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TECHNICAL PAPERS

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SHERPA TRACK

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Waste Management and Waste- to-Energy

Waste policy guidance for Climate Change Mitigation and Energy Generation

ISWA Team

Deji Fawole, Senior Project Manager, SCS Engineers[1]

Mpendulo Ginindza, Head SHEQ & ERM, Mintek/Advisory Board Chair, ISWA ARC

Kurannen Baaki, Senior Lecturer, Liverpool John Moores University

Denis Kalumba, Professor, University of Cape Town

Suzan Oelofse, Principal Researcher, Council for Scientific and Industrial Research

Wisdom Dlamini, Senior Lecturer/Coordinator, Centre for Climate Change and Sustainability Research, University of Eswatini

Alex Akhigbe, Founder, African Clean Up Initiative

Department of Forestry Fisheries and the Environment (DFFE)

Mamogala Musekene, Deputy Director-General, Chemicals and Waste Management

Kgauta Mokoena, Chief Director, Chemicals and Waste Policy, Monitoring and Evaluation

Matjelele Phaladi, Director: Waste Licensing

Mishelle Govender, Chief Director: Hazardous Waste and Licensing

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EXECUTIVE SUMMARY

The global surge in municipal solid waste (MSW), driven by rapid urbanization and economic growth, poses a severe threat to climate stability, environmental health, and public safety. Mismanaged waste—particularly in developing regions like sub-Saharan Africa—results in pollution, greenhouse gas emissions (GHG), and resource depletion. Traditional and unsustainable disposal methods, such as non-engineered landfilling and open dumping, demand urgent replacement with circular and integrated waste management systems. This technical paper evaluates the global waste management landscape, emphasizing the promise and challenges of waste-to-energy (WtE) technologies as part of the transition toward sustainability, which under the right circumstances is preferable to disposal in the waste hierarchy. WtE offers dual benefits: reducing the volume of waste while generating partly renewable energy. However, technology adoption faces considerable barriers in low-income countries, including high capital costs, inadequate waste collection infrastructure, and policy gaps. Also, broadly, further technology development need to carefully avoid creating lock-in effect of over-capacity. This paper underscores the need for policy coherence, investment in infrastructure, stakeholder collaboration, and inclusive approaches such as integrating informal waste pickers into formal systems. It also advocates for the selection of context appropriate technologies based on local waste composition and economic capacity. Drawing from recent G20 deliberations, the paper aligns waste management reforms with global commitments to the Sustainable Development Goals (SDGs) and the Paris Agreement. It outlines strategic policy recommendations, such as promoting extended producer responsibility (EPR), public-private partnerships (PPP), and digital innovations to modernize waste systems. The role of Africa in leading regional adaptation and circular economy strategies is highlighted, especially within the broader G20 framework. In summary, effective waste management and WtE technologies are essential tools in combating climate change, advancing sustainable development, and ensuring environmental justice. The paper presents a roadmap for action to ensure resilient, inclusive, and sustainable waste systems across developing and developed nations alike.

1 INTRODUCTION

The escalating generation of municipal solid waste (MSW) has become a critical global issue, significantly contributing to climate change, environmental degradation, and biodiversity loss. Rapid urbanization, industrialization, and population growth—across both developed and developing regions—have intensified the challenges associated with effective waste management, making it one of the most urgent sustainability concerns of the 21st century.

If left unaddressed, the unchecked increase in waste volumes will continue to strain ecosystems, compromise public health, and deplete natural resources.

Leading organizations such as the International Solid Waste Association (ISWA) and the United Nations Environment Programme (UNEP) have warned of the profound risks posed by mismanaged waste. Both emphasize that improper disposal practices represent a major global threat to human well-being, ecosystem integrity, and climate stability.

Traditional disposal methods like open dumping and non-engineered landfilling are environmentally unsustainable. These practices contribute to severe pollution through plastic accumulation, methane emissions, and toxic leachate, all of which harm air, soil, and water systems. Given the magnitude of these impacts, there is an urgent need to shift from linear, disposal-centric models to integrated, circular approaches that prioritize waste prevention, material recovery (reuse), recycling and where possible recovery (energy generation).

Among emerging solutions, waste-to-energy (WtE) technologies offer a promising dual benefit: reducing landfill dependency while generating partly renewable energy, but should be carefully developed to avoid creating a lock-in effect of over-capacity. This paper examines the global waste management landscape and advocates for immediate, coordinated action to strengthen national and regional waste strategies.

