



# Cooperative environmental governance in urban South Asia: implications for municipal waste management and waste-to-energy

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## Abstract

This paper critically discusses the importance of cooperative environmental governance (CEG) for efficient waste management and waste-to-energy (WtE) generation in the context of growing urban South Asia. Focusing on Bangladesh, India and Pakistan experiences, the paper reveals that even though much progress has been done in the urbanisation in the selected countries, the process of waste management (mainly municipal solid waste) has not been effective due to low level of local inclusion. As a result, the WtE generation potential has not been realised to its fullest. In addition, it has been argued that institutional and social reforms are extremely important for strengthening the CEG, and it will eventually lead to effective and optimal WtE generation in the urban cities of the selected South Asian countries for green transition and urban sustainability. Finally, an integrated solid waste management framework has been formulated for policy implications in South Asia.

**Keywords** Waste management · Waste-to-Energy (WtE) · Cooperative environmental governance (CEG) · South Asia · Urbanisation · Green transition · Sustainability

## Introduction

Over the last decade, South Asia has made remarkable progress in sustaining its robust economic growth, alleviating poverty, and emphasising healthcare and education. According to World Bank (2020), average economic growth rate in this region from 2013 to 2019 was 6.50%, which was significantly higher than other developing nations. Furthermore, South Asia grew at the fastest rate of 45.3% between 1990 and 2020, according to the Human Development Index (HDI). Despite the sudden economic downturn because of the COVID-19 crisis, the emerging nations of the South Asian region are back on track, with growth projected to be 7.2% in 2021 and 4.4% in 2022, rising from historical lows in 2020. Consequently, the improvement of South Asia's economic recovery prospects exacerbates the rapid pace of unplanned urbanisation and urban population growth.

The eight countries—Bangladesh, India, Pakistan, Nepal, Sri Lanka, Maldives, Bhutan and Afghanistan—of this

subcontinent have a total population of about 1.9 billion, accounting for 23% of the world population, which is projected to rise to 2.4 billion by 2050 (UN 2019). South Asia also comprises six of the world's megacities, Bangalore, Delhi, Dhaka, Karachi, Kolkata and Mumbai, along with an urban population soaring by 130 million from 2001 to 2011, and is expected to reach 250 million in 2030 (UN 2019). As a result of emerging urbanisation, increasing amounts of waste are generated, thus posing a new threat to our already deteriorated environment. This escalating trend of waste generation raises the risk of severe social instability, threats to critical infrastructure, potential water crises and the devastating spread of disease. Furthermore, the prevailing rise in carbon or greenhouse gas (GHG) emissions, besides the accelerated depletion of fossil fuels in South Asia's Developing Member Countries (DMCs), is responsible for global climate change. South Asia is considered vulnerable to the multiplicity of impacts and consequences involving rising sea levels, melting Himalayan glaciers and increasing frequency of typhoons. Hence, environmental degradation not only poses threats that go beyond health risks but causes major setbacks in development pathways for its economy's foreseeable future.

In the developing countries, solid waste management (SWM) is the single largest budgetary problem for the cities,

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where poor SWM system contributes to the negative impacts on health, economy and environment (Hoorweg and Bhada-Tata 2012; Cremiato et al. 2018; Malav et al. 2020). South Asia produces approximately 334 million tonnes of waste annually, with 174 million tonnes (57%) being organic. Kaza et al. (2018) highlight that the waste generation in South Asia is estimated to be around 466 and 661 million tonnes per the year 2030 and 2050, respectively, where the share of urban areas is significantly high. Controlling household waste is becoming more and more difficult for the cities as it rises in tandem with the unprecedented transition of settlements from rural to urban areas. Against this backdrop, municipal waste management (MWM) programmes come to play in combatting pollution and climate change. Although most cities in South Asia engage in open dumping, there have recently been more investments in sanitary landfills and recycling methods. India, for example, has adopted a national initiative known as Swachh Bharat Mission to strictly monitor and improve SWM by classifying biodegradable waste before disposal. However, in Bangladesh, municipal city corporations face an undesirable scenario due to over-reliance on landfilling in a country where land is already scarce.

In contrast, waste management in developed nations, especially in Europe, emerges to be more successful due to better enforcement mechanisms. For instance, Germany's waste management sector contributes significantly to the sustainable production processes that have high recovery and recycling rates, prioritising the concept of a circular economy. This, in turn, helps save raw materials and primary energy. Well-established modern sorting, treatment and recycling technologies also enhance the overall system. About one-third of the total electricity consumed is generated from waste (Weber et al. 2020).

Germany's environmental policies may help set an example for South Asia in resolving SWM issues, such as the waste-to-energy (WtE) strategy. Utilising this approach manages municipal solid waste (MSW) safely as it simultaneously mitigates rising energy demands by converting waste to heat or electricity through technological processes, such as incineration, mechanical–biological treatment (MBT) and anaerobic digestion (AD) (Tun et al. 2020; Siddiqi et al. 2020; De Gisi et al. 2018). WtE is a sustainable substitute for a clean and renewable energy source with minimal societal and environmental impact as it minimised the amount of waste dumped into landfills. Furthermore, WtE technologies have immense potential to serve as an intermediary in achieving the Sustainable Development Goals (SDGs) 7 and 11: ensuring access to adequate and clean energy and leading cities to achieve inclusiveness (Malav et al. 2020; AlQattan et al. 2018; Zhao et al. 2016). Together, effective WtE and MWM schemes supported by strong environmental governance will accomplish the SDGs by 2030.

The role of cooperative environmental governance (CEG) is to enforce environmental laws and policies as a joint responsibility for all regulating bodies within and beyond international borders. In recent years, this concept is applied as an avenue for creating collaborative partnerships with relevant stakeholders to integrate a local essence in technology and environmental decisions (Forsyth 2006; Ba 2021; Coenen et al. 2021). CEG accounts for remarkable benefits, such as cost reductions for investors by achieving local maintenance. For instance, the involvement of local citizens in Biratnagar, Nepal, has significantly reduced the costs of public policy objectives due to higher levels of environmental services leading to the proliferation of new waste management technologies (Pathak et al. 2020). WtE is relevant to CEG because it allows citizens and investors to form partnerships for various tasks such as waste collection and the provision of new technologies. This successively provides pro-poor employment opportunities and local waste management to assist development (Forsyth 2006; Coenen et al. 2021). In an economic outlook, the strongest economies in South Asia at the moment are India, Pakistan, and Bangladesh, with escalating GDP growth rates. Given the macroeconomic structural changes, the rate of urbanisation is increasing at an annual rate of change of 34% for India, 38% for Bangladesh and 37% for Pakistan, exceeding the remaining South Asian territories (World Bank 2020). Rapid urbanisation not only comes with advanced economic activities and improved standard of living, but also raises the concern on the issue unsustainable waste management.

