INITIATIVE ON Resilient Cities

Market conditions for circular bioeconomy in emerging economies

Avinandan Taron, Supriya Bhandarkar, Susanne Bodach, Solomie Gebrezgabher

November 2024

Contents

Introduction

With rapid economic growth and a massive population increase, emerging economies grapple with resource scarcity and an immense increase in solid waste generation (Bui et al. 2022). Waste collection in these countries is minimal, capturing less than half of the total waste produced (Kaza et al. 2018). This inadequacy has resulted in significant environmental and public health issues, (Lazurko 2018; Ferronato and Torretta 2019). To combat these challenges, emerging economies are exploring ways to shift from a linear to a circular bioeconomy framework. Circular bioeconomy "aims at products and services from recovered resources to promote sustainable growth through regenerative practices. It focuses on processing biomass from different waste streams into marketable products such as organic fertilizer and bioenergy" (Taron et al. 2023a).

The move from a linear to a circular economy has received impetus through government policies and regulations (Koval & Weis, 2019). This approach involves incentivizing technological advancements and offering economic incentives like subsidies and easing financing mechanisms. The adoption of circular economy principles is also guided by SDG targets, including Goal 6 (clean water and sanitation), Goal 7 (affordable and clean energy), and Goal 12 (responsible production and consumption) (Ferraz & Pyka, 2023). However, the sector remains nascent, with regional growth disparities stemming from insufficient enabling conditions such as infrastructure gaps, financial constraints, limited technical expertise, and low public awareness (Cantu et al. 2021). This technical brief explores the potential and current state of key markets within the circular bioeconomy in the Global South, specifically focusing on biogas, compost, and wastewater reuse in agriculture. These markets represent significant opportunities to create value from waste management and transition to a sustainable consumption and production process.

Energy Recovery from Organic Waste

A significant challenge for these countries is access to affordable and reliable energy. Currently, 758.93 million people lack electricity, and 2.6 billion rely on traditional biomass, coal, or kerosene for cooking, which leads to significant health and environmental issues (IEA 2023). Renewable energy sources like biogas can mitigate these issues by converting organic waste (food waste, livestock and crop residue, municipal sewage, and household solid waste) into usable energy (Afridi et al. 2023).

Biogas adoption varies significantly across emerging economies in Southeast Asia. The region's capacity remains limited, with less than one gigawatt (Villegas, 2024). China leads in biogas production, boasting an installed grid-connected capacity of about 500 MW as of 2017 (Lu and Gao, 2021). However, Thailand, Malaysia, and Indonesia have set ambitious biogas expansion targets. Thailand aims to achieve 5,570 MW by 2036, while Indonesia and Malaysia target 810 MW and 1,065 MW by 2025, respectively (Villegas 2024).

Thailand's biogas initiatives began at the household and farm levels but have since expanded to industries such as cassava starch, palm oil, and rubber, as well as municipal waste. As the first Southeast Asian country to introduce a feed-in tariff (FiT), Thailand offers investment incentives like corporate income tax exemptions and import duty waivers to boost biogas projects. Financial analyses indicate that compressed biomethane gas plants with capacities below six tons/day require 30% government funding to achieve a 5-6 year payback period. Larger plants with capacities over six tons/day can achieve a 7-8 year payback without government support (Tonrangklang et al., 2022). The government is focusing on areas over 50 km from natural gas pipelines, indicating potential for further expansion.

Malaysia has also extended its biogas generation targets to industries reliant on agrowaste, particularly palm oil. Since 2016, the Malaysian biogas sector has grown, driven mainly by the palm oil industry. The installed biogas capacity of 68 MW under the FiT scheme is set to increase, with an additional 73 MW approved and awaiting commencement (Jain 2019).

These developments serve as examples for Indonesia and Vietnam, where biogas initiatives at the household and farm levels, primarily using livestock waste, are ongoing. The Indonesia Domestic Biogas Program (IDBP) and Vietnam's Biogas Program for the Animal Husbandry Sector (BPPMU) began in 2009 and 2003, respectively. By 2021, Indonesia had constructed 26,818 biogas units, while Vietnam had installed 158,500 domestic biogas digesters, offsetting 800,000 tons of CO2 equivalent annually (SNV, 2019). Both countries have significant potential to further utilize agricultural waste for biogas production.

Beyond these nations, biogas production in Southeast Asia remains minimal despite its vast potential. For instance, the Philippines is an agricultural country that generates large quantities of biowaste and is committed to attaining a sustainable and clean energy future. However, biogas accounted for less than 1% of the power generation mix in 2020 (German-Philippine Chamber of Commerce and Industry 2020).

In South Asia, India has made significant progress in biogas development, boasting approximately 5.04 million biogas plants and 22 bio-CNG plants, which collectively produce substantial amounts of biogas daily. This growth is bolstered by government initiatives such as the National Bioenergy Program and the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme, which aim to promote the adoption of biogas and bio-CNG across the country. The SATAT scheme, in particular, targets the establishment of 5,000 Compressed Bio-Gas (CBG) plants by 2025, which are expected to produce 15 million tons of biogas annually (Press Information Bureau, 2022).

Nepal has also made strides in the biogas sector, with nearly 7,000 biogas plants installed across the country. The growth of biogas in Nepal has been significantly supported by microfinance institutions, which have provided the necessary financing to rural households for the installation of biogas systems (Afridi et al. 2023). These efforts contribute to energy security and environmental sustainability in rural areas.

Conversely, Pakistan and Bangladesh have yet to fully realize their biogas potential. Despite having ample agricultural waste and livestock manure that could be used for biogas production, both countries have lagged in adopting this technology. A few pilot projects exist in Pakistan, but large-scale adoption remains limited due to financial, technical, and infrastructural challenges (Afridi et al. 2023). Similarly, Bangladesh has focused more on solar energy, with biogas development receiving less attention, resulting in underutilized potential (REN21 2023).