Key objectives include promoting a life-cycle approach to waste, enhancing national policy frameworks, fostering international collaboration, and investing in circular economy principles. Special emphasis is placed on energy recovery as a transitional strategy. Furthermore, the alignment of waste strategies with broader environmental, sub-regional, and international climate goals is vital to avoid a looming crisis in public health and environmental stability. The paper underscores the critical role of policy coherence, technological innovation, and stakeholder engagement in achieving long-term sustainability in waste management.

2 STATE OF WASTE MANAGEMENT AND WTE TECHNOLOGIES

The Global Waste Management Outlook 2024 (UNEP, 2024) reports that as of 2020, about 38% of global MSW disposal was uncontrolled (dumping and open burning). Regional distribution of MSW disposal paints a starker picture for the African continent with, for example, about 85% of MSW disposal in sub-Saharan Africa is uncontrolled disposal. However, waste collection coverage in African cities range widely and sub-Saharan Africa is forecast to become the dominant region globally in terms of total waste generation if current generation trends persist (UNEP, 2018). The Global report also indicates that a significant portion of uncollected MSW is from low-income countries particularly in Africa and Asia. Besides uncontrolled disposal and uncollected MSW, a significant global challenge with

waste management is transboundary movement. Transboundary waste movement poses major environmental and governance issues, especially for developing countries that frequently receive hazardous and non-recyclable waste from high income nations. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989) provides the global legal framework for regulating transboundary movement of wastes. The Convention, with 191 party countries, emphasizes environmentally sound management and requires prior informed consent of a receiving country before hazardous and certain other wastes are exported. Recent amendments such as the Plastic Waste Amendments (2021) have strengthened controls to curb illegal dumping and ensure greater accountability.

WtE is potentially a viable option in low-income countries facing uncontrolled waste disposal challenges. However, a lack of effective waste collection systems to move household waste out of communities into sustainable waste management systems is often at the core of MSW management challenges. Introducing waste treatment technology on its own, will not address the collection challenge. Furthermore, according to the World Bank (Hoornweg and Bhada-Tata, 2012), the composition of MSW in sub-Saharan Africa is significantly different when compared to global MSW. In sub-Saharan Africa, the organic fraction contributes 57% and plastic 13% of MSW while global MSW contains 46% organic waste and 10% plastic. A high percentage of organic waste in MSW means a high moisture content, which has a direct bearing on the management of the waste. Therefore, the selection of technology solutions must be informed by the composition of the waste stream and a comprehensive feasibility assessment.

WtE technologies refer to any waste treatment process that can produce usable energy in the form of heat or electricity from a range of waste materials. WtE technologies are broadly categorised into thermal (e.g., combustion or incineration, pyrolysis and gasification) and non-thermal or biochemical (e.g., anaerobic digestion, landfill gas recovery, fermentation, composting) treatment processes. WtE as a waste treatment technique sits below recycling in the waste management hierarchy (UNEP, 2019a) and considered to have a lower negative environmental impact compared to other disposal options such as controlled (incineration without energy recovery, landfilling) and uncontrolled disposal (open burning and open dumping). There are also arguments that WtE cushions the detrimental economic effects of an immediate and total transition to renewable energy (Khawaja et al., 2024; Kalyani et al., 2014; Stehlík, 2009). Despite recognition of a variety of WtE technologies, thermal WtE remains the most widely developed WtE technology accounting for about 88% of global WtE market (UNEP, 2019a; Varjani et al., 2022). However, the majority of thermal WtE technologies are in developed countries, led by Japan, France, Germany and the United States (UNEP, 2019a). In Africa, the Reppie plant in Ethiopia remains the only flagship thermal WtE plant. The abundance of organic waste resources in African countries have potential as feedstock for domestic or large-scale biodigesters through anaerobic digestion,

however, only a few advanced and commercial scale biodigesters such as the Bronkhorstspruit biogas plant in South Africa and Gorge Farm Energy Park biogas plant in Kenya are operational in Africa (Adeleke et al., 2021) and landfill gas-to-energy has potential to reduce the global warming potential by 72.2% in urban areas of Africa (Cudjoe and Han, 2021). Electricity recovery from MSW through landfill gas-to-energy technology is economically feasible in most African countries (Cudjoe and Han, 2021).