As mentioned above, the megacities of South Asia are facing an unprecedented rural–urban migration which is leading to an increase in the generation of MSW and inefficiency in SWM has already led to environmental degradation and development setbacks among other consequences. Therefore, it is imperative to divert attention to the region-specific contemporary matter of MSW and consider closely the implementation of WtE strategies, especially in major cities, namely New Delhi, Dhaka and Karachi. Therefore, the rationale behind choosing India, Bangladesh and Pakistan for the analysis is to dive deeper and address their ongoing and prospective critical waste management strategies in order to overcome the perilous burden of waste on the economy, while viewing them as theoretical extremes. This, in turn, will critically serve as a guiding principle for the rest of the developing world.

The objective of this paper is to highlight the need for South Asian countries to consider the significance of efficient SWM in order to reduce MSW safely, as well as explore the WtE strategy and participate in CEG for further sustainable development. The novelty of this paper is threefold. First, the paper intends to discuss current situation of SWM and WtE in the context of the selected South Asian countries for reasons previously discussed. Second,

it critically explains the importance of institutional and social reforms required in South Asian countries to advance in terms of CEG and WtE, as these countries are lagging behind the exceptional achievements of their western counterparts despite possessing huge potential. Third, this paper intends to provide policy suggestions for future sustainability in terms of the creation of an integrated SWM (ISWM) system utilising the concepts of CEG and WtE.

The rest of the paper has the following algorithm. The ‘[Critical review of existing literature](#)’ section discusses review literature from the existing body of knowledge. The ‘[South Asian overview on municipal waste management](#)’ section provides an overview of waste management in the South Asian region. The ‘[Current situation of WtE in South Asia](#)’ section shows the case studies on the context of waste management, CEG and WtE in the selected South Asian countries. The ‘[An integrated SWM framework](#)’ section discusses developing country perspectives and formulates an ISWM on the basis of institutional aspects and reforms for facilitating CEG and WtE. The ‘[Conclusion and way forward](#)’ section concludes the paper.

## Critical review of existing literature

### Waste management

Technological and economic progress in the past decades has resulted in a snow-balling use of materials for production and consumption. As a result, the degree of MSW generation worldwide accelerated quickly (ISWA 2017). MSW generation would reach 6.1 million tonnes per day within 2025 (World Bank 2012). As a result, incineration of MSW will play a prominent role in managing waste and generating energy (Cucchiella et al. 2017; EPA 2016; Curea 2017 Malinauskaite et al. 2017; Makarichi et al. 2018). Currently, 80% of the global energy supply is coming from non-renewables. So, MSW incineration can help to increase renewable energy share by offsetting fossil fuel consumption while simultaneously assisting in waste management (Tester et al. 2012). Most municipal solid waste incineration (MSWI) plants are currently located in Europe, the USA and East Asian countries. In addition, some Latin American and African countries have also adopted MSWI to eliminate medical and hazardous wastes without energy recovery (Lu et al. 2017). Although the WtE industry has faced significant challenges over the years, it is now a booming industry, generating over USD 20 billion a year (WEC 2013).

Food waste represents a significant portion of MSW. About 1.3 billion tonnes of food products per year (one-third of all food produced annually) is lost or wasted in the supply-chain process (FAO 2011). Due to this, food WtE is said to be an untapped resource of energy production and reduces

the environmental burden of food waste disposal. Pham et al. (2015) provided valuable insight into food WtE conversion technologies as well as their challenges. Current technologies of food WtE are divided into biological technology (AD and fermentation of ethanol) and thermal and thermochemical technology (incineration, pyrolysis and gasification, and hydrothermal carbonisation). The study revealed that biological conversion treatments are cost-effective and easy to set up but suffer from a long treatment time and may cause inhibition of bacteria due to the presence of contaminants. Among thermal and thermochemical techniques, pyrolysis and gasification are considered environmentally and energetically unfavourable due to food waste’s high moisture content. Hydrothermal carbonisation (HTC) seems like the most eye-catching alternative for transforming waste from food into different energy sources. Nevertheless, there needs a proper analysis for large-scale production.

Perrot and Subiantoro (2018) discussed the WtE potentials in New Zealand. Waste management is a concerning issue for New Zealand as the country was ranked 10th worldwide for per capita waste generation in 2012 (Hoornweg and Bhada-Tata 2012). The country’s current strategy to tackle waste management is by reducing heavy waste, promoting the reuse of different products and recycling generated waste, while dumping the rest in landfills. The study explored other WtE technologies and concludes that AD is the most viable option as it is economical and environmentally friendly for the country.

Ouda et al. (2016) explored Saudi Arabia’s WtE potential. The study examined the power generation potential of refuse-derived fuel (RDF) and biomethanation. RDF has a higher power generation potential, but it also has major constraints in the form of high capital and operational cost and higher skill requirements. Biomethanation, having a lower WtE potential, is the more economically and environmentally sustainable solution.

Similar to New Zealand and Saudi Arabia, China’s MSW is also primarily disposed of in landfills. However, the Chinese government has taken the initiative to set up WtE plants that convert biomass into energy via incineration. Xin-gang et al. (2016) conducted an economic analysis of China’s WtE industry by considering its current technology, cost and benefit, and concluded that the industry can expect stable profits in the coming years due to the latest technology’s low operational costs. The study, however, did not take into account the risk of using China-made equipment that has a 30%–35% lower cost than imported equipment.

### Cooperative environmental governance

CEG is a general term used to describe active participation from citizens and businesses in policymaking to create a symbiotic policy toward a sustainable environment (Forsyth

2006). Pellizzoni (2003) asserted that CEG is simply a form of participatory technology assessment that considers feedback from people while using and implementing environmental technologies. Nallathiga (2012) established that environmental governance reflects a sustainable quality of life that can be experienced from both the societal point of view and the community's requirements. Many countries are trying to usher toward a more cooperative governance culture, including South Asian countries. According to Dorman and Olsen (2019), the Association of Southeast Asian Nations (ASEAN) is pursuing effective ways to create a regional ecosystem management regime by creating cooperation in transboundary issues while considering the conceptual problems of the ASEAN chapter and by integrating the local knowledge of non-state actors to resist the bureaucratic management. Dorman and Olsen (2019) also believed that the concept of sovereignty and non-interference is less prioritised by countries, even though such forms of cooperative governance are desirable for sustainable environmental growth.