The Africa Biogas Partnership Programme (ABPP), implemented in 2009 across several countries, including Ethiopia, Kenya, and Uganda, boosted Africa's biogas sector. The program installed small-scale biogas digesters for household use, provided training and provided financial support. Despite not meeting installation targets, ABPP improved agricultural productivity and created jobs, benefiting many households, especially women (Ton et al. 2019). Despite being unable to meet the intended target of installation, other benefits of the program were noticed, such as the fertilization of more than 300,000 ha of land, leading to a 20-30 percent crop production increase. 90 biogas construction enterprises (BCEs) were also established leading to the generation of 4,200 jobs. More importantly, approximately 38,000 women no longer needed to collect firewood or scrub soot from vessels, saving them 2.5 hours per day.

In Latin America and the Caribbean (LAC), small-scale biogas digesters have been installed in rural areas, primarily using agricultural residues. Countries like Colombia, Costa Rica, and Mexico have adopted Taiwanese models due to their low-cost design. Brazil, despite initial setbacks, now has significant biogas production potential, with 2.8 billion cubic meters produced annually from 885 plants. Argentina also produces notable amounts of biogas, primarily for thermal energy and electricity. Colombia has developed several biogas projects using diverse substrates like manure and municipal waste (Vega et al. 2024). In contrast, Mexico's biogas production remains limited, with less than 1% of biofuels coming from biogas. Most installed biodigesters use cattle and pig manure, and municipal solid waste is not yet a common substrate for biogas production (Vega et al. 2024).

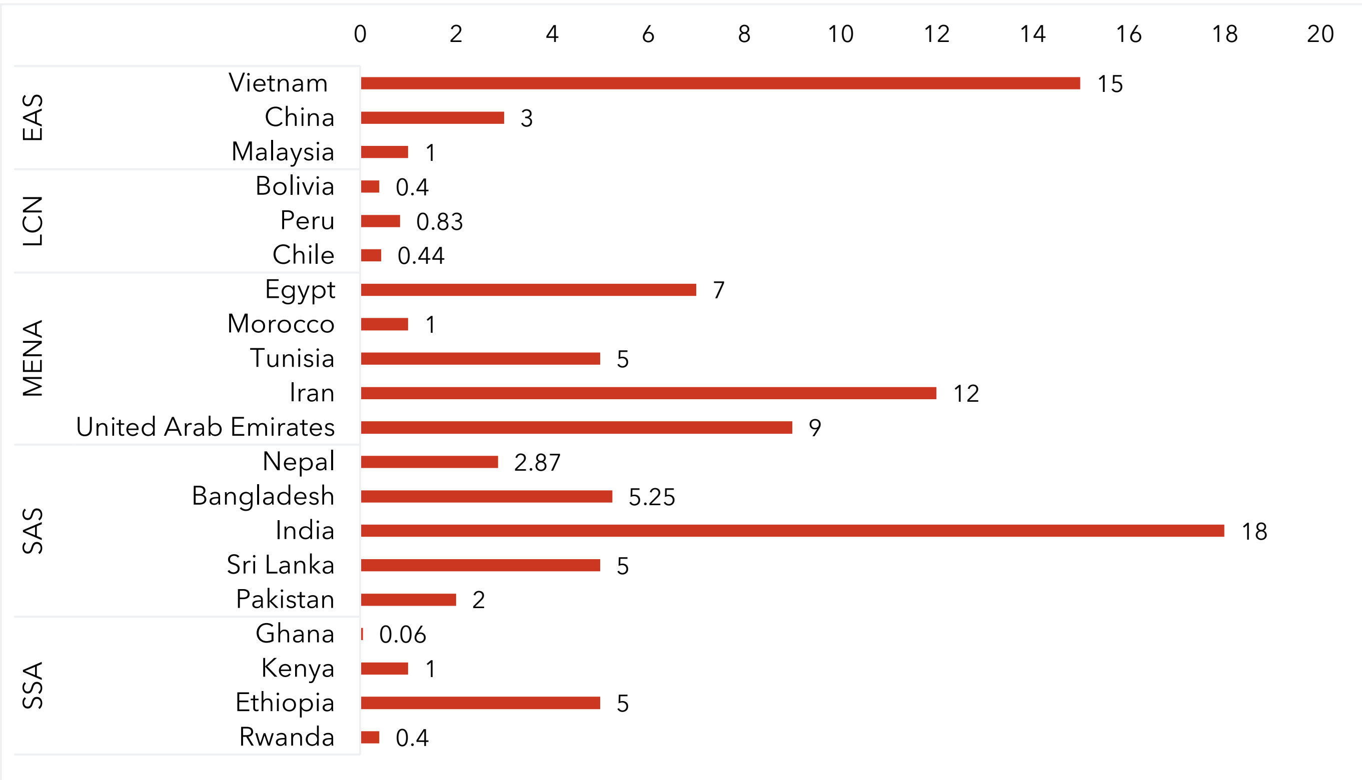
While biogas has proven benefits and growing adoption, its potential is underutilized in many emerging economies. Strategic policies, financial incentives, and technology adoption are crucial for advancing biogas as a sustainable energy source, addressing energy access issues, and promoting environmental health.

Market for organic fertilizers

Recovering compost from organic waste remains underutilized in many regions of the global south. The primary reason behind the underdeveloped market is the competition organic soil amendments face from chemical fertilizers. In South Asia, composting is prevalent, especially in Bangladesh, India, and Sri Lanka, which have established standards for compost manufacturing. Sri Lanka's standards (SLS 1634:2019 for municipal solid waste and SLS 1635:2019 for agricultural and livestock waste) specify physical, chemical, microbiological, and biological requirements for compost (Sri Lanka Standards Institution 2019). Sri Lanka, facing issues with open dumping and burning of waste, launched the *Pilisaru* (national solid waste management program). Although the country briefly banned synthetic fertilizers to promote organic farming in 2021, the policy was reversed due to a lack of support for farmers (Weerahewa & Dayananda 2023). The major issue with the compost produced at the *Pilisaru* compost plants – it does not reach the market, and there is a lot of inventory of compost not properly marketed. Beyond the capacity of Public Health Inspector (heading the compost plant) to monitor and market the compost.