3 PAST G20 DELIBERATIONS AND COUNTRY POSITIONS

Previous G20 deliberations have culminated in Leaders' Declarations clearly articulating respective country positions. The themes are consistent with the broader commitments to sustainable and inclusive growth, climate resilience, and international cooperation and reflect the urgent need to align economic development with the complexities of emerging geopolitical, socio-economic, and environmental challenges. Despite all efforts, progress toward the Sustainable Development Goals (SDGs) remains inadequate, with many targets either stalled or regressing. Some gains have been reversed by the years of cascading challenges and crisis (G20, 2022; G20, 2023; G20, 2024). In 2024, G20 leaders reaffirmed their dedication to fostering a just world and protecting the planet, emphasizing the need to scale up climate actions in line with the Paris Agreement.

A prominent topic in recent discussions has been waste and secondary resource management. As economies grow, so does waste generation, necessitating responsible management strategies. The G20 has highlighted the critical role of international cooperation in advancing sustainable waste management and transitioning to a circular economy. Leaders have stressed the importance of reducing waste generation, particularly unmanaged and poorly managed waste, through initiatives like zero waste programs. Prioritizing waste prevention, reduction, reuse, and recycling has been identified as vital for combating plastic pollution and promoting environmental sustainability. These efforts align with global initiatives to end plastic pollution through fair, transparent, and legally binding instruments (G20, 2024).

Climate finance has also been a focal point of G20 deliberations. Leaders have emphasized the need to scale up climate finance and investment for developing countries (G20, 2024), ensuring these efforts are transparent, targeted, and aligned with global climate and sustainability goals. Support for both public and private investments in climate and environmental initiatives is crucial for reducing greenhouse gas emissions and advancing sustainable development. The G20 recognizes that such investments must align with the priorities and strategies of individual countries to maximize their impact. Implementing digital transformation opportunities to boost sustainable and inclusive growth is recommended. By addressing systemic inequalities and promoting equitable opportunities, the G20 aims to build resilient economies that benefit all segments of society. Moving

forward, the G20's ability to translate these commitments into tangible outcomes will be critical for achieving a sustainable and equitable future.

4 CURRENT INITIATIVES AND DEBATES

This section presents initiatives and debates on climate change and SDG priorities, waste management, WtE and barriers to the adoption of such technologies.

4.1 Climate Change and SDG Priorities

The SDGs, also known as the Global Goals, were adopted by all United Nations Member States in 2015. They represent a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030. These priorities, commonly referred to as the 5Ps of the SDGs; People, Planet, Prosperity, Peace, and Partnership, form the framework to achieve sustainable development through integrated social, environmental, and economic dimensions.

The Global Waste Management Outlook 2024 highlights how waste management is directly linked to all 17 SDGs (UNEP, 2024). For Africa, key SDG priorities include SDG 13 (Climate Action), SDG 2 (Zero Hunger), and SDG 6 (Clean Water and Sanitation), as these areas are critically impacted by climate change. The adverse effects of climate change, such as prolonged droughts and erratic rainfall, continue to undermine efforts to improve food security, water availability, and health outcomes. According to the UNDP South Africa Climate Change Adaptation Programme, South Africa's economy and livelihoods, for instance, are heavily dependent on climate sensitive sectors such as agriculture, forestry, and tourism (UNDP, 2025). Changes in temperature and precipitation patterns can significantly affect these sectors, leading to widespread social and economic disruptions.

Additionally, SDG 12: Responsible Consumption and Production also plays a crucial role in ensuring sustainable waste management and resource utilization. According to the United Nations, our planet is running out of resources, but populations are continuing to grow. If the global population reaches 9.8 billion by 2050, the equivalent of almost three planets will be required to provide the natural resources needed to sustain current lifestyles. A significant transformation in consumption habits is required, including a shift toward renewable energy sources and more efficient resource use. However, global crises have led to a resurgence of fossil fuel subsidies, which nearly doubled between 2020 and 2021 (IEA, 2022) undermining progress toward sustainable energy transitions.

Effective waste management and the integration of WtE systems are essential to addressing today's interconnected global crises. These solutions play a vital role in advancing multiple SDGs by combating climate change, reducing environmental degradation, and fostering inclusive economic growth. In South Africa, as in many other regions, WtE technologies are

being explored to simultaneously meet energy demands and waste management challenges. While SDG 12 focuses on responsible consumption, SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. Waste-to-energy technologies contribute to both goals by converting waste materials into usable energy, reducing dependence on fossil fuels, and minimizing the burden on landfills.

