia

To shift toward the CE through resource recovery, the country's development strategies need to go beyond engineering paradigms (Kurniawan et al., 2010). For this purpose, the waste has to be recycled in a way that creates not only benefits with technological aspect, but also sustainable jobs for the local community (Lin et al., 2018). The challenge of the 5R scheme in Indonesia is how to recycle or reuse most of the waste without just selecting recycled materials and leaving a large portion of the waste unmanaged, resulting in health risks to the public amidst the current Covid-19 pandemic. Nevertheless, environmental gains in terms of indirect reduction of GHG emissions may be achieved by decoupling economic growth from resource consumption or through offsetting the direct GHG emissions from GHG savings (Campbell, 2016).

If Indonesia adopts a resource recovery approach concerning MSW management practices, several policy implications need to be taken into account. Presently, the lack of environmental policies and regulations presents obstacles to undertake the best practices of MSWM through recycling (Xue et al., 2019). The authors suggest that the government needs to issue environmental laws and strictly enforces a recycling program nationwide.

In Germany, recycling is undertaken by both private and public systems. Over 300 local municipalities in Germany participated in waste separation at source. Since Germany has Laws in place on economic instruments such as DRS, it can arrange a waste disposal fee and determine the potential quantity of waste that will be generated after manufacturing. Manufacturers and consumers must be responsible for the treatment and disposal costs of unrecyclable or non-environmentally friendly products. The Packaging Act target 70% of reusable bottle for beverage packaging. Therefore, manufactures need to apply a life cycle approach from product design to production, packaging, use, and re-entry into the waste hierarchy after the end of its life. Every part of the life cycle of a product offers an opportunity for intervention to generate less waste (Chu et al., 2019).

The Indonesian government also needs to involve stakeholders such as waste generators at the household level through recycling. Sharma et al. (2020) argue that the effectiveness of the recycling program depends on public participation and environmental awareness. Since households are the main waste generators, waste sorting and separation should start at home to minimize time and collection costs. Whether the incentive to generate less MSW is created or not depends on the waste disposal fee. If the charge is set based on an average of the waste generated per household unit, there is no real incentive for waste minimization (Bel and Gradus, 2016).

As evidenced by the German's proven experiences, the Green-Bin program is a powerful tool to promote the separation of waste and retrieval of useful materials. So far, over 22 million households in Germany have been involved in the program (Dunkelberg et al., 2019). Needless to say, an effective waste separation at source requires active participation and cooperation from the government, public and private sectors. By implementing a "zero-waste" policy, of which close-to-zero waste generation is enforced through waste minimization, Germany requires the environmentally compatible disposal of waste to attain a recycling based-economy that conserves resources and reduces adverse impacts on the environment through recycling and reuse. Indonesia needs to learn from Germany's mature experiences in undertaking the CE paradigm by optimizing an efficient use of raw materials, maximizing recovery, and removing the residual waste with no economic value (Kurniawan et al., 2011).

A conceptual framework (Fig. 3) justifies various lessons that Indonesia needs to draw from Germany's successful implementation of economic instruments for its MSWM practices over the past decades. The application of the CE paradigm in the framework of the resource recovery approach coupled with people's adherence to the rule of law has enabled Germany to confront and tackle the MSW problems effectively and efficiently at source.

Fig. 3 also shows how this work paves the way forward for global climate change mitigation at local level. Unless immediately tackled, the Earth cannot manage the produced waste. The United Nations' Agenda 2030 recognizes the importance of treating waste for creating healthy and clean human settlements, as reflected by the Target 12.5 of SDG, which aims at 'substantially reducing waste