## South Asian overview on municipal waste management

### Waste generation

Waste is the by-product of every consumption and production that happens in the world today. Every day, a large amount of waste is generated, in different forms and from different places. The global average of waste generation in 0.74 kg per capita per day according to the World Bank

(2016), as shown in Fig. 1. South Asian countries on average produce less waste than the rest of the world, as shown in the figure below, with an average of 0.52 kg per capita per day. Among the many countries, Maldives dominates the waste generation in South Asia by large, with a generation of 1.44 kg per capita per day and Nepal having the lowest waste generation, 0.17 kg per capita per day. Other South Asian countries such as Sri Lanka generate 0.34 kg per capita per day waste. Bangladesh generates 0.28 kg per capita per day of waste, and India generates 0.57 kg per capita per day of waste, as of 2016. The management of these waste is imperative to ensure a clean and healthy environment in these countries.

The waste that is generated can be classified into many different types, as shown in Fig. 2. As we can see, most of the waste in South Asia comes from food and green, with around 57% of the generated waste being food and green. Among others, plastic waste accounts for 8% of the generated waste in South Asia, paper and cardboard waste accounts for 10% and glass accounts for 8% of the waste. Most of the waste goes unclassified, and around 15% of the waste falls in the unclassified category.

All these different types of waste are mostly generated from residential areas, households, commercial facilities, traditional markets, public facilities and municipal services, and institutional and office spaces. We can better understand the sources of these wastes by delving deeper into the different compositions of wastes in India, Bangladesh and Pakistan, as shown in Fig. 3. Bangladesh has the highest percentage of biodegradable waste products of around 77.2%, while India and Pakistan have a biodegradable waste of 51% and 48%, respectively, as shown in the figure below.

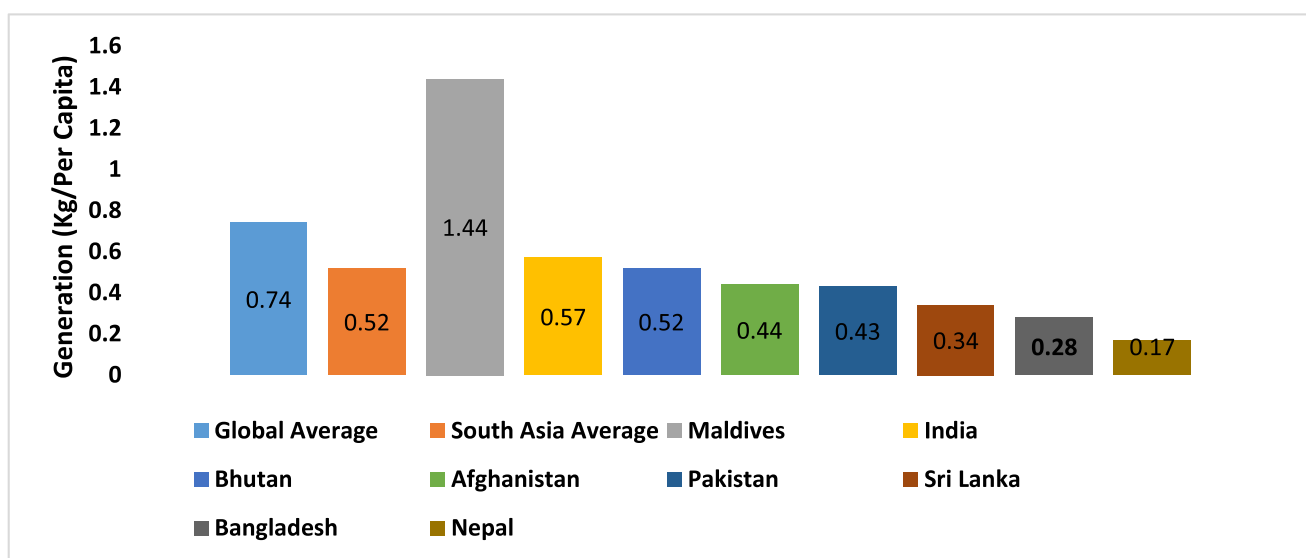


Fig. 1 Waste generation in kg per capita in South Asian countries daily. Source: Kaza et al. (2018)

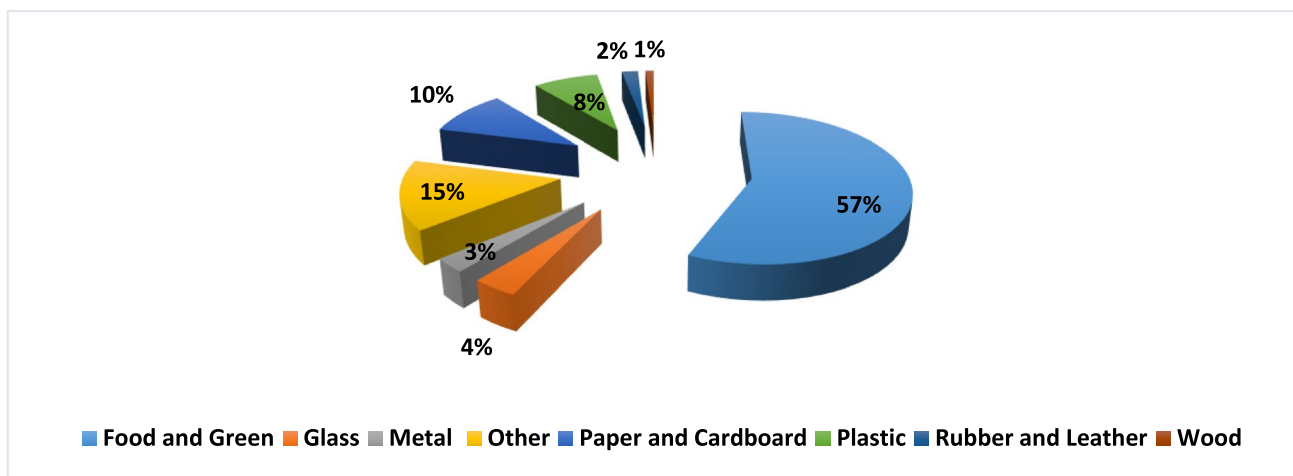


Fig. 2 Type of waste generated in South Asian countries. Source: Kaza et al. (2018)

Pakistan has a relatively high paper waste compared to the other two countries, with almost 13% of the waste being paper, while Bangladesh and India have 9.1% and 7% of paper waste. Bangladesh is also the least plastic waste country of the three, with only 4.3% of the waste being plastic, whereas India has 10% plastic waste and Pakistan has 9% plastic waste.