This highlights the urgent need for targeted climate adaptation and mitigation strategies that align with the SDGs. These strategies must be inclusive, integrating local knowledge and traditional practices, promoting sustainable land use, and strengthening the resilience of vulnerable communities. Equally important is the role of government policy, international cooperation, and public-private partnerships in establishing effective pathways toward achieving the SDG targets.

Across the African continent, countries have made meaningful progress in confronting these overlapping challenges. Many have submitted Nationally Determined Contributions (NDCs) under the Paris Agreement, outlining their commitments to reduce greenhouse gas emissions and enhance resilience. These efforts are complemented by a growing policy shift from a linear to a circular economy. According to the Council for Scientific and Industrial Research (Padayachi et al., 2023), circular economy strategies focus on designing out waste and pollution while regenerating ecosystems thereby aligning environmental, economic, and social priorities.

Regional coordination is also gaining momentum. The African Adaptation Initiative (AAI), launched in 2018, supports sustainable agriculture, water management, and disaster risk reduction across the continent. In addition, the SADC Regional Circular Economy Strategy 2023 aims to enhance coordination and unified action among member states. These initiatives underscore Africa's commitment to addressing climate challenges and elevating waste management as a strategic sector. Africa's growing role in the global economy is reflected in the African Union's permanent membership in the G20, and its recognition in global forums such as the G20 Summit 2024 further emphasizes the continent's importance in international decision making.

At the local level, municipalities are increasingly aligning their waste management policies with specific SDGs. For example, reducing landfill use supports SDG 12.5, decreasing methane emissions contributes to SDG 13.1, and ensuring equitable access to sanitation addresses SDG 11.6. Indicator 11.6.1 specifically measures the proportion of urban solid waste that is regularly collected and adequately managed. Many municipalities monitor these efforts through sustainability dashboards or annual environmental performance reports, which provide transparent metrics to assess progress. Additionally, some pursue ISO 14001 certification to formalize their environmental management systems and publicly demonstrate their commitment to sustainability goals.

A comprehensive and inclusive approach to waste management, grounded in solidarity, equity, and sustainability, can drive significant progress across the African continent. By addressing the root causes of pollution, enhancing livelihoods, and building climate resilience, such efforts will contribute meaningfully to the broader global goals of sustainable development and environmental justice. This paper emphasizes the critical importance of prioritizing climate action within the broader SDG framework and offers a roadmap for policymakers and stakeholders working to foster resilience and sustainability in Africa, particularly within the South African context.

4.2 Waste Management

Waste management represents one of the most pressing yet often overlooked challenges in global environmental governance. Municipal solid waste generation has risen in tandem with urbanization, industrialization, and shifting consumption patterns. According to the Global Waste Management Outlook 2024, global MSW generation reached an estimated 2.3 billion tonnes in 2023 and is projected to increase to approximately 3.8 billion tonnes by 2050 under a business-as-usual scenario (UNEP, 2024). This exponential growth is concentrated in rapidly developing regions such as sub-Saharan Africa and South Asia, where waste generation is outpacing the capacity of municipal systems to manage it safely or efficiently.

There are stark inequalities in how waste is generated and managed across the globe. High income countries, despite comprising only 16% of the global population, generate over 30% of the world's waste, much of which is diverted to controlled treatment methods such as recycling, composting, or incineration (Kaza et al., 2018; UNEP, 2024). By contrast, in low- and lower-middle-income countries, waste collection rates can be as low as 40%, with up to 90% of the collected waste disposed of in open dumpsites or through open burning (Wilson et al., 2012; Hoornweg & Bhada-Tata, 2012). This disparity not only reflects economic and institutional capacity gaps but also has major implications for public health and the environment.

Poorly managed waste contributes substantially to global climate change. Organic fractions of waste, particularly food and garden waste, dominate MSW composition in lower-income regions and are the primary source of landfill methane emissions—a GHG with 84 times the global warming potential of carbon dioxide over a 20-year period (Saunois et al., 2020). It is estimated that waste contributes about 3% of total anthropogenic GHG emissions globally, with the bulk of it originating from landfills and open burning (Bogner et al., 2008). Furthermore, black carbon released from waste incineration and open burning has been identified as the second most important climate-forcing agent after CO_2, amplifying the urgency of controlling these practices (Bond et al., 2013; Wiedinmyer et al., 2014). The continued use of non-engineered dumpsites, particularly in regions with inadequate

regulatory oversight, not only accelerates emissions but also contaminates soil and groundwater, endangering terrestrial and aquatic ecosystems (Ferronato & Torretta, 2019).