In Bangladesh, regulations like the National Agricultural Policy 1999, National Policy for Water Supply and Sanitation 1998, and the Fertilizer Act 2008 promote composting. The National Fertilizer Standardization Committee has set compost standards and empowers the Ministry of Agriculture to certify commercial composting industries. The government supports composting by exempting VAT and sales tax on compost, 5-10 years tax holiday and reducing import duties on eco-friendly technologies (Sultana et al. 2020). However, the sustainability and scalability of composting plants are hindered by a lack of proper training and technologies. Many organizations and individuals operate composting processes without adequate knowledge of material selection, processing, packing, storage, and marketing. Authorized commercial composting industries are lower in Bangladesh, limiting compost availability in the market (Kabir 2015; Matter et al. 2015). Cofie et al. 2014 reported that 32 compost companies have government certification, and about 200 companies are in the queue. Product licensing takes over 600 days, and for some companies, it takes more than three years. Further, compost companies need to file separate certifications for different products. Presently, only 5 percent of the collected waste is composted, whereas 79 percent of the generated waste is organic. AIIB (2024) reported 3 urban local bodies (Rangpur, Chattogram, and Kushtia) to have compost plants of 5-20 tons among the 12 ULBs where the project is planned.

Composting percentage for emerging economies



Source: World Bank, 2024

India’s standards under the Fertilizer (Control) Order, 1985, and Fertilizers (Control) Amendment Order, 2003, amended in 2013, provide specifications for compost and the criteria for a certificate of registration with a validity for three years. Certification is not required for state governments and municipality manufacturers or manufacturers producing less than 50 tons of vermicompost. The government tried to promote the composting of organic waste from cities through the Swachh Bharat Mission. However, this could reach merely 5 percent of the urban organic waste. The Market Development Assistance (MDA) scheme by the Ministry of Chemicals and Fertilizers, was introduced in 2016. This policy stated subsidies for compost sales along with inorganic fertilizer. This subsidy was to reduce the selling price of compost for farmers. It required agreements amongst municipal bodies, compost manufacturers and compost marketers, including fertilizer companies. According to the mobile Fertilizer Management System (FMS) portal, fertilizer companies have claimed market development assistance (MDA) for 0.12 million tons of compost, whereas 30 compost manufacturers have claimed MDA for the sale of 62,394 tons of compost. So, in total MDA was claimed for 0.18 million tons of compost in 2017–18. This policy was revoked in 2021 since the subsidies recovered were low and the policy merged with incentive mechanisms offered on biofertilizers.

Box 1. Examples from India in developing marketing mechanisms for compost.

HARIT Ticker by GIZ:

The HARIT Ticker is a blockchain-based platform designed to improve the organic compost value chain in Maharashtra, India. This platform connects compost producers, farmers, agricultural institutions, and other buyers, facilitating faster transactions and better management of compost production, storage, and distribution. Currently, the HARIT Ticker has registered numerous urban compost producers and farmers, creating a significant business potential. The platform is supported by government subsidies and aims to make the composting process more sustainable and profitable.

MENA countries have significant potential for composting due to high organic waste. Except for Bahrain and Libya which have a low organic fraction (35-37%), the average organic fraction is 50-65%, with the highest in Egypt (79%) (Hussein et al., 2021). Egypt produces 90 million tons of waste annually and composts only 20.7 million tons, far below the demand of 54.5 million tons (Negm & Shareef, 2020). Jordan and Kuwait lack composting facilities, leading most waste to landfills. Saudi Arabia, with 15 million tons of food waste annually, has recently established the National Center of Waste Management under Vision 2030 to reduce landfill waste by up to 82% through 1329 facilities. However, the quality of compost is often poor, with bad odor and heavy metal contamination (Zajonc et al., 2014).

Although organic waste constitutes approximately 50% of the total waste stream in Latin America, less than 1% is currently composted, with such efforts being limited to a few countries. The majority of waste—52%—is disposed of in sanitary landfills, while 26.8% ends up in open dumps (Kaza et al., 2018). This low rate of composting can primarily be attributed to the lack of established standards and the low tipping fees that do not incentivize organic waste diversion.

In Mexico, 19 composting plants process organic waste from urban areas, agricultural and livestock operations, and forestry. Mexico City alone hosts four composting stations that produce around 295 tons of compost daily. Brazil, in contrast, sees minimal engagement in composting, with only 127,500 tons of organic waste composted annually. In Chile, composting initiatives are limited, with just 13% of municipalities actively working on organic waste recovery. Compost plants in the region tend to be concentrated in areas with strong demand and easy access to organic waste, such as in Cundinamarca near Bogotá, Colombia, which hosts 16 composting facilities.

Governments have begun addressing organic waste management (UNEP, 2020). Some countries, including Colombia, Peru, and Brazil, are in the process of developing policies aimed at enhancing resource recovery. Brazil's recent National Plan of Solid Waste sets ambitious targets, including the elimination of controlled dumps starting in 2024 and an increase in the recovery rate of municipal solid waste (MSW) to 48.1% by 2040. In contrast, Panama’s policies focus narrowly on food waste, and current initiatives are still experimental. This overview underscores the pressing need for improved composting infrastructure and policies across the region to better manage organic waste and reduce landfill dependency.