**Waste collection coverage**

With so much waste being generated every day in these countries, it is crucial to collect and dispose of them to ensure environmental safety and health. Collection of the waste varies for different areas; as shown in Fig. 4, urban collection coverage of South Asian countries is around 77%, while rural collection coverage is only 40%, and the total

waste collection coverage is 51% on average. Most of the uncollected waste is goes through the process of open incineration in the streets or dumped in the rivers, creeks, marshy areas and empty lots in the vicinity of the waste generation, causing environmental and health problem hazards in the areas (Visvanathan and Glawe 2006).

To better understand the waste collection coverage, we can take a deeper look at the coverage rates of the largest cities in South Asia, as shown in Fig. 5. Greater Mumbai in India has achieved 100% collection coverage, while cities like Thimphu in Bhutan, Jalalabad in Afghanistan, Colombo in Sri Lanka, Kathmandu in Nepal, and Chennai in India have achieved more than 80% waste collection coverage rate. Other cities like Rangpur in Bangladesh have a meagre collection coverage rate of 32%; Karachi in Pakistan has a collection coverage rate of 60%.

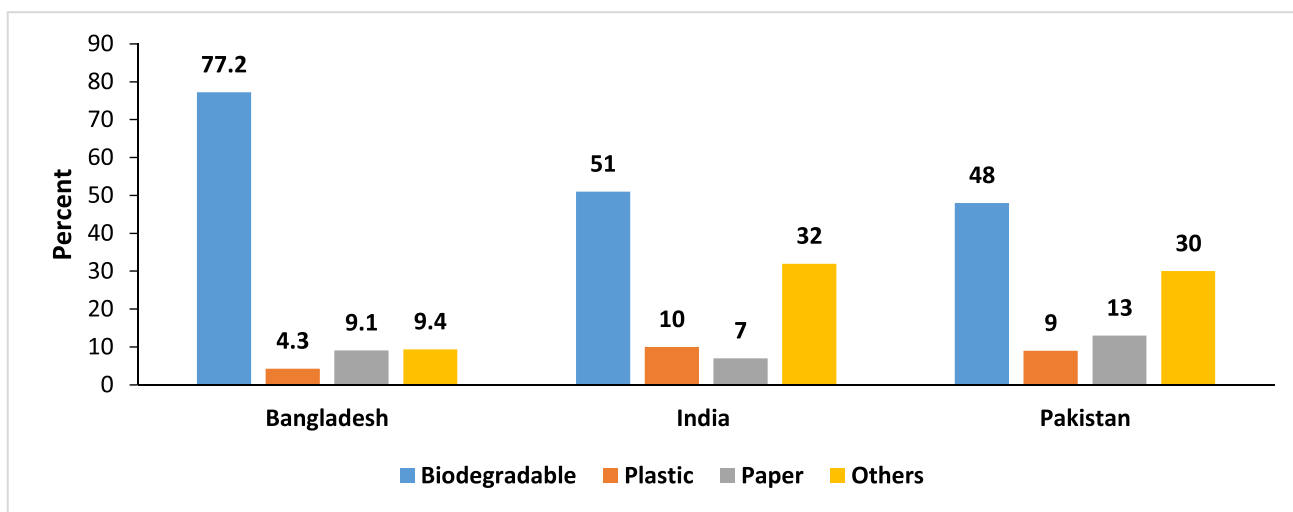
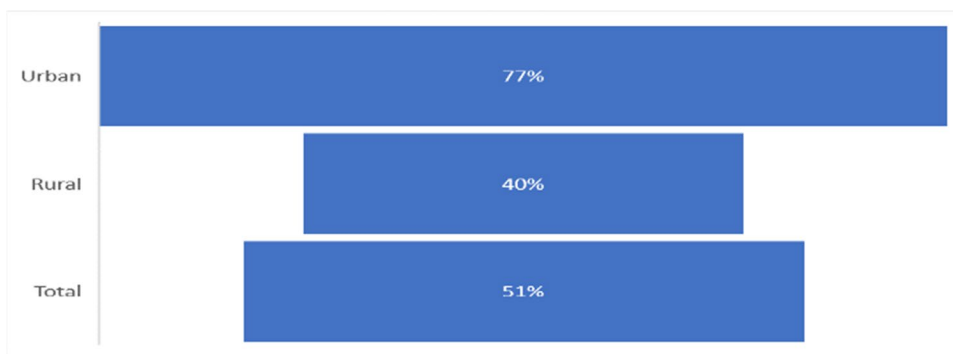


Fig. 3 Type of waste in India, Bangladesh and Pakistan. Source: Ghauri (2018); Ahluwalia and Patel (2018); Habib et al. (2021)