Health impacts linked to mismanaged waste are significant, particularly in densely populated urban areas. Informal settlements near dumpsites are often exposed to hazardous emissions and vectors of disease, leading to elevated rates of respiratory illness, gastrointestinal disorders, and vector-borne diseases (Giusti, 2009). Epidemiological studies have linked prolonged exposure to landfill leachates and particulate matter from burning waste to chronic conditions including cancer, developmental abnormalities in children, and impaired immune responses (Rushton, 2003; Nweke & Sanders, 2009). The informal waste sector, comprising an estimated 15 million people globally, plays a critical role in resource recovery but operates under hazardous conditions without adequate occupational health protections or social security (Zolnikov et al., 2021).

Despite its risks, the waste sector remains underprioritized in global climate and development strategies. Waste management was historically excluded from the first round of NDCs under the Paris Agreement, though there is growing recognition of its mitigation potential (Pires et al., 2011; UNEP, 2015). Recent advances in WtE and material recovery technologies offer opportunities for integrating waste into circular economy strategies, but uptake is slow in low-income contexts due to high capital costs, inadequate technical expertise, and competing development priorities (Patrício Silva et al., 2020). Moreover, over-reliance on WtE facilities can undermine higher order waste reduction strategies if not properly aligned with upstream waste minimization and recycling initiatives.

A transition toward sustainable waste management systems necessitates a shift from linear, end-of-pipe approaches to integrated resource management. This includes establishing robust legal frameworks, incentivizing waste prevention and product stewardship, and a global policy trend towards ‘waste picker integration’, a term that does not have a commonly agreed definition. According to Samson et al. (2020) most agree that, at the very least, integration means treating waste pickers with respect, recognizing their knowledge and contributions, stopping discrimination against them, including them in decisions about recycling, making sure they can access materials, and helping them earn more and work in safer conditions. Furthermore, waste picker integration is advocated by international financial institutions, donor agencies, governments, non-governmental organisations and waste picker organisations (Samson et al., 2020). Economic instruments such as landfill taxes, pay-as-you-throw systems, and extended producer responsibility (EPR) schemes have proven effective in higher-income countries and are gradually being adopted in emerging economies (Nelles et al., 2016). The recently adopted EPR regulations of South Africa specifically require waste picker integration into EPR schemes including fair compensation for services and savings (South Africa, 2020). At the same time, significant investments are required to modernize waste infrastructure and to build capacity for data

monitoring, reporting, and verification—areas that remain critically underdeveloped in many regions.

A wide array of sustainable waste management practices can play a pivotal role in reducing environmental impacts and advance circular economy goals. *Waste reduction at source* is the most effective strategy, focusing on minimizing waste generation through product redesign, eco-packaging, and sustainable consumption habits. *Reuse and repair* initiatives extend product lifespans and reduce demand for virgin materials. *Recycling* remains a cornerstone of sustainable waste systems, enabling the recovery of valuable materials and reducing the need for resource extraction. *Composting and anaerobic digestion* of organic waste are essential for managing food and agricultural waste, producing nutrient-rich soil amendments and biogas while mitigating methane emissions from landfills. Finally, *EPR* and *pay-as-you-throw* policies incentivize more responsible waste generation and management behaviours across industries and households. Together, these practices support a hierarchy that prioritizes waste prevention and resource efficiency, with WtE serving as a complimentary option for non-recyclable residues.

4.3 WtE Technologies and Barriers to Adoption

As mentioned earlier, WtE technologies are broadly categorised into thermal and nonthermal or biochemical treatment processes. Thermal technologies use heat to convert waste materials into energy and include combustion or incineration, pyrolysis and gasification.

Incineration technologies utilise combustion of waste materials between 750 and 1100^{0}C in the presence of oxygen to produce heat or electricity. Currently, proven technologies for both prepared and unprepared wastes for WtE incineration include fluidised beds combustion and advanced moving grate combustion (ISWA 2022). The fluidised beds technology requires significant upstream waste preparation such as shredding and metal separation, while advanced moving grate is proven to treat unprepared wastes. The combustion process for fluidised beds is mechanically simpler than advanced moving grates but preparation, operation, waste and residue handling is more complex.