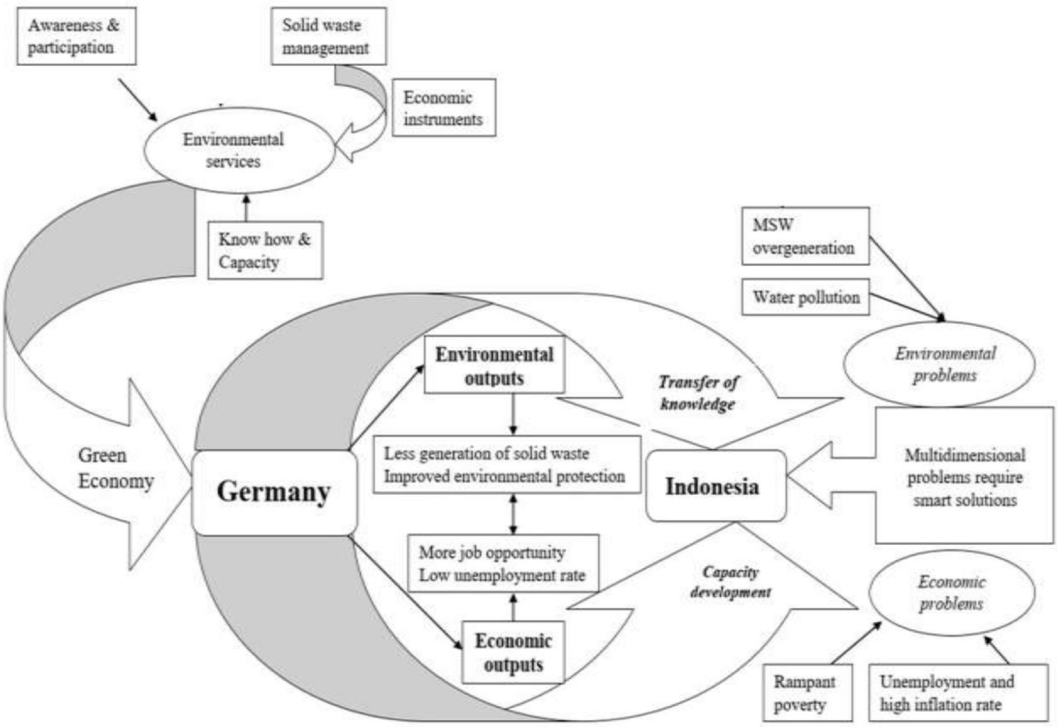

Fig. 3. Conceptual framework of German capacity for MSWM practices in Indonesia.

generation through prevention, reduction, recycling and reuse' by 2030 (Wijayanti and Suryani, 2015).

To achieve this target, a proper management of the MSW system would benefit its stakeholders and the environment through waste avoidance, resource recovery and net reduction of GHG emissions (Pujara et al., 2019). A sound MSWM could improve resource recovery and tackle environmental deterioration caused by resource shortages, thus promoting sustainable development in the long-term. If the MSW growth in Indonesia could be addressed by tackling it from upstream to downstream in the same way as does Germany through resource recovery, this would facilitate CE's implementation on sustainable paths in the long-term.

3.4. Applying CE paradigm to waste sector – experiences of Sukunan village (Yogyakarta)

Indonesia has maintained a consistent 5% of economic growth over the past five years. The country has made a progress toward sustainable development, while confronting the MSW problems.

To transform the MSW problem into an economic opportunity, business solutions need to be scaled-up to support waste recycling through incubators. The BTP is one of the first business incubators in Indonesia for cultivating innovation during the incubation (Tricahyono et al., 2018). To support the BTP's mission, the government needs to develop an integrated ecosystem for the implementation of CE, where all stakeholders in the ecosystem are involved in accelerating the development of new business creation for SMEs.

To educate and advocate CE paradigms in society, collaboration among government, businesses, universities, NGOs, and civil society is important (Meijer and Thaens, 2016). The government needs to lead the CE expansion nationwide by using cultural approaches such as the 5R pillars. One example based on local wisdom is that when a younger sibling is born and has the same gender, he or she will reuse the same clothes and items used previously by his/her older siblings. This culture can reduce apparel use, while parents may prevent wastage. This practice can be promoted and incorporated into the school's curricula to increase public participation and their awareness on the importance of the CE to control MSW generation through resource recovery initiatives. This approach, which represents an integrated effort to address climate change, aims at addressing local environmental problems due to the MSW, while promoting local development needs at the same time (Velvizhi et al., 2020).

By adopting the CE paradigms, major companies in Indonesia have identified new business opportunity for their waste materials by recycling used packages to cope with the increasing packaging waste. Instant noodle producer Indofood, mineral water producer Danone, and Coca Cola started packaging programs, in which packaging waste is recycled and processed into pallets and construction material (Coelho et al., 2020). By decoupling economic growth from environmental impacts, their products do not immediately become waste, but are reused to extract their value before safely returning to the biosphere. Their recovery for reuse not only keeps the packaging in circulation longer, but also delivers materials savings greater than does the conventional system.