**Fig. 4** Percent coverage of waste collection rates in urban and rural areas



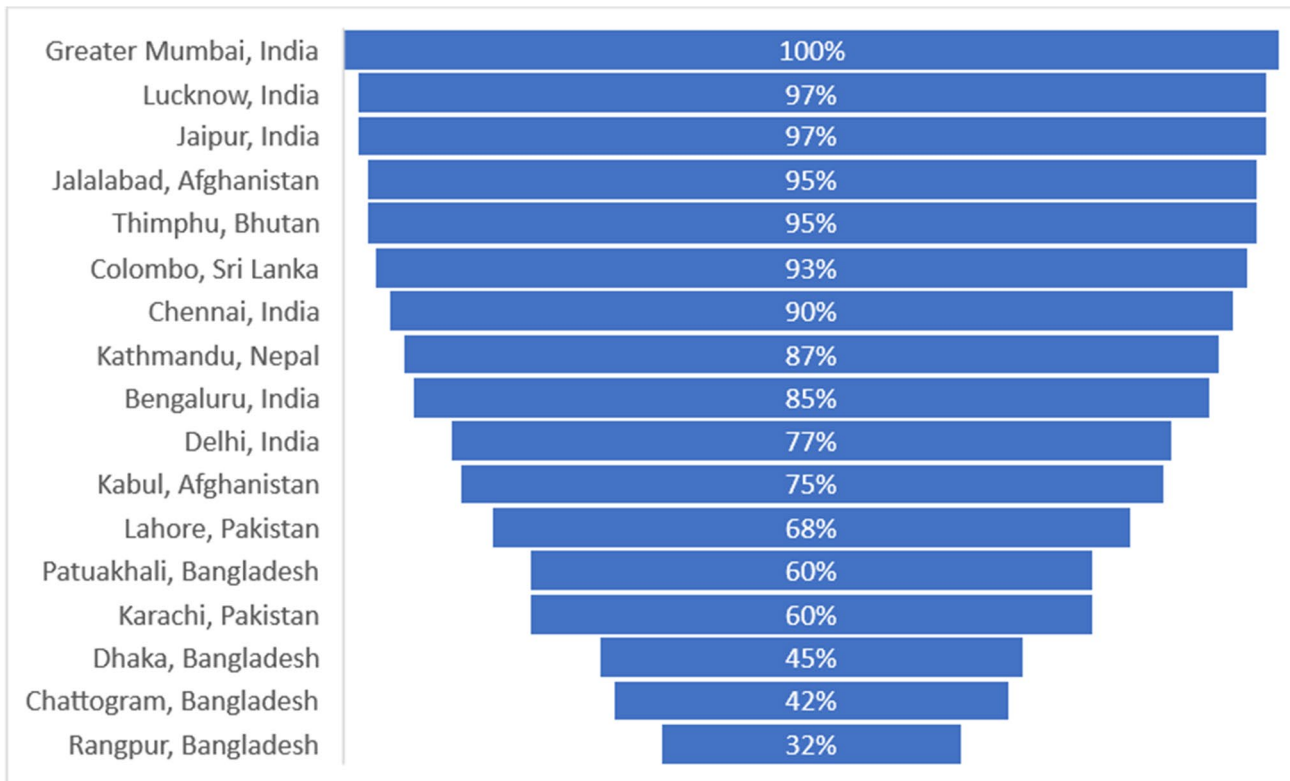
The collected waste is often incinerated to generate energy, giving the scope of converting the waste to energy. The amount of energy generated from the waste depends on the calorific value of the solid waste that is collected. As shown in Table 1, the average calorific value of the solid waste collected from Bangladesh is 2316 kcal/kg, one of the highest averages in countries from South Asia. India has an average calorific value ranging from 1411 kcal/kg to 2150 kcal/kg (Bhushan 2019). Sri Lanka also has a similar range. Its average calorific value extends from 1552 to 1791 kcal/kg (Kumarasiri and Dissanayake

2020), with Pakistan having an average calorific value of around 2310 kcal/kg (Shahzad et al. 2017).

### Current situation of WtE in South Asia

#### Overview of global WtE trends

Economic growth, rapid urbanisation and changing consumer choices result in increasing volumes and varieties of solid municipal waste (Kumarasiri and Dissanayake



**Fig. 5** Percent coverage of waste collection rates in big cities of South Asia

**Table 1** Average calorific value of solid waste in kcal/kg of Asian countries

Countries	Average calorific value (kcal/kg)	Source
Bangladesh	2316	Alam and Qiao (2020)
India	1411–2150	Bhushan (2019)
Sri Lanka	1552–1791	Kumarasiri and Dis-sanayake (2020)
Pakistan	2310	Shahzad et al. (2017)

2020; European Environment Agency 2018). Globalisation has additionally exacerbated waste management problems by expanding international waste trade, with developing countries of South Asia often at the receiving end. Inefficient waste management within the major economies of South Asia calls for an integrated approach of WtE strategies, which will be a crucial step towards sustainable development.

Today, the number of active WtE facilities worldwide is approximately 2500, which have a disposal capacity of around 400 million tonnes of organic waste per annum. According to Ecoprog (2020), the number of newly installed thermal plants is 83, which have a treatment capacity of more than 29.8 million tonnes per year in 2019. It is worth to be noted that Europe has the largest market for WtE electricity generation (47.6%). On the other hand, Japan's market share is 60% of the Asia–Pacific WtE market. China, on the other hand, has been increasing its capacity since 2011. The global WtE industry has grown by more than 16 million tonnes of MSW since 1995 and is anticipated to expand at 9.7% per annum as it becomes more economically feasible. Although WtE is a growing field from a global perspective, challenges and limitations faced by Urban South Asia impede the proper implementation of WtE recovery technologies. Therefore, introducing advanced WtE treatments varies considerably among South Asian countries, providing very limited substantial results on the successful application of projects across the subcontinent.

## India

India, the world's second-most densely populated country with 1.2 billion people, generates massive waste every day, with per-capita waste generation at 0.5 kg/day. This encompasses an enormous potential for power generation in this energy-hungry country. According to estimates from the Ministry of New and Renewable Energy (MNRE), there is about 1460 MW of potential energy in MSW. Many attempts concerning WtE technologies were made in India, which did

not reach fruition due to myriads of institutional and operational bottlenecks (Kalyani and Pandey 2014).

India's WtE measures comprise 209 composting plants, 82 biomethanation plants, 207 vermicomposting units and 45 RDF plants that are not fully operational (CPCB 2016). The five gasification/incineration plants currently operating or in the trial run have a cumulative installed capacity of about 66.5 MW. Only one of these plants is working in full capacity at Okhla, New Delhi, while another AD plant is operational at Ghazipur, Delhi. The remaining three projects are still being tested, and at least 53 WtE plants with a total capacity of 405 MW are either under construction or at tendering stages (MNRE 2018). Six projects in total are set off for power generation from MSW with a capacity of 65.75 MW (MNRE 2018). Big companies like Hindustan Petroleum Corporation Limited, Engineers India Limited and Indian Oil Corporation Limited have proposed tenders for the installation of pyrolysis plants (Gupta et al. 2018). Furthermore, the government of India is formulating numerous projects in WtE across the country in the upcoming years. MSW from towns and cities can generate almost 50.5 GW of energy, which has the potential to rise to 1.12 GW by 2031 and to 2.78 GW by 2050 (Paulraj et al. 2019). The installed capacity of WtE was previously estimated to be 43.45 MW in 2007. According to reports, it was increased to 75.80 MW in April 2017, with 3.5 MW sourced from the urban areas. As of December 31, 2018, the collective achievement was 138.30 MW (Paulraj et al. 2019).

Extensive barriers involving inappropriate methods of waste recovery and disposal, such as lack of effort in segregating waste and open dumping, create obstacles to the sustainable development of WtE (Chinwan and Pant 2014). This further challenges the outcome of CEG in India, as it constricts efficacy at the brim. There exists a vacuum amidst the governance of essential natural resources such as social and environmental forestry, surface and groundwater resource management, and land cover/land use management. Other causes underlying the failure of WtE attempts are institutional fragmentation, the absence of a strong policy framework, and a shortage of financial and logistical planning for WtE processes. Consequently, inefficiencies over time have turned the citizens alongside investors against the process. Furthermore, proper execution of CEG towards WtE in India lacks public participation, litigation, financial support, and a robust framework for policies (Malav et al. 2020). Nevertheless, India's WtE efforts prove to be promising from a South Asian context.