Gasification converts wastes, mostly solid waste materials, via partial oxidisation into liquid fuel or synthetic gas (syngas) with a high calorific value (ideally 10 to 18 MJ/Nm3). Syngas is majorly composed of hydrogen and carbon monoxide and can be used as feedstock to produce other chemicals or fuels or generate electricity. Gasification can be staged where low temperature gasification is followed by combustion of syngas (low quality syngas) and then recovery of energy in a single installation. High temperature gasification produces higher quality syngas, which with subsequent cleaning the syngas is supplied to a higher efficiency thermal process (gas turbine or a gas motor) or to produce liquid fuels.

Pyrolysis is the thermochemical decomposition of waste at temperatures between 500 and 800°C in the absence of air. This process produces char (e.g., converting wood into charcoal), pyrolysis oil and syngas. Nonthermal or biochemical technologies use chemical or biological processes to convert waste materials into energy and include processes such as anaerobic digestion, landfill gas recovery, fermentation and composting.

Anaerobic digestion is the breakdown of organic waste such as food, sewage sludge, residues from agriculture, etc. using microorganisms in the absence of oxygen. The biogas produced from this process is primarily made up of methane and carbon dioxide and can be used to generate heat or electricity or as fuel. Digestate remaining from the process can be used as a fertilizer in agriculture.

Landfills produce biogas naturally from the decomposition of organic waste materials. Where equipped, this biogas can then be captured and used to generate electricity or heat.

Fermentation is a biochemical process that can convert organic waste such as biomass into fuels like ethanol.

4.3.1 Benefits of WtE Adoption

Benefits of WtE include: a safe and clean way to treat residual waste; accommodates a variety of unprepared, mixed or degraded waste materials; enables recycling and material recovery by treating hazardous wastes; preventing contamination of the recyclable waste streams; recovery of embedded energy in residual waste, which in turn reduces reliance on fossil fuels for energy supply; recovery of metals and bottom ash for use in construction aggregates; and waste volume reduction for landfilling (ISWA, 2022).

Current developments indicate that maximizing WtE implementation and all its benefits rely on its specific link to local energy demand and consumption needs (industries, heating, cooling, agricultural, public facilities, etc.). It is thus important to define energy needs and applications at the early stages of WtE project implementation to help secure energy waste flows and improve social acceptability. Further discussions regarding the policy positions of the various technologies will focus more on incineration as it is the most widely used in developing or low-income countries (UNEP, 2019a). The key debate about WtE incineration centres on its role in the sustainability agenda. Aspects such as waste prevention, reduction, reuse and recycling are increasingly being prioritised by governments as more cost-effective and environmentally sound waste management approaches (UNEP, 2019b). There are views that WtE incineration goes against circular economy efforts in a variety of ways such as undermining efforts to reduce carbon emissions, disincentivising waste prevention, minimisation, recycling and reuse (European Commission, 2019; UNEP, 2019b). The EU, for example, has seemingly pulled funding for WtE incineration and identified new incineration plants as an example of non-compliance with the ‘do no significant harm’ (DNSH) principle

with legislation and policy focused on non- or less-emitting waste management approaches (European Commission, 2019). As would be discussed below under barriers to WtE adoption, these views and apparent shift in sentiment, however, aligns more with contexts where systems have developed enough to facilitate implementation of the 3Rs (reduce, reuse, recycle) in the waste hierarchy.

4.3.2 Barriers to WtE Adoption

Key barriers to WtE adoption include costs, institutional barriers, feedstock, legislation and national policies, scale and technical know-how, social acceptance (not in my backyard – NIMBY resistance) (Adeleke et al., 2021; Malav et al., 2020; IEA Bioenergy, 2023; ISWA, 2022; Khan et al., 2022; Maisarah et al., 2018; Mutezo et al., 2015; UNEP, 2019a; Williams et al., 2023). According to Adeleke et al. (2021), the main reasons for the limited application of advanced waste treatment technologies in Africa relate to high running costs, high standards involved in its operation and maintenance, lack of technical know-how, the heterogeneous nature of the waste stream and the additional fuel requirement for combustion due to the high moisture content of the waste. Regarding *costs*, large scale WtE implementation requires huge capital investments. Globally, most WtE incineration technologies are in developed countries where technological infrastructure is far more mature, and resources are more readily available. For low-income countries with more dire priorities like poverty, high setup and management costs of WtE plants remain a barrier to widespread adoption. For example, Africa's first WtE plant, the Reppie WtE facility in Addis Ababa was reported to cost $120m and was fully financed by the Ethiopian government. Where national governments do not fund these projects, WtE projects such as these will be too expensive for municipalities and regional government. *Institutional barriers* include aspects such lack of political will and support for WtE adoption, particularly incineration. Developed countries with superior power and influence appear to be leading sustainability efforts, creating fears that they may exert undue influence on developing countries to adopt inappropriate technologies and / or programmes which may be unaffordable and unsustainable. In sub-Saharan Africa and South Asia ineffective waste collection systems, the absence of waste separation at source, and absence of coordination between different governmental institutions are other aspects of institutional barriers affecting WtE adoption (Khan et al., 2022). *Feedstock* is another important barrier. While some WtE technologies such as incineration can treat heterogenous or mixed waste (although with limitations), achieving optimal performance of each WtE technology requires appropriate feedstock (Maisarah et al., 2018). Currently, about 57% of MSW streams generated in developing countries is organic with a moisture content of up to 56% making anaerobic digestion the most appropriate WtE technology solution (Alao et al., 2022). There is, however, a lot of stigma associated with widespread adoption of biogas projects such as anaerobic digestion due to factors such as incompatibility with traditional and religious beliefs (Nevzorova et al., 2019).