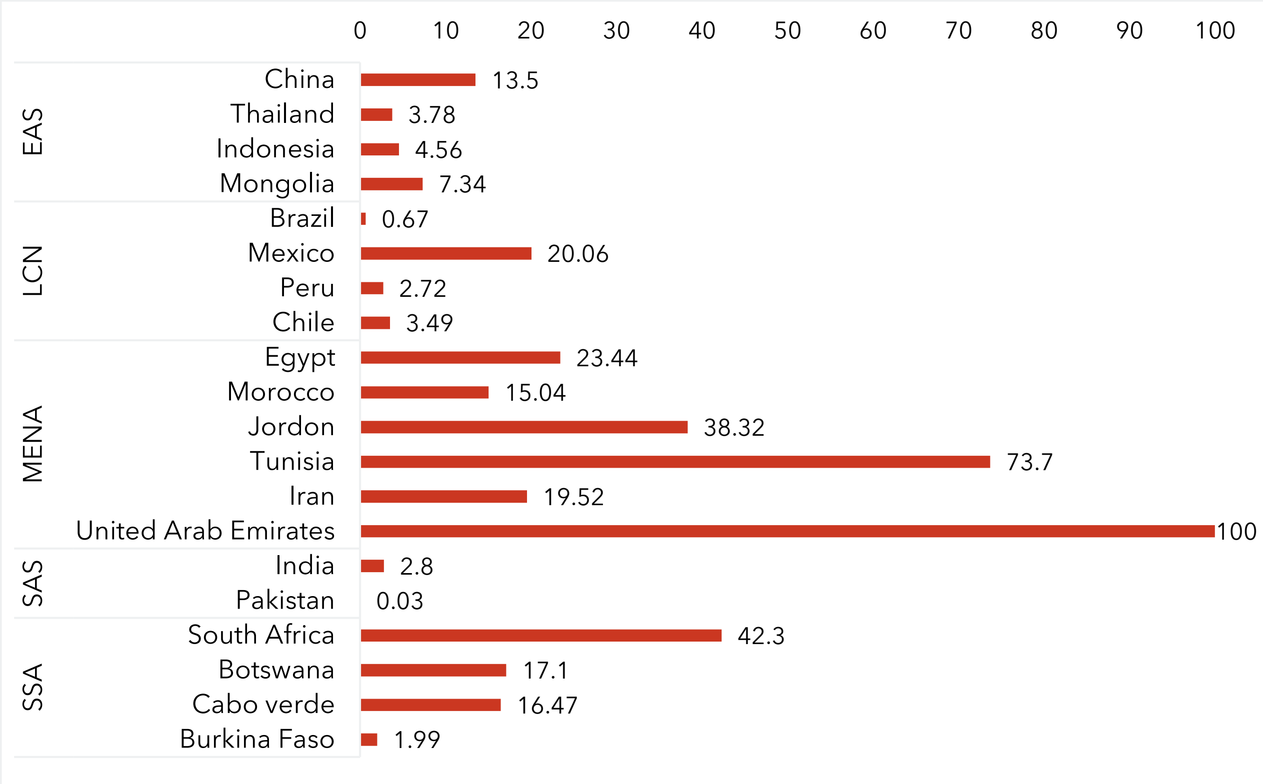
Many countries are experimenting with fecal sludge-based compost to tackle soil nutrient depletion. Otoo et al. (2018) studied the market adoption and diffusion of compost derived from fecal sludge in the Greater Accra and Western regions in Ghana; Kampala, Uganda; Bangalore, India; Hanoi, Vietnam; and Kurunegala, Sri Lanka. The study indicates that the farmers were less willing to pay for the compost above a certain price (comparable to existing compost and artificial fertilizers). Farmers with larger land holdings were willing to pay more. However, farmers were concerned about product safety and the related need for third-party certification. The study recommends that future businesses will need to invest in strong awareness programs coupled with actual field experiments to increase product recognition and eventual adoption.

Wastewater treatment and reuse

In the Middle East and North Africa (MENA) region, efficient reuse of treated wastewater is prevalent due to high water stress. The number of water reuse projects has increased to 409 in 2020 with 11% of the total wastewater being used directly, 35% indirectly reused, and 54% lost unproductively (Velpuri et al., 2023). Countries like Egypt, Morocco, UAE, Tunisia, and Jordan lead in this practice, with the UAE, Kuwait, and Qatar reusing over 80% of their wastewater, and Saudi Arabia using 90% for irrigation. Abu Dhabi aims for 100% reuse by 2030. Different countries in the region use treated wastewater for various purposes: forestry and agriculture in Egypt, Tunisia, and Jordan, and landscaping in Morocco, UAE, and Oman (Mateo-Sagasta et al. 2022). However, increased wastewater treatment leads to more sludge, which poses environmental challenges. For instance, Kuwait produces 250 tons of sludge daily, while Tunisia and Jordan produce one million and 105,000 tons annually, respectively (Taron et al. 2023b).

In South Asia, the reuse of treated wastewater is limited. Most wastewater is used untreated or partially treated for agriculture, posing significant public health risks. India is the only country with established guidelines for reclaimed water (RW) reuse in irrigation, considering soil nature, crop salinity tolerance, and metal ion limits (GoI 2013). However, other South Asian countries lack such guidelines, leading to the widespread use of untreated wastewater. Bangladesh treats only 2% of its wastewater, but the new Dasherkandi Sewage Treatment Plant is expected to increase treatment capacity by 500 million litres. Sri Lanka has treatment plants like Moratuwa-Ratmalana and Ja-Ela, but sludge management remains a challenge (Taron et al. 2023b).

Wastewater reuse percentage for emerging economies



Source: UNU-INWEH, 2019

In India, urban areas generate 72,368 million liters of wastewater daily, with only 28% treated. Smaller cities lack resources for treatment plants, leading to untreated wastewater being disposed of in water bodies. Most sludge from wastewater treatment plants (WWTPs) is disposed of in dumpsites without proper treatment. Of the treated water, only 3% is reused across the country for different purposes, mainly irrigation (Mishra et al. 2023). However, there is potential for energy generation from treated sludge through incineration or anaerobic digestion (Singh et al. 2020; Mitra 2021). In East Asia and the Pacific, Singapore leads in wastewater treatment and reuse. The Changi Water Treatment Plant, with a capacity of 900 million liters per day, produces NEWater, which meets 30% of Singapore's water demand. By 2060, NEWater is expected to meet 55% of the demand (Lefebvre 2018). China has also improved its water treatment and reuse, treating 63.3 billion cubic meters of water annually, with 19.9% reused. Most of the water is reused for landscape irrigation and industrial cooling followed by agricultural irrigation, and other urban uses such as toilet flushing and car washing. China's sludge management involves land applications, incineration, and sanitary landfills (Hu et al. 2021; Wei et al. 2020).