## Pakistan

Pakistan produces nearly 30.76 metric tonnes of MSW per year, which contains 58% of organic substance overall, according to studies conducted by Korai et al. (2017). The

use of AD to treat 0.57 million tonnes of annually generated organic waste disposed of in landfills would potentially yield 0.45 m<sup>3</sup> CH<sub>4</sub>/kg of volatile solids, having a total energy value of 2.43 TWh. MSW in Pakistan can generate 6191.13 TJ or 1.72 TWh of energy each year, relative to an approximate RDF value of 7.71 MJ/kg (Sadef et al. 2016).

Karachi and Lahore, the economic hubs of Pakistan, are willing to invest in WtE projects since the alarming rise in the amount of solid waste along with the ongoing energy crisis persists as an obstacle for the regulatory authorities of urban Pakistan. Given that the effective management of MSW in Pakistan is in its prime, the implementation of WtE measures is yet to flourish in this country (Majeed et al. 2008; Jehangir 2018). It is a common practice to either dump household waste directly on low-lying grounds or burn it outdoors, thus lacking a well-devised method of disposal. On the flip side, Pakistan's MSW has a significant potential to generate energy through biochemical and thermochemical processes, with yearly capacities of up to 50.35 million m<sup>3</sup> and 265 million m<sup>3</sup>, respectively. Solid waste energy accounts for nearly 0.41% of the country's overall primary energy supply via biochemical and thermochemical processes (Korai et al. 2017).

Pakistan only features a few WtE power plants based in Lahore, Karachi, and Punjab. In 2018, Pakistan's National Electric Power Regulatory Authority (NEPRA) approved the country's first 40 MW WtE power station in Lahore. NEPRA anticipates that its successful implementation will pave the path for more projects to address Pakistan's critical waste management, landfill space constraints and pollution. This will, in turn, lead to more hygienic environments for cities. Similarly, a cost–benefit analysis was conducted on an innovative 150 kW capacity pilot WtE plant. The novel AD plant demonstrated sustainable and propitious characteristics with 142.4 MWh annual generation, rate-of-return of 15.4% over the capital investment and an annual economic benefit of USD15,430.00 (Rasheed et al. 2019).

Pakistan, on a similar note with its neighbour India, struggles in stably devising CEG. Jahangir (2018) indicated cultural and climatic factors as the country's main contributors to incompetent waste management. Weak institutions, political instability, poorly financed resources, lack of cooperation between government organisations and awareness among people are root factors for worsening the scenario of MWM programmes.

## Bangladesh

WtE is a comparatively new dimension in generating electricity for Bangladesh. The urbanised city of Dhaka dwells in a humongous waste load of 1.04 million tonnes to an estimated 6.6 million tonnes annually from the year 2000–2050. On the other hand, the country's fossil fuel-driven energy

mix is inefficient due to the lack of distribution facilities. WtE through incineration provides a lucrative solution to waste management and diversifies the electricity generation mix, besides addressing issues concerning land/space limitations in Bangladesh. Significantly less space is needed for WtE and can process huge volumes of waste in a single processing plant; however, it bears the cost of environmental and health implications as incineration gives rise to air pollution (Hossian 2020).

The government of Bangladesh has recently commenced the installation of two WtE power plants in Dhaka, one in Aminbazar and the other in Matuail landfills. This will serve as the first WtE project that will generate energy from waste in the country, thus aiming to create a habitable and clean city (Mamun 2020). About 42.5 MW of electricity will be generated daily by utilising 3000 tonnes of MSW. A combustion technology will be followed to burn the waste, which will increase carbon emissions in the city on the downside. The developed nations of Canada, the USA and most European countries are currently implementing an environment-friendly gasification technology to tackle such problems. Other development projects of WtE plants are underway in Narayanganj and Gazipur (Byron and Alam 2020).

Dhaka has been growing without much of plan, given the existing loopholes in the city's waste management schemes (Islam 2016). Hence, successful and sustainable solid waste management can be achieved only through a joint involvement of all stakeholders, which again underpins the importance of CEG.

## An integrated SWM framework

### A comparative analysis with developed nations

The developed nations of Denmark, Italy and the UK have revolutionised WtE by innovation in WtE technologies, effective MWM policies and integrated mechanisms for SWM. Thus, by analysing the success strategies of these countries, developing nations can take lessons for creating their own ISWM framework.

#### Denmark

Denmark has initiated many advancements in waste management and energy conversion techniques to establish itself towards a circular economy. As a result, the country has emerged in pioneering effective WtE measures (Thomas 2012; Edo 2021; Kleis and Dalager 2004). The nation built the first waste incinerator in 1903 and currently has 23 waste incinerators with a total capacity of 4.3 million tonnes. These plants contribute 20% of the country's district heating and 5% of electricity consumption. Roughly 40% of the

renewable energy in Denmark comes from WtE (DAKOFA 2018).

Policy instruments, including the prohibition of incinerating waste from landfills, proved revolutionary in managing municipal waste. Denmark's goal to upscale recycling of various fractions of household waste to 50% by 2022 is set on a target, according to the midterm evaluation of the waste strategy (EPA 2016). The rates of recycled organic waste, plastic, wood, glass, paper and cardboard, together, had risen from 22% to 36% within 5 years since 2011.

Furthermore, the Copenhill WtE plant, built in 2013 within the urban central of the capital Copenhagen, epitomises the notion of a WtE plant by resolving the struggle to treat excess waste which was not of use to the governing body. The project exemplifies integrating WtE plants within an urban environment setting as it seeks to collaborate with residents to obtain acceptability. As the absence of a collaborative approach is often cited as a factor for rejected project proposals in developing nations like South Asia, Copenhill emerges as a lesson pinpointing CEG for integrating WtE plants in urban areas.

Developing nations of South Asia can similarly make a wise move to exploit this silver lining of burgeoning waste as an effort to reoxygenate its economy sustainably.

## Italy

Italy has one of the highest number of incinerators (41) in the European Union (EU), and 5.6 million tonnes of MSW were incinerated in 2015, and about 3.4 million tonnes of MSW were converted to 2.7 million MWh energy. Moreover, out of the 5.2 million tonnes of MSW produced currently, about 3.4 million tonnes move towards composting plants, 1.6 million tonnes converted in integrated plants such as MBTs to be converted to energy by AD, and the remaining goes to other biological WtE plants, with the rest being imported (Malinauskaite et al. 2017). Moreover, from the approach of Italy, it is evident that a step-by-step mechanism where each function of the MWM is unbundled to different entities is an effective solution to unsustainable MWM. Thus, developing countries can follow the footsteps of Italy to develop such an integrated mechanism.

