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Making Circularity Work

How digital innovation enables circular economy approaches in waste management

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Executive summary

This report takes stock of how and where digital innovation supports circular economy models in waste management. It presents insights from the recently completed GSMA Innovation Fund for Digital Urban Services, which included organisations working on digitalising waste management. These are supplemented with insights from across the ecosystem, with a focus on the start-ups and early-stage companies working in Sub-Saharan Africa, South Asia and Southeast Asia.

The growing waste challenge

With the rapid population growth of the last century and developments in material sciences, the volume of 'waste' has increased on a near exponential path. The per capita increases in material consumption mean that the growth in waste is outstripping population growth by a factor of two globally. E-waste is also the fastest growing major waste stream, exceeding population growth by a factor of three.

Despite an increased focus on circular economy approaches and recycling, the proportion of materials in the global economy cycled back into use fell between 2018 and 2023 from 9.1% to 7.3%. Global recycling rates also remain alarmingly low. Fewer than 10% of the world's plastic is recycled, and global e-waste recycling rates stand at 22%. Across low- and middle-income countries (LMICs), only half of municipal waste is collected in the first instance.

This growing body of waste has a significant impact on people, ecosystems and climate. The global food system is estimated to account for 22% of global greenhouse gas (GHG) emissions, and food waste alone accounts for 6-10% of global emissions. In the context of more intense and unpredictable rainfall, an estimated 218 million people are at heightened risk of flooding due to plastic waste. E-waste and sewage pose acute health risks if not properly managed, with an estimated 30 million adults and children currently experiencing adverse health impacts from informal e-waste recycling, and the costs of poor sanitation in African and Asian countries are estimated at nine per cent of GDP.

The negative impacts on waste management are no more profound than on the estimated 20 million informal waste pickers working globally. Up to 85% of waste workers operate in the informal sector, working with few, if any, safeguards and are subject to unpredictable working patterns and remuneration. In many markets they form the backbone of the waste management system and are critical actors in enacting any change.

Drivers for changes in the market

There is growing momentum behind national and global policy change governing waste. In many cases, these changes are market-making for those working towards circular economy approaches. Extended producer responsibility (EPR) policies, built on the 'polluter pays' principle, emerged in law in the European Union in the 1990s and have been slowly growing momentum globally since. Notably India, Indonesia, South Africa, Kenya and Ghana have all recently signed into law EPR policies governing plastics and e-waste. Additionally, the draft text of the Global Plastic Treaty currently being negotiated includes EPR provisions.

Demand for secondary materials in manufacturing is rising; in the case of e-waste this is partially in response to the limited global supply in critical inputs. 2022 saw the first ever rise in global battery prices, and the International Energy Agency forecast a major shortfall in the minerals and materials needed for the energy transition. With the global supply of these critical inputs often highly concentrated in a few key countries, e-waste is becoming an increasingly valuable resource.

That the waste sector is such a significant source of emissions presents the opportunity for mitigation, and for access to climate finance. Waste sector emissions are largely from methane, which is a far more potent GHG than carbon dioxide, but it also has a shorter atmospheric half-life, meaning any action taken to reduce methane production will result in a slowing of heating more quickly. Recent research has shown that composting all organics would achieve the same impact on GHG emissions as halving global waste.

Lastly, start-ups working in the waste sector are increasingly being viewed favourably by investors. Series raises in the tens of millions are increasingly common. This, paired with government investments and the demand for secondary materials, is contributing to the development of functioning waste management ecosystems where the secondary materials produced can find their market. The development of the ecosystem is also increasingly supporting the specialisation of firms within value chain niches.

The digital solutions supporting circularity

Start-ups working in the space have offers related to app-based systems for arranging the collection of waste from households. Mobile payments and tracking allow for the delivery of incentives for behaviour change. In the case of solid waste, this is most often the case for segregating waste or even just recycling in the first place. In the absence of functioning collection systems in many cities, these tools are a vital first step.

Many of the app-based solutions for collections also include a focus on the welfare of the waste pickers. Examples include premium payment amounts when using a digital app, micro health insurance, or the channelling of EPR payments to waste pickers. Digitalising payments can itself be of value to waste pickers in creating a credit history and accordingly access embedded financial services.