In Latin America and the Caribbean, wastewater reuse is limited and often does not meet quality standards. Sludge treatment is minimal due to inadequate legislation and regulations. Brazil's SANEPAR, however, has made progress, treating sludge to produce Class A biosolids, which are used in agriculture and have proven more efficient than mineral fertilizers (Martin-Hurtado & Nolasco, n.d).

Box 2. Examples of reclaimed wastewater reuse in MENA

Sfax Sud wastewater treatment plant:

The Sfax Governate in Tunisia is a region where the demand for water exceeds the supply. Due to the scarcity of natural water resources including both groundwater and surface water, recycled water from wastewater treatment plants provides a valuable new water source that can be used for irrigation. The Sfax Sud WWTP uses both industrial and domestic wastewater and serves a population of 526800 residents. It has also helped improve agricultural production to include 533.5 t of olives, 2,045 t of milk, 68.72 t of meat, 4165 t of manure and 150 heifers thereby improving farmers income. Safar and Chamtouri 2022).

El Berka wastewater treatment plant:

The El Berka wastewater treatment plant in Cairo, Egypt treats 0.4-0.5 million m3/day of which 5% is used for irrigating lemon, Khaya senegalensis and jajoba trees. Another 12% of the treated water is used by farmers to irrigate 1000 ha of land. In addition to this the plant also produces 50-60000 t of sludge of which one third is sold for composting and to the construction sector (Drechsel & Hanjra, 2018).

In conclusion, while MENA and East Asia lead in treated wastewater reuse, South Asia and Latin America face significant challenges. Effective policies, infrastructure development, and adherence to quality standards are essential for improving wastewater treatment and reuse practices globally.

Why is resource recovery and derived products not picking up?

The poorly developed market and low adoption rates of RRR products in emerging economies are attributed to various factors. The major challenge faced by most of the countries is the consistency and quality of waste. Most developing countries do not have regulations regarding the sorting of waste, and these regulations are not implemented strictly across the country. For example, countries in Latin America and the Caribbean have a significant amount of food and green waste in their MSW. Major food loss takes place during the processing stage, especially for cereals, fruits and vegetables and seafood. Large amounts of husks and leaves from farming also contribute to this organic waste (Hettiarachchi et al. 2018). This waste is harder to burn and provides a lower caloric value leading to a fluctuation in electricity output and revenue uncertainty for biogas plants. The input and output market should be controlled through strong market protection policies to ensure that the entire value chain is not disrupted. Setting segregation standards will enable easy access to organic waste, especially for composting. Similarly, for the output markets, all the RRR products face competition from their liner counterparts. The RRR markets, if not protected from externalities, may be disrupted by their liner substitutes.

In addition, for biogas, the major techno-economic and institutional barriers limiting the uptake include limited availability of feedstock to produce biogas to meet the daily energy demands (especially in rural households), as well as large land requirements, high investment cost due to the dependency on external technology and skilled labor, and ultimately lack of coordination between public and private sectors for promoting biogas energy to the market and making it commercially stable. These challenges are faced in India, where despite a large number of biogas plants being installed most of them are not in use (Afridi et al. 2023). Besides, renewable energy sources such as solar, wind, and hydro also present challenges to the growth of the biogas market. The combined market value of renewable energy reached $ 970 billion in 2022 (Precedence Research, 2023)—approximately 12 times greater than the 2022 estimates for the biogas market. Despite their linear economic value, these sources are favored by governments due to their scalability, ease of storage, relatively lower operational costs, and existing technological advancements.

The composting sector in emerging markets is confronted with inadequate source segregation and waste collection, resulting in organic wastes seldom reaching composting plants for treatment (Ferronato et al. 2019). Furthermore, compost faces direct competition from organic and chemical fertilizers, both of which serve a similar purpose of soil nourishment at subsidized prices which distorts the market for compost. Moreover, composting yields a low-value product ($0.06 to $0.02/kg), and its localized demand, coupled with significant variations in quality, fails it to pick up. Compost products are also not adequately marketed in most countries. Andhra Pradesh has taken up 'demand profiling', where the major demand areas are identified at the urban local body (ULB) level, and only then are suitable treatment systems installed to meet the demand. This can be implemented in more areas to reduce loss of revenue.

Many emerging countries face various institutional, economic and technological challenges in setting up and operating wastewater treatment plants in their countries. For example, in India, ULBs are responsible for installing and operating water treatment plans. However, most of these institutions suffer from a lack of manpower and infrastructure such as monitoring stations, laboratories, water testing equipment etc. A survey conducted showed that there were staff shortages upto 37.6%, 39%, and 52.3% in scientific, technical, and administrative domains respectively (NITI Aayog, 2022). Countries also face technological challenges such as reliance on older, nonperforming technology to save on capital costs, difficulty in procuring land in urban areas and lack of large scale and continuous electricity supply (Kumar & Tortajada. 2020). Studies have also shown that the reuse of treated wastewater is also adversely impacted by social factors such as lack of awareness and acceptance to reuse treated wastewater for potable and non-potable uses. It was seen that in Singapore, a change in terminology from treated wastewater to 'recycled' water helped increase social acceptance by 74% (Timm & Deal. 2018). Most people also do not want wastewater plants installed near places where they reside due to concerns about odour, noise and the probability of a decrease in land value. This further creates problems for the acquisition of land. China has, therefore, set up underground treatment plants that are hidden from the public eye.