## The UK

The potential of WtE in the reduction of carbon dioxide or CO<sub>2</sub> emissions in the UK was realised in 2011 upon the formulation of the Anaerobic Digestion Strategy and Action Plan (DECC and DEFRA 2011). They not only doubled the number of AD in the next 2 years, but have developed their energy recovery mechanism in a large scale with 29 energy recovery facilities (ERFs) in 2014 (Malinauskaite et al. 2017). Moreover, the innovative pyrolysis chamber

(PC) for domestic use, called home energy recovery unit, was invented as a way to include households in the energy recovery mechanism (Spencer et al. 2015). Moreover, the UK is the largest exporter of waste in Europe.

Since the innovative policies and technology of the UK were successful in creating a sustainable SWM system, developing countries can follow suit.

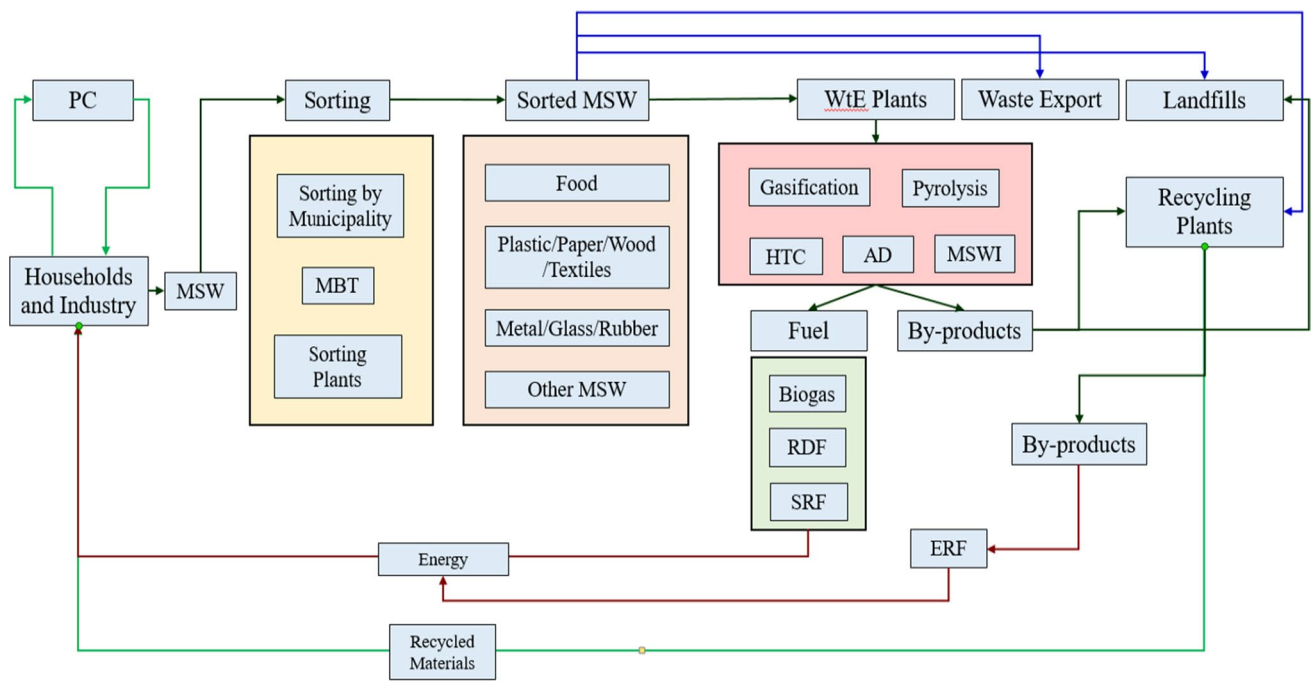
## The ISWM framework

From the above discussion, it is evident that there is a need of a proper mechanism, collaboratively followed by all stakeholders involved, for the sustainable management of MSW in developing nations. To this backdrop, the following ISWM framework has been formulated, as shown in Fig. 6.

The integrated framework represents not only the channels through which MSW can be sustainably managed but also how MSW can be utilised as a resource for recycling, energy production and waste export. As Fig. 6 below shows, the MSW generated from households and industry initially needs to be sorted into varied forms for efficient utilisation. This can either be done through the cooperation of households and industry, where there will be an initial sorting. Afterwards, the MSW will be sent either to a centralised sorting plant or an MBT.

After sorting, the different forms of MSW will be sent to different WtE plants according to their use. For instance, the food and kitchen wastes will be sent to an HTC to be converted to energy, while the plastic or paper wastes can either be incinerated in an MSWI or pyrolysis plant to be converted into biogas, or shredded to form RDF or solid recovered fuel. Besides, MSW from an MBT will undergo AD to be converted to RDF or biogas to be ploughed back into the households for use. The benefit of using methods such as AD as an alternative to MSWI is the minimisation of harmful GHG emissions. The by-products of the WtE plants will be passed onto recycling plants or thrown in landfills.

As we can see, there are three other channels, apart from WtE plants, through which the MSW can move. The MSW that is not utilised in the WtE plants will either be thrown in landfills or recycled, or exported to developed countries such as Latvia, Austria, Hungary and Estonia, with large WtE industries. The more MSW is channelled through WtE, recycling and exports, the less will be the requirement for landfills. This will ensure that the environmental harms of landfills can be mitigated to a large extent. Moreover, the materials in the recycling plants which cannot be recycled can be passed onto an ERF to be converted to energy. Another possible channel through which MSW can be circulated sustainably as energy is by the use of a PC in households and industry (Spencer et al. 2015; Nyoni and Hlan-gothi 2022). Thus, proper implementation of the integrated



**Fig. 6** An integrated sustainable waste management (ISWM) framework

framework will allow the developing countries to nudge closer to a circular economy.

However, the construction of regional and national sorting, recycling and WtE plants requires the collaboration and cooperation amongst the stakeholders involved (Amin et al. 2022). This makes CEG an important factor in the investment and operation of such an integrated SWM system. Moreover, in developing countries like Bangladesh, India and Pakistan, there needs to be proper institutional reforms for the functioning of such a sophisticated system. There also needs to be proper guidelines by the government and policymakers to ensure that the channels through which the MSW is mechanised to go through are being followed by the various stakeholders. Moreover, there are some environmental harms of incineration which needs to be taken into consideration while formulating policies, to ensure that the MSW is diversified into different methods of WtE to reduce carbon emission from MSWI. The next subsection discusses key aspects of institutional reforms in more details.