Since the huge differences in socio-economic development are observed between Jakarta in Indonesia and BW in Germany, improvements of MSWM with economic instruments should be considered to adapt to unique circumstances in Indonesia using a variety of resource recovery initiatives. Since 2010, resource recovery approaches have been one of the principles for national actions in maintaining friendly urban development by integrating low-pollution and low carbon measures in the waste sector (Machmud, 2017). This has been implemented by promoting a triple-track strategy: pro-poor, pro-jobs, pro-growth with a pro-environment principle.

In this regard, the CBSWM scheme represents the power of the local community in Sukunan (Yogyakarta) to collaborate through new and creative ways to tackle the most pressing issues due to

MSW generation (Dhokhikah et al., 2015). For resource recovery purposes, they cooperate to reduce the amount of waste and improve resource circulation by specifying the obligations of relevant stakeholders (government and households as the waste producers) to the end of life cycle of a product.

As the implication of the CBSWM model in Sukunan, only non-organic waste with economic values are recycled, while the rest is not. Without an effective intervention from their own community, the MSW disposal could not accomplish its environmental objectives. It is not mandatory to punish individual households, who do not comply with relevant legislation with respect to the CBSWM. If the households decline to participate in the CBSWM scheme, their waste can be collected at source periodically for an annual service fee that ranges from US$ 17 to 42 per household, depending on the volume of the waste generated. However, if they agree to be involved in the scheme, Sukunan residents do not have to pay for the waste collection service to the government, thus reducing their household expenses. People, who work part-time as waste collectors, receive an extra monthly income of US$ 30. As a result, more people have become interested in joining the waste industry recently, thus driving a gradual change towards the CE movement (Smol et al., 2020).

In the long-term, the CBSWM scheme could reduce the impacts of urban waste on climate change mitigation, especially when urban dwellers still treat their trash in unsustainable ways. Furthermore, the scheme demonstrated the benefits of applying a zero-waste approach by adapting local resource recovery initiatives in the context of CE.

To implement the scheme, the local municipality has played roles in formulating and implementing appropriate environmental policies and regulations to support CBSWM at local level. Since 2003, Sukunan has undertaken waste management based on the CE principles by adopting resource recovery to attain a zero-waste approach. The ISWM principle was implemented by the local community by separating refuse and composting organic waste at source (Rada and Cioca, 2017). Subsequent steps involve the organized collection and processing of recyclable waste, which was made into handicraft articles or sold as scrap to trash collectors, who deliver them to recycling centres. This would divert valuable materials for re-use or recycling and minimize the amounts of waste disposal into landfills (Lin et al., 2018). So far, the ISWM has worked effectively in Sukunan, as the environmental health, livelihood, and a sense of ownership among the people within the community have improved.

Due to economic benefits, small and local entrepreneurs that include scavengers and homemakers are the key actors in this business. The scavengers sort out waste in disposal sites and search for items that could be sold or recycled, while homemakers make handcrafts articles with recycled beverage packaging. They also purchase recycled materials from school canteens to produce small items such as wallets and handbags. The income received from their sale goes to the person, who made the item. About 20 homemakers are involved and each one receives an additional monthly income of US$ 55–92 from the sale of handicraft articles. To pave the way forward for a transition towards CE, Sukunan entrepreneurs need business incubators. Their presence is essential to provide networking services, capital support, as well as training and coaching programs to new entrepreneurs (Jiménez-Antillón et al., 2018).

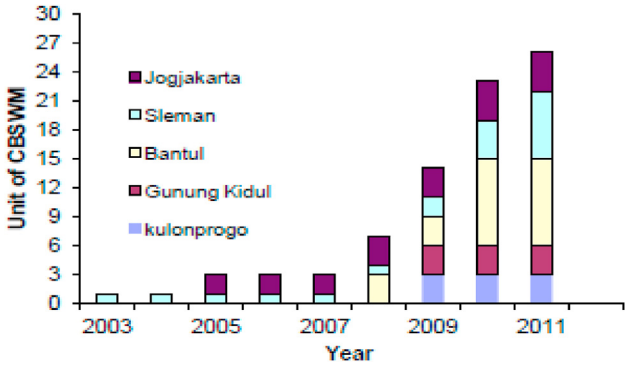

Fig. 4. Distribution of CBSWM in Yogyakarta province.