Raising awareness about RRR products, especially among consumers, is therefore crucial. This can be achieved through campaigns, posters, and educational programs in public places, as well as integrating the importance of such products into school curriculums. Increased awareness will create natural demand for organic products, encouraging businesses to innovate and supply the market. One such way is promoting the organic produce market. Globally, there is increasing demand for organic food and beverages, estimated at $174.37 billion in 2024. Governments should also invest in research and development – as one of the major challenges faced by RRR products is technological efficiency. Developing and refining the technology will help local governments and other businesses to adapt and make higher profits.

References

ADB (Asian Development Bank). 2011. Toward Sustainable Municipal Organic Waste Management in South Asia: A Guidebook for Policy Makers and Practitioners. Metro Manila, Philippines: Asian Development Bank. 75p.

Afridi, Z. U. R.; Ullah, K.; Mustafa, M. F.; Saleem, H.; Shaker, B.; Ashraf, N.; Aslam, S. 2023. Biogas as sustainable approach for social uplift in South East Asian Region. *Energy Reports* 10: 4808-4818. https://doi.org/10.1016/j.egyr.2023.11.037

Ali, S.; Yan, Q.; Razzaq, A.; Khan, I.; Irfan, M. 2023. Modeling factors of biogas technology adoption: a roadmap towards environmental sustainability and green revolution. *Environmental Science and Pollution Research* 30(5): 11838-11860. https://doi.org/10.1007/s11356-022-22894-0

Bui, T. D.; Tseng, J. W.; Tseng, M. L.; Lim, M. K. 2022. Opportunities and challenges for solid waste reuse and recycling in emerging economies: A hybrid analysis. *Resources, Conservation and Recycling*, 177: 105968. https://doi.org/10.1016/j.resconrec.2021.105968

Cantú, A.; Aguiñaga, E.; Scheel, C. 2021. Learning from failure and success: The challenges for circular economy implementation in SMEs in an emerging economy. *Sustainability* 13(3): 1529. https://doi.org/10.1016/j.resconrec.2021.105968

Castellani, B.; Rinaldi, S.; Bonamente, E.; Nicolini, A.; Rossi, F.; Cotana, F. 2018. Carbon and energy footprint of the hydrate-based biogas upgrading process integrated with CO2 valorization. *Science of the Total Environment* 615: 404-411. https://doi.org/10.1016/j.scitotenv.2017.09.254

Cofie, O.; Rao, K.; Fernando, S.; Paul, J. 2014. Composting Experience in Developing Countries: Drivers and constraints for composting development in Ghana, India, Bangladesh and Sri Lanka.

Drechsel, P.; Hanjira, M.A. 2018. Wastewater for fruit and wood production (Egypt). In: Otoo, M.; Drechsel, P.; Hutton, G. (eds.) Resource recovery from waste: Business models for energy, nutrient and water reuse in low- and middle- income countries. New York: Routledge.

Ferraz, D.; Pyka, A. 2023. Circular economy, bioeconomy, and sustainable development goals: a systematic literature review. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-023-29632-0

Ferronato, N.; Torretta, V. 2019. Waste mismanagement in developing countries: A review of global issues. *International Journal of Environmental Research and Public Health* 16(6): 1060. http://dx.doi.org/10.3390/ijerph16061060

Gatto, F.; Ilaria R. 2021. Circular Bioeconomy Business Models to Overcome the Valley of Death. A Systematic Statistical Analysis of Studies and Projects in Emerging Bio-Based Technologies and Trends Linked to the SME Instrument Support. *Sustainability*. 13(4): 1899. https://doi.org/10.3390/su13041899

German-Philippine Chamber of Commerce and Industry. 2020. Biogas in the Philippinen. https://philippinen.ahk.de/en/initiatives/biogas-in-the-philippinen

GoI. 2013. Recycling and Reuse of Sewage. Manual on sewerage and sewage treatment systems Part A: Engineering. New Delhi, India: Ministry of Urban Development, Government of India.

Hettiarachchi, H.; Meegoda, J. N.; Ryu, S. 2018. Organic waste buyback as a viable method to enhance sustainable municipal solid waste management in developing countries. *International Journal of Environmental Research and Public Health*, 15(11): 2483. https://doi.org/10.3390/ijerph15112483

Hu, H.; Chen, Z.; Hao, S.; Wu, Y. 2021. *Towards the new era of water reuse in China*. The Source. International Water Association. Available at https://thesourcemagazine.org/towards-the-new-era-of-water-reuse-in-china/ (accessed on August 16, 2024).

Hussein, L., Uren, C., Rekik, F., & Hammami, Z. 2021. A review on waste management and compost production in the Middle East-North Africa region. *Waste Management & Research*. 40(8): 1110-1128. https://doi.org/10.1177/0734242X211068236

IEA (International Energy Agency). 2023. *For the first time in decades, the number of people without access to electricity is set to increase in 2022*. Paris, France: International Energy Agency. Available at https://www.iea.org/commentaries/for-the-first-time-in-decades-the-number-of-people-without-access-to-electricity-is-set-to-increase-in-2022 (accessed on August 16, 2024).

Jain, S. 2019. Malaysia Market Report. World Biogas Association. https://www.worldbiogasassociation.org/wp-content/uploads/2019/03/WBA-malaysia-4ppa4_v1.pdf

Kabir, M. R. 2015. Municipal Solid Waste Management System: A Study on Dhaka North and South City Corporations. *Journal of Bangladesh Institute of Planners*, 8: 35-48.