Also related to feedstock is the lock-in effect of particularl thermal WtE technologies which require a fixed quantity of feedstock to operate (UNEP, 2019a). Sweden, for example, in 2014 had to import over 1 million tonnes of waste to feed the Sävenäs Plant in Gothenburg. With regards to *scale*, currently, some WtE technologies such as gasification and pyrolysis have either not been proven to do well at scale or can only be implemented in small applications and are more region or country specific. For example, gasification is largely only implemented in Japan. Other examples such as the Schwarze Pumpe in Eastern Germany and pilot facility in Edmonton, Canada have all shut down. Pyrolysis has also not done well with MSW at industrial scale with attempts in Europe finally shut down in 1999 and 2015. Despite efforts by developing countries to transition to circular economy *legislation and national policies* they are either lacking (Malav et al., 2020; Williams et al., 2023), incentives favour other disposal options (such as landfilling), are not clear or are contradictory (IEA, 2023). In some developed countries, legislation and policies now prioritise waste prevention, minimisation, reuse and recycling. These policies such as the EU Emissions Trading System (EU ETS) which focuses on GHG emissions reduction have made WtE adoption progressively more difficult. As more countries improve waste prevention, minimisation, reuse and recycling, demand for WtE will decrease.

5 G20 CONSIDERATIONS AND RECOMMENDATIONS

The following policy recommendations, strategic interventions, future directions and innovations are proposed.

5.1 Future Directions and Innovations

The future of waste management and WtE lies in a cohesive approach that integrates upstream prevention with downstream resource recovery, aligning with global goals on climate mitigation, circular economy, sustainable and inclusive development. This section highlights strategic innovations that can accelerate a just, sustainable, and efficient transition in line with the theme of Solidarity, Equality, and Sustainability.

- **Integrated waste management and circularity:** Effective waste systems prioritize prevention, reuse, recycling, and energy recovery, reducing reliance on landfills, and open dumping. In many G20 countries, this shift is guided by circular economy policies that address the full lifecycle of materials. Policies such as EPR, plastic bans, and eco-design are central to upstream waste reduction (European Commission, 2020; UNEP, 2024). For example, in South Africa, advancing source segregation, improving collection coverage, and modernizing recycling infrastructure are foundational. Integration of informal waste workers through cooperatives and digital platforms is critical for enhancing recovery rates and achieving social equity (UNEP, 2024).