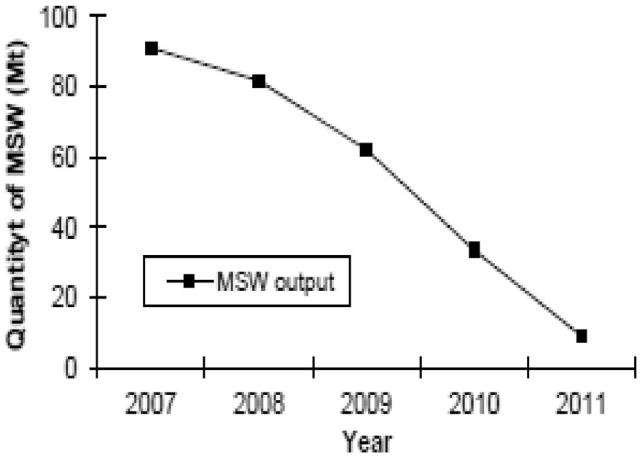

Fig. 5. MSW generation in Yogyakarta after CBSWM implementation.

The economic benefits of reusing and recycling activities by the community resulted in a reduction of 30% of the waste and the residents have been benefited from applying the CE. This not only saves the government budget on waste collection, transport and disposal, but also extends the lifetime of local landfills as the final disposal sites (MacRae and Rodic, 2015). After years of practice, the number of CBSWM units in Yogyakarta has increased (Fig. 4) to address the MSW problems.

This indicates that the CBSWM scheme has remarkably reduced the waste output from the community, as compared to the common practice of bulk collection and mass disposal. In Sukunan, the implementation of the CBSWM scheme has achieved a 30% target of MSW reduction that must be disposed of into landfills (Fig. 5).

After applying 5R to the MSW generated, approximately 0.2 million Mt of CO_2 emissions could be decreased every year. About 0.2 million Mt of $CO_{2\text{-eq}}$ emitted from local landfills was avoided annually according to the life-cycle analysis (LCA) framework reported by Menikpura et al. (2013),

$$GHG_{\text{Avioidance/Savings}} = \sum(PA_i \times EF_i) \quad (1)$$

where: PA represents potential avoidance of ith GHG via materials/energy recovery or avoided landfilling, while EF_i is the equivalency factor of ith GHG, and i is CO_2, CH_4, etc. The value of the equivalence factor depends on the type of GHG emitted.

This promising result is in agreement with another waste treatment undertaken in Muang klang, one of the municipalities in Thailand, which attained a GHG saving of 385.58 kg of $CO_{2\text{-eq}}$/tonne of collected MSW from a local ISWM system (Menikpura et al., 2013). In terms of environmental benefits, this net CO_2 saving represents a significant achievement of the CBSWM practices in GHG emission reduction (Taleb and Al-Farooque, 2021), as most of the GHG emitted from landfills might be diverted or collected through composting activities (Lee et al., 2017).

In tropical countries like Indonesia, an anaerobic composting process rapidly takes place. Approximately 1.5 Mt of compost is produced monthly. About 60% of the compost produced is used as fertiliser by themselves and the rest is sold as a fertilizer for US$ 0.07 per kg (Zamri et al., 2020). The approximate monthly income is about USD 35. In Sukunan, the compost generated helps local farmers to supply nutrients for agricultural farming and increase production yields. Waste composting also recovers resources and collects CO_2. Composting activity has less environmental impacts and does not compromise local public health.

To enhance our understanding about the potential of environmental implications associated with the waste composting, an LCA of the compost suggests that the composting process that used a Takakura composter could be completed within a week, yielding about 35% (on dry weight basis) of compost from the total organic feedstock. Converting organic waste into compost could save USD 328 million annually nationwide (Iswanto et al., 2018). This information provides local decision-makers with a means not only to better understand the complexity of MSWM, represented by one of the waste treatment options like composting, but also supply them with complete information about its techno-economic performance with respect to the scientific aspects of the waste treatment.

As the implications of the study, if the Sukunan community could improve the 5R implementation by sorting recyclable materials and utilizing their organic waste through composting, the village could attain "net-zero GHG emissions". By increasing the composting rate of organic waste, Sukunan could reduce GHG emissions via waste avoidance and material recovery (Kurniawan and Oliveira, 2014).

In addition to environmental benefits, over USD 0.11 million of expenditure was saved annually in the provincial budget for waste management (Iswanto et al., 2018). This was attributed to waste avoidance and the creation of benefits from recycled waste through resource recovery initiatives. The CBSWM program also has improved the living conditions of neighbouring communities and created job opportunities such as waste composting, which generates benefits for the local community (Liao et al., 2020).