Kaza,S; Yao,L. C.; Bhada, T.P.; Van, W.F.; Martin, T.M.R.; Serrona, K.R.B.; Thakur, R.; Pop, F; Hayashi, S.; Solorzano, G.; Alencastro, L.N.S.; Poveda, R.A.; Ismail, A. 2018. What a Waste 2.0: A Global Snapshot of Solid Waste Management in 2050. Washington, D.C.: World Bank Group. Available at http://documents.worldbank.org/curated/en/697271544470229584/What-a-Waste-2-0-A-Global-Snapshot-of-Solid-Waste-Management-to-2050 (accessed on August 16, 2024).

Koval, V.; Weis, L. 2019. *State regulation and investment management in the development of circular economy*. Sustainable development under the conditions of European integration. Ljubljana, Slovenia: Ljubljana School of Business, 296-309p.

Kumar, M.D.; Tortajada, C. 2020. Health Impacts of Water Pollution and Contamination. In: *Assessing Wastewater Management in India*. SpringerBriefs in Water Science and Technology. Singapore: Springer. https://doi.org/10.1007/978-981-15-2396-0_5

Lazurko, A. 2018. *Assessing the value of resource recovery and reuse: social, environmental and economic costs and benefits for value creation and human well-being*. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 41p. (Resource Recovery and Reuse Series 13). https://doi.org/10.5337/2018.229

Lefebvre, O. 2018. Beyond NEWater: an insight into Singapore's water reuse prospects. *Current Opinion in Environmental Science & Health* 2: 26-31. https://doi.org/10.1016/j.coesh.2017.12.001

Liao, Z.; Chen, Z; Xu, A. O.; Gao, Q.; Song, K.; Liu, J.; Hu, H. Y. 2021. Wastewater treatment and reuse situations and influential factors in major Asian countries. *Journal of Environmental Management*, 282: 111976. https://doi.org/10.1016/j.jenvman.2021.111976

Lohani, S. P.; Acharya, R.; Shrestha, P.; Shrestha, S.; Manisha, K. C.; Pradhan, P. 2024. Sustainable biogas production potential in Nepal using waste biomass: A spatial analysis. *Sustainable Development*. https://doi.org/10.1002/sd.2937

Lu, J., & Gao, X. 2021. Biogas: Potential, challenges, and perspectives in a changing China. Biomass and Bioenergy, 150: 106127.

Mateo-Sagasta, J.; Al-Hamdi, M.; AbuZeid, K. (Eds.). (2022). Water reuse in the Middle East and North Africa: A sourcebook. Colombo, Sri Lanka: International Water Management Institute (IWMI). 292p. doi: https://doi.org/10.5337/2022.225

Martin-Hurtado, R; Nolasco, D. n.d. Managing Wastewater as a Resource in Latin America and the Caribbean Towards a Circular Economy Approach.
https://programme.worldwaterweek.org/Content/ProposalResources/allfile/managing_wastewater_as_a_resource_in_lac.pdf

Matter, A., Ahsan, M., Marbach, M., & Zurbrugg, C. (2015). Impacts of Policy and Market Incentives for Solid Waste Recycling in Dhaka, Bangladesh. *Waste Management*, 39, 321-328. https://doi.org/10.1016/j.wasman.2015.01.032

Mishra, A., Arunlal K., Anand, S., Goel, S. 2023. Reuse of treated wastewater in urban/peri-urban agriculture in India, NITI Aayog, Govt. of India, New Delhi. https://www.niti.gov.in/sites/default/files/2023
08/Revised_Strategy_Paper_on_Reuse_of_Treated_wastewater_in_peri-urban_agriculture_in_India.pdf

Mitra, I. 2021. A leap to advanced sewage treatment for India. https://www.cambi.com/resources/blog/a-leap-to-advanced-sewage-treatment-for-india/

Negm, A.M.; Shareef, N. 2020. Introduction to the Waste Management in MENA Regions. In: Negm, A., Shareef, N. (eds) Waste Management in MENA Regions. Springer Water. Springer, Cham. https://doi.org/10.1007/978-3-030-18350-9_1

NITI Aayog. 2022. *Urban Wastewater Scenario in India*. New Delhi, India: NITI Aayog. 80p.

Otoo, M.; Gebrezgabher, S.; Danso, G.; Amewu, S.; Amirova, I. 2018. Market adoption and diffusion of fecal sludge-based fertilizer in developing countries: cross-country analyses. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE). 68p. (Resource Recovery and Reuse Series 12). doi: 10.5337/2018.228

Poudel, S.; Shrestha, A.; Kandel, N.; Adhikari, S.; Paudel, S. R. 2023. A review of reclaimed water reuse for irrigation in South Asian countries. *ACS ES&T Water* 3(12): 3790-3806. Available at https://pubs.acs.org/doi/10.1021/acsestwater.3c00487 (accessed on August 16, 2024).

Precedence Research. 2023. *Renewable Energy Market Size, Share, and Trends 2024 to 2034.* *https://www.precedenceresearch.com/renewable-energy-market#*

Press Information Bureau. (2022). Targets under SATAT Scheme. Ministry of Petroleum and Natural Gas. https://pib.gov.in/PressReleasePage.aspx?PRID=1881749

Ray, L.; Adhya, T. K. 2020. Energy, nutrient, and water resource recovery from agriculture and aquaculture wastes. In: *Current Developments in Biotechnology and Bioengineering*. pp. 343-362. https://doi.org/10.1016/B978-0-444-64321-6.00018-5

REN21. 2023. Renewables 2023 Global Status Report Collection, Renewable Energy Systems and Infrastructure.