IoT and other sensing devices are increasingly being deployed to determine the fill levels of waste containers and their status. This data is important for the effective logistics in collecting the waste as well as ensuring a higher level of service for customers by emptying full containers promptly. Combined with GIS and vehicle tracking, the data can also be used for route optimisation.

As accountability measures in waste management become stronger through EPR legislation, a vital offer of digital is in the tracking and tracing of waste. In the case of legislative compliance, the use of tokenisation or blockchain technologies can add much needed credibility to claims.

A fast-growing use case for AI and machine learning is in the identification and analysis of waste stream components and patterns, and combined with robotics at centralised facilities to fully automate waste segregation. These analytics are particularly important in the case of e-waste, where estimating the value of components can be challenging to do at scale effectively.

The combination of knowledge of a product's value and the ability to track it opens the door to 'urban mining' and supports the reverse logistics. The most advanced form of this is digital product passports (DPPs), a digital twin of the product which can share data on a product's entire lifecycle, including information on the material contents, production processes and end-of-life disposal.

Data scarcity is a major constraint for many urban bodies across LMICs in urban planning and service delivery. Additionally, a lack of data at the national level inhibits the development of effective policies and regulation. Remote sensing data, payment data or the data from digitising collection processes can begin to build the necessary foundations for data-driven decisions. Additionally, data-sharing partnerships between the public and private sector can bridge this gap.

Looking forward

In the last few decades, circularity has moved from the fringes to take centre stage in global and national policy making. While the concepts are much talked about and increasingly established, global recycling and reuse rates for materials are testament to the fact that we are only at the very beginning of operationalising circularity principles. In the coming years, tightening global legislation, the pressing material needs of the energy transition and bringing consumption within planetary boundaries will all enable and strengthen markets and solutions focused on circularity. The digital solutions highlighted in this report, and the companies developing and delivering them, offer a vision for how these more sustainable economic models can be realised.

The global waste management challenge

Waste production

PLASTICS

The OECD estimate that without action, the volume of plastic waste will reach over

1tn tonnes

by 2060,

and plastic production is forecast to account for

20% of global oil production by 2050

Plastic pollution is a particular concern for the world's ecosystems

For example, an estimated **2,141 marine species** have been found to encounter **plastic pollution** in their natural environments

In 2019 the EU exported nearly **2 million tonnes** of plastic waste

In 2018 the US exported over **1 million tonnes** of plastic waste,

78% of which went to countries that lack safe waste management legislation

SANITATION

It is currently estimated that only **58% of the world's wastewater is safely treated**, but with wide regional variation. In Sub-Saharan Africa, the figure is 20%

The water sector as a whole is responsible for up to **10% of global GHG emissions,** and recent studies indicate that **wastewater and faecal sludge** contribute **62%** of this total

ORGANICS

Food waste accounts for **6% of global GHG emissions,** not including on-farm waste

If food waste were a country, it would be the world's **third largest GHG emitter** behind China and the USA

E-WASTE

In 2022, an estimated **62Mt** of e-waste was produced,

just over **7.8kg** a year for every person on earth

and **more** by weight than **all commercial airliners ever made**

1. World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company. (2016). *The New Plastics Economy: Rethinking the future of plastics.*
2. WWF International. (2022). *Impacts of Plastic Pollution in the Oceans on Marine Species, Biodiversity and Ecosystems*
3. World Food Programme. (2020). *5 facts about food waste and hunger* (Accessed 22 March 2024).

Recycling and reuse

Currently, fewer than **10%** **of the world's plastics are recycled** Around **half of all plastics end their life in landfill**

90% **of all ocean-bound plastic** comes from just **10 rivers** (eight in Asian countries and two in African countries)

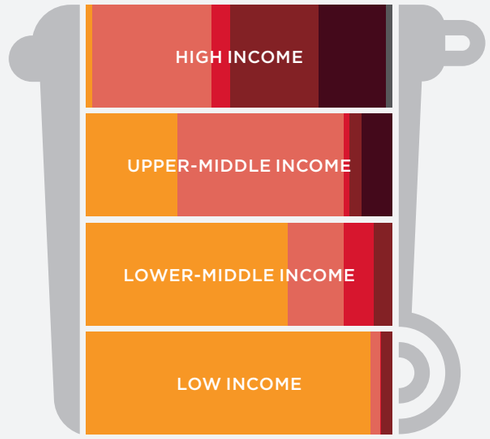
For countries with complete data, only **32%** **of wastewater flows** received some form of **treatment**