Due to extensive public participation (Table 6), the Sukunan village has become a role model for waste management nationwide. It is not only about MSWM, but also creates transformation and environmental awareness within the community. In the same village, public participation reduces waste at source through a variety of resource recovery initiatives and helps the local government to cope with the lack of public budget for waste management (Slorach et al., 2019).

In recent years, Sukunan has become an Eco-Tourism Village in Indonesia. Inspired by the promising results, local people continue to develop their village to conserve a significant amount of valuable materials and to promote environmental protection. Sukunan's achievement in controlling MSW generation through the implementation of CE has demonstrated the effectiveness of resource recovery in GHG emission reduction, thus encouraging other cities in Indonesia to embark on a zero-waste approach for a green neighbourhood.

By 2009, the Sukunan's experience of implementing the CE model had been replicated in 196 villages in the Yogyakarta Province. By 2018, the same model of Sukunan had been implemented by over 2850 community groups in Indonesia (Ministry of Environment of the Republic of Indonesia, 2015). Since the replication of CBSWM nationwide would facilitate resource recovery in local urban areas, it is important to develop an environmental policy that takes into account regional needs and its capacities when promoting practical solutions for solving MSW problems effectively (Ordieres-Meré et al., 2020).

4. Concluding remarks

MSWM problems in Jakarta have been attributed to the city's high population density and rapid industrialization. As a result, they have not become a priority for the government due to under-resourced governance. On the other hand, BW lacks in natural resources. As a result, the German state relies on its strengths in engineering and creates green technology to deal with GHG emissions by using clean energy.

In spite of differences between Germany and Indonesia due to economic gaps, this case study has demonstrated that the successful implementation of the CE paradigm in BW (Germany) could be directly applicable to Sukunan (Indonesia). The CE paradigm has worked well in both locations due to good governance and people's adherence to the rule of law. This suggests that not only could the community experience based on the Sukunan model work in the rest of Indonesia, but the same approach of the CE could also be applicable and transferable to the other parts of developing world, which also have confronted MSW problems recently. As long as the incorporation of MSWM based on the 5R scheme involves the government, local community, and business sectors, this facilitates the acquisition of collective responsibilities among the stakeholders, adoption of new public policies, and promotion of environmental awareness to minimize MSW generation at source.

In policy spheres, countries need to incorporate economic instruments, adherence to the rule of law and resource recovery initiatives as key-drivers of their ISWM approaches. In tandem with the implementation of the ISWM, environmental benefits in terms of substantial CO_2 reductions, and economic benefits have proven to be accessible by Sukunan, the demonstration village.

To accomplish this goal, pilot projects in the form of MSW collection services among the urban community for six months of the trial are necessary to assess the reaction of local households toward the implementation of economic instruments like waste disposal fees and to determine the amount of money charged to waste generators based on the volume of waste generated. It is important to balance between the levy and the associated administrative cost of collecting the levy, as the waste disposal fees charged to MSW in Indonesia could be an additional burden to a family unit, which is often heavily populated (over 5 persons per family unit). The associated levy could be used to subsidize other programs on waste reduction, resource conservation, or environmental education.

Table 6
Public participation in waste minimization through composting.

Stakeholder	Responsibility
Households	Separating organic waste in Takakura bins
Environmental cadres	Training households with technical support for operating CBSWM
Facilitators	Raising environmental awareness in the community and training several environmental cadres
Local NGOs	Providing technical training and financial support to the community for waste separation activities
Media	Disseminating and distributing information
Municipality	Establishing composting centres citywide

Imposing a direct tax on manufacturers is also effective in addressing waste generation. The tax could be used to develop recycling industries, integrated waste management facilities and educational resources in Indonesia.

Presently, technology also plays critical roles in managing our waste to build a sustainable economy (Fatimah et al., 2020). Technological developments of digitization for non-organic waste are essential for waste recycling. In the framework of circular economy, the use of such technologies could minimize the use of raw materials and retain unused resources in the production circuit, leading to a cost reduction.

By incorporating the CE paradigm into its MSWM practices through the implementation of economic instruments, digitization technology, and adherence to the rule of law, Indonesia could replicate the Germany's successful experiences in making positive changes in its environmental policy and regulation on MSWM, while ensuring the economic sustainability of waste management activities nationwide. A sound MSWM in Indonesia could play key roles in promoting the effectiveness of urban development with resource recovery approaches to facilitate its transition towards a CE nationwide in the long-term.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2020.124775.

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