Safar, C.; Chamtouri, I. 2022. Case Study 3: Tunisia, Sfax Sud wastewater treatment plant and El Hajeb public irrigated perimeter. In: Mateo-Sagasta, J.; Al-Hamdi, M.; AbuZeid, K. (Eds.). 2022. *Water reuse in the Middle East and North Africa: a sourcebook*. Colombo, Sri Lanka: International Water Management Institute (IWMI). pp.200-211. doi: https://doi.org/10.5337/2022.225

Silva-Martínez, R. D.; Sanches-Pereira, A.; Ortiz, W.; Galindo, M. F. G.; Coelho, S. T. 2020. The state-of-the-art of organic waste to energy in Latin America and the Caribbean: challenges and opportunities. *Renewable Energy* 156: 509-525. https://doi.org/10.1016/j.renene.2020.04.056

Singh, V., Phuleria, H. C., & Chandel, M. K. 2020. Estimation of energy recovery potential of sewage sludge in India: Waste to watt approach. Journal of Cleaner Production, 276: 122538. https://doi.org/10.1016/j.jclepro.2020.122538

SNV. 2019. Vietnam Biogas Programme. https://www.snv.org/project/vietnam-biogas-programme

Sri Lanka Standards Institution (2019). SLS 1634: Specification for compost made from raw materials of agricultural origin. https://www.agrimin.gov.lk/web/images/pdf/Forms/2021.10.11/Annexure%2007.pdf

Sultana, M.; Kibria, M.; Jahiruddin, M.; Abedin, M. 2020. Composting Constraints and Prospects in Bangladesh: A Review. *Journal of Geoscience and Environment Protection* 8: 126-139. https://doi.org/10.4236/gep.2020.89008

Taron, A.; Majumder, A.; Bodach, S.; Agbefu, D. 2023a. Public-private partnerships for the circular bioeconomy in the Global South: lessons learned. Colombo, Sri Lanka: International Water Management Institute (IWMI). 50p. (Resource Recovery and Reuse Series 22). https://doi.org/10.5337/2023.205

Taron, A.; Singh, S.; Drechsel, P.; Ravishankar, C.; Ulrich, A. 2023b. Sewage sludge: a review of business models for resource recovery and reuse. Colombo, Sri Lanka: International Water Management Institute (IWMI). 98p. (Resource Recovery and Reuse Series 23). doi: https://doi.org/10.5337/2023.211

Timm, S. N.; Deal, B. M. 2018. Understanding the behavioral influences behind Singapore's water management strategies. *Journal of Environmental Planning and Management* 61(10): 1654-1673. https://doi.org/10.1080/09640568.2017.1369941

Ton, P; Rijke, E; Kizito, A; Konate, L. (2019). Africa Biogas Partnership Programme (ABPP): Phase 2, Effect Evaluation. Fair and Sustainable Consulting, ADE.

Tonrangklang, P., Therdyothin, A. & Preechawuttipong, I. 2022. The financial feasibility of compressed biomethane gas application in Thailand. Energy, Sustainability and Society 12, 11. https://doi.org/10.1186/s13705-022-00339-3

Torre, A.; Vázquez-Rowe, I.; Parodi, E.; Kahhat, R. 2024. A multi-criteria decision framework for circular wastewater systems in emerging megacities of the Global South. *Science of the Total Environment* 912: 169085. https://doi.org/10.1016/j.scitotenv.2023.169085

UNEP. 2020. *In Latin America and the Caribbean, the closure of ageing dumps is helping to clear the air*. Available at https://www.unep.org/news-and-stories/story/latin-america-and-caribbean-closure-ageing-dumps-helping-clear-air (accessed on August 16, 2024).

Vega, L. P., Bautista, K. T., Campos, H., Daza, S., & Vargas, G. 2024. Biofuel production in Latin America: A review for Argentina, Brazil, Mexico, Chile, Costa Rica and Colombia. *Energy Reports.* 11: 28-38. https://doi.org/10.1016/j.egyr.2023.10.060

Velpuri, N.M., Mateo-Sagasta, J., Orabi, M.O.M. 2023. Spatially Explicit Wastewater Generation and Tracking (SEWAGE-TRACK) in the Middle East and North Africa region, Science of The Total Environment 875: 162421, https://doi.org/10.1016/j.scitotenv.2023.162421

Villegas, V. 2024. *How Southeast Asia can unlock its biogas potential*. Asian Power. Available at https://asian-power.com/exclusive/how-southeast-asia-can-unlock-its-biogas-potential (accessed on August 16, 2024).

Wei, L., Zhu, F., Li, Q., Xue, C., Xia, X., Yu, H., ... & Bai, S. 2020. Development, current state and future trends of sludge management in China: Based on exploratory data and CO2-equivaient emissions analysis. *Environment International*, 144: 106093. https://doi.org/10.1016/j.envint.2020.106093

Weerahewa, J., & Dayananda, D. 2023. Land use changes and economic effects of alternative fertilizer policies: A simulation analysis with a bio-economic model for a Tank Village of Sri Lanka. *Agricultural Systems* 205: 103563. https://doi.org/10.1016/j.agsy.2022.103563

Zajonc, O.; Frydrych, J.; Jezerska, L. 2014. Pelletization of compost for energy utilization. *IERI Procedia* 8: 2-10. https://doi.org/10.1016/j.ieri.2014.09.002

Urban farming near East Kolkata wetland using reclaimed wastewater
(*photo*: Chhandak Pradhan, IWMI).

INITIATIVE ON
Resilient Cities

INITIATIVE ON
Nature-Positive Solutions

Suggested citation

Taron, A.; Bhandarkar, S.; Bodach, S.; Gebrezgabher, S. 2024. *Market conditions for circular bioeconomy in emerging economies.* Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on Resilient Cities. 16p.

Acknowledgements

This work was finalized under the CGIAR Initiatives on Resilient Cities and Nature-Positive Solutions. The authors are grateful for the support of CGIAR Trust Fund contributors (www.cgiar.org/funders).

Avinandan Taron, IWMI, Colombo, Sri Lanka, a.taron@cgiar.org

Supriya Bhandarkar, IWMI, New Delhi, India, supb2891@gmail.com

Susanne Bodach, IWMI, Colombo, Sri Lanka, s.bodach@cgiar.org

Solomie Gebrezgabher, IWMI, Accra, Ghana, s.gebrezgabher@cgiar.org

INITIATIVE ON
Resilient Cities

INITIATIVE ON
Nature-Positive Solutions