### Institutional reforms: from where to start?

Given the composition of MSW in the selected South Asian countries, WtE can be a pathway for green transition in the upcoming years. Relying on the country level discussion, to strengthen both the CEG and WtE, we argue that institutional reforms are extremely important. Institutional reforms and its impact on green transition has been discussed widely (Chen and Liu 2017; Mittal et al. 2018; Amin and Rahman 2019; Nevzorova and Kutcherov 2019; Amin et al. 2022). Institutional

reforms in simple words can be the way of eradicating or at least mitigating institutional barriers prevailing in the existing setup. It is worth mentioning that instructional reforms can initialise from different channels given the source of the problem. From the theoretical literature, dynamics in the intuition's role can be described by three distinct legitimacies (Markard et al. 2016; Deephouse and Suchman 2008). First is cognitive legitimacy, which mainly describes the best use of resources within the institutions and managerial activities. Second, normative legitimacy describes the linkage between prevailing social values and intuition's role in different activities. Third, regulatory legitimacy discusses the structure of standard rules, policies and effectiveness in the process of bureaucracy.

For facilitating both the CEG and WtE, we emphasise on the regulative legitimacy for introducing institutional reform in the selected South Asian countries. The reason behind such an argument is that existing literature widely agrees on the fact that the government dynamics in the South Asian countries are based on a fragmented work system in a centralised framework (Mirza et al. 2008; Vijay et al. 2015; Yasar et al. 2017; Amin et al. 2022). The resulting loopholes due to such characteristics have been found to be associated with sluggish advancement of WtE transition through CEG and its dissemination to the consumers. Some of the examples of some poor outcome resulting from lack of solid instructional assistance is convenient in this discussion. For instance, Bangladesh could not be able to achieve efficiency in community-level WtE (especially gas and electricity) generation due to institutional regulations

and policy inconsistencies. On the other hand, many WtE plants in India started to close down due to lack of feedstock availability given there was no proper institutional collaboration between institutions related with MSW collection and inter-ministerial bureaucracy (Mittal et al. 2018). Similarly, in Pakistan, several green energy programmes failed because of insufficient regulatory guidelines (Yasar et al. 2017). For these South Asian countries, basic waste treatment operations should be established properly first and then implementation of WtE technologies might be an option.

Therefore, it is imperative for the governments of the selected countries to prioritise the institutional reform related with CEG and WtE generation, for instance, reforms in the institutions which are linked to domestic technology and human development, infrastructure development, waste management system, market monitoring, financial system, as well as decision-making for future sustainability.

## Conclusion and way forward

In this paper, the main aim has been to critically discuss waste management in urban South Asia and the implications of CEG and WtE to formulate a realistic ISWM framework. Given the rapid urbanisation, waste generation from the urban municipals is increasing at a reasonable rate. Even though the waste management systems are improving in different South Asian cities, due to the lack of cooperative governance, the collected waste is not realised for generating energy through WtE technologies. Besides, most of the collected waste is being dumped in the dumping zone in an unsustainable manner, leading to environmental pollution. In addition, if most of the waste is incinerated, it can lead to an increase in harmful GHG emissions.

This has been done by first analysing the current situation of South Asian nations on MSW production and management. Then, a comprehensive case study on South Asian nations was conducted to find the problems that contribute to inefficient and unsustainable MWM. Afterwards, the success cases of developed countries were analysed to form an integrated SWM (ISWM) framework, to find fruitful policy implications.

The results of the framework suggest that if MSW can be sustainably managed in an integrated manner to include WtE, recycling, export and other MWM mechanisms, it will not only mitigate environmental damage, but also improve energy security in the developing countries by reducing the dependency on imported oil, as portrayed by Jamasb and Nepal (2010) for the case of the UK. Therefore, governments should augment WtE policies with CEG to ensure future energy security and SWM. In addition, WtE strategies such as AD and MBT, among others, not only have the benefit of reducing landfill, but also as an effective way of dealing with MSW without incineration and production of harmful GHG emissions.

Moreover, advancement in the urban waste management system needs to be improved by introducing different skills development programmes in soft skills and technological skills. This will be very useful for maximising the level of organic waste collection by the responsible entities of the urban municipal corporations in the cities of the selected countries and further lead to infrastructural development. Besides, such action will also help run WtE generation programmes fluently in the urban areas since WtE plants do not have to worry about feedstock availability and extensive sorting of collected waste before usage. Besides, following Amin et al. (2022), we argue for a quick introduction of energy service companies (ESCOs). The enlisted ESCOs will be extremely helpful in providing the necessary technical assistance to different WtE plants to improve their production efficiency scales. On the other hand, we highlight the importance of the integrated regional WtE act for regional collaboration to strengthen bilateral investment in the WtE projects and share technology and information.

A rational beginning in terms of reform related with social activities can be through targeted promotional activities. It is worth mentioning that the promotional activities should be based on the concept of social justice; otherwise, alteration in the traditional norms and behaviours within the societies regarding waste management may not bring desirable outcomes. For facilitating the promotional activities, the government needs to collaborate with local and international non-government organisations. In addition, following the developed countries, incentive-based mechanisms should be introduced to attract households to cooperate with the efficient waste management programmes, for example, e-tokens or vouchers for keeping organic and inorganic wastes separately before waste collectors come to collect waste, or helping to support the clean-up of the community.

A continuation of this paper can be to analyse the concept of CEG and WtE of different regions for the formulation of region-specific policies and the potential process of inter-regional collaboration. Another extension avenue can be to empirically test the effects of CEG implementation and WtE acceleration on different SDGs and macroeconomic aspects both from country and region perspectives.

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**Author contribution** SA generated the idea of the paper and supervised the paper. FK reviewed literature and prepared parts of the paper. MKK reviewed literature and prepared parts of the paper. JJ and SZR reviewed literature and prepared parts of the paper. All authors read and approved the final manuscript.

**Data availability** The dataset of different variables generated and/or analysed during analysis are available in the World Development Indicators (WDI) repository (<https://databank.worldbank.org/source/world-development-indicators>).

## Declarations

**Ethical approval** Ethical approval is not applicable for this paper since the analysis does not involve any test on animals or human subjects.

**Consent to participate** Consent to participate is not applicable for this paper due to the nature of the analysis. This is a purely analytical paper using secondary macroeconomic data.

**Consent for publication** Consent for publication is not applicable for this paper since the paper does not use any data or other instruments prepared by other individuals.

**Conflict of interest** The authors declare no competing interests.

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