- **Decentralized and climate-responsive infrastructure**: Localized solutions—such as biogas digesters and micro gasifiers—can process organic and mixed waste while supplying clean energy to underserved areas. These technologies reduce transport costs and emissions while enabling off-grid energy access (World Bank, 2018). Container-based sanitation systems co-managed with waste services also help manage organic fractions while improving public health outcomes (UNEP, 2024).
- **Advanced WtE Technologies**: Organic and residual waste streams unsuitable for recycling can be harnessed through advanced WtE technologies, including advanced digestion, moving grate combustion, fluidized beds, and co-combustion. These systems, particularly when combined with material recovery and flue gas treatment, offer a safe and low-emission alternative to landfilling (ISWA, 2022). To further decarbonize the sector, WtE systems can integrate Carbon Capture and Storage (CCS) and process biogenic waste to achieve carbon-negative energy outcomes (IPCC, 2023). South Africa's integration of WtE with material recovery facilities and power grids can enhance resilience and energy security.
- **Digitalization and governance innovation**: Digital tools, such as smart sensors, AI-driven sorters, and blockchain-enabled EPR tracking, improve efficiency, transparency, and emissions monitoring across the waste value chain. These systems also enable evidence-based policy decisions and facilitate the formalization of the informal sector (UNEP, 2024). However, digital technologies are reliant on sustainable internet connectivity and energy supplies which are no longer guaranteed in many countries. Innovation is therefore required to overcome energy and connectivity challenges. Strong governance frameworks, long-term infrastructure planning, and blended finance—via public-private partnerships—are essential to ensure scalability, affordability, and alignment with Nationally Determined Contributions (NDCs) (World Bank, 2018; UNEP, 2024)
- **Policy innovation and financing mechanisms**: Aligning WtE with national energy and climate frameworks enhances regulatory certainty. Tools such as feed-in tariffs, landfill diversion targets, and climate-aligned budgeting improve market readiness (UNEP, 2024; ISWA, 2022). Blended finance, green bonds, and access to funds (e.g., GEF) are vital for infrastructure development in emerging markets.
- **South-South Knowledge Innovation Hubs**: Regional cooperation accelerates adoption of context-specific technologies. South Africa can serve as a regional anchor for demonstration projects, policy exchange, and technology transfer. Innovation hubs housed in universities and industrial parks can catalyse local R&D, technical training, and scale pilot projects across Africa (UNEP, 2022; UNEP, 2024).

5.2 Policy Recommendations and Strategic Interventions

To effectively meet global sustainability goals, it is essential to prioritize inclusive, environmentally sound and resilient waste management strategies. Developing economies and low-income countries are making notable progress in embracing circular economy principles and aligning local actions with global frameworks. The following policy recommendations and strategic interventions, as appropriate, are proposed:

- Strengthen regulatory frameworks
    - Enforce legislation on waste segregation collection, recycling and disposal
    - Legal frameworks should support EPR for manufacturers and importers
    - Establish and harmonize legislation on WtE with strict monitoring for hazardous waste treatment
    - Policymakers should continue aligning strategies across national and municipal levels
    - Strengthen cost recovery mechanisms through full cost accounting
- Promote Circular Economy principles, for example:
    - Encourage design for reuse and recyclability in production
    - Support markets for recycled materials through incentives and public procurement
- Invest in waste infrastructure
    - Expand and adapt waste collection, sorting and treatment systems and facilities (centralised and decentralised) to accommodate waste picker integration
    - Prioritise engineered sanitary landfills and appropriate WtE technologies to deal with residual waste that is not suitable for reuse or recycling
    - Investment in WtE infrastructure, including anaerobic digestion, offering a dual benefit of reducing waste volumes while expanding access to clean energy
    - Set up dedicated WtE infrastructures in the most exposed regions (control mixing of hazardous and non-hazardous waste)
    - Create industrial synergies around WtE infrastructure, for example, linking waste-to-energy centres to industrial parks to optimize energy consumption
- Encourage Public-Private Partnerships (PPPs)
    - Attract investment by de-risking waste management projects
    - Create transparent and accountable frameworks for PPP contracts
    - Adopt the establishment of a G20 level PPP Centre of Excellence for MSW management
- Foster research and innovation

  - Research and innovation into ways to maximise implementation of the waste hierarchy in particularly low-income countries

- Strengthen public awareness participation
  - Launch national awareness campaigns on waste reduction, recycling, and proper waste management
  - Promote community-based waste sorting and composting programs
- Support informal sector integration
  - Create an enabling environment for waste picker integration (refer to the waste picker integration website https://wastepickerintegration.org/
  - Waste picker integration creates an opportunity for the development of innovative waste collection systems in low-income countries
  - Provide access to training, protective gear and fair compensation
- Implement appropriate alternative policy instruments
  - Regulatory instruments (bans, permits, norms and standards)
  - Economic instrument (environmental taxes, fees and user charges, certificate trading, Environmental financing, green public procurement, subsidies)
  - Information instruments (sustainability reporting, eco-labelling, public information/education, consumer advisory services, environmental quality targets and monitoring
  - Cooperation instruments (Voluntary agreements e.g. on Technology Transfer)
- Promote international collaboration and transparent data collection
  - Exchange knowledge and technology voluntarily and on mutually agreed terms, among G20 members
  - Align strategies with global agreements like the SDGs, Basel Convention, etc.
  - Transparent data collection and reporting systems are essential to track progress, identify gaps, and ensure accountability

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