Around **a third of all food produced is wasted,** with 13% lost between harvest and retail and 17% wasted within households

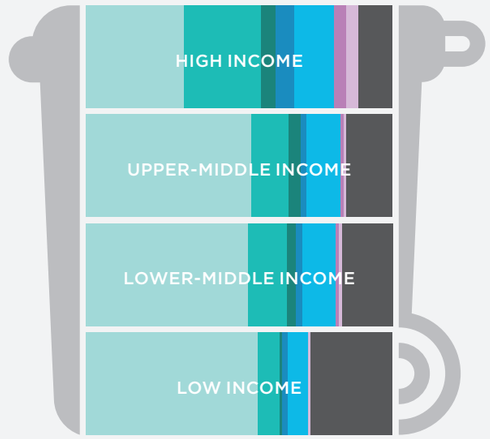
Currently only **22%** **of e-waste is formally collected and recycled** in an environmentally sound manner

Waste composition and disposal by income level

Waste disposal method



Waste composition



Waste Disposal

- Open dump
- Landfill
- Composting
- Recycling
- Incineration
- Other advanced methods

Waste Compostion

- Food and green
- Paper and cardboad
- Glass
- Metal
- Plastic
- Rubber and leather
- Wood
- Other

Source: Kaza et al. 2018

Contents

List of figures, spotlights, and abbreviations

Figures

Spotlights

Abbreviations

AI	Artificial intelligence
API	Application programme interface
DPPs	Digital product passports
DRHs	Decentralised recycling hubs
EPR	Extended producer responsibility
GHG	Greenhouse gas
ILO	International Labour Organisation
IoT	Internet of Things
LMICs	Low- and middle-income countries
MRF	Material recovery facility
PET	Polyethylene terephthalate
PPE	Personal protective equipment
PROs	Producer responsibility organisations

1 Introduction

Waste has become a pervasive feature of modern life in every corner of the world, and without change this will only become more so. The United Nation's Environment Programme (UNEP) estimate that, as of 2023, the world's cities produced 2.3 billion tonnes of municipal solid waste, which is equivalent to ~285 kg per year for every person on the planet. Their forecasts estimate this will grow to 3.8 billion tonnes by 2050; outstripping population growth rate by a factor of two.[4] These estimates are consistent with previous World Bank figures that have similar projections.[5] To 2050, the total amount of waste generated is expected to triple in Africa and double in Asia. This rate of growth is even more pronounced for some waste streams; the volume of e-waste produced per person per year is forecast to increase from seven kilograms in 2020 to almost nine kilograms by 2030.[6] Only minimal amounts of materials used in the global economy are recovered for reuse, and this number is falling rather than rising. The Circularity Gap Report estimates that in 2018, 9.1% of the materials used in the global economy were cycled back into reuse. By 2023, this figure had fallen to 7.2%.[7]

Cities in low- and middle-income countries (LMICs) face considerable pressure to provide adequate waste management services. Higher consumption, driven by urbanisation and economic growth, will on a business-as-usual path, result in a much larger volume of waste to manage. At the same time, municipalities are often already stretched to provide only limited services. In low-income countries, over 90% of waste is dumped or burned, yet in those same countries waste management accounts for approximately 20% of municipal budgets.[8] Municipalities risk being caught in a vicious cycle where they are spending a large proportion of their budget on waste and yet residents are dissatisfied with the service, damaging willingness to pay and creating political risks for budget setters.

Very little of the waste produced is adequately managed, and recycling and reuse rates are low across all waste streams. Only two per cent of all the plastic waste ever produced has been reused in the same function, while 80% has been landfilled, incinerated or leaked into the environment.[9] Similarly, global rates of e-waste recycling stand at only 22%, despite the value of the raw materials within devices and surging commodity prices.[10] Mismanaged waste often ends up entering the environment, with plastics and e-waste particularly harmful. Pollution is one of the top five contributors to global biodiversity loss.[11] Without action it is estimated that the amount of plastics entering the oceans will triple by 2040 to 29 million tonnes per year, equivalent to an astonishing 50 kg of plastic per metre of coastline worldwide.[12] The ingestion of plastic fragments are of particular concern for sea life, affecting hundreds of species, including 86% of all marine turtles, 44% of all seabird species and 43% of all marine mammals. The estimate the externality costs of plastic pollution at between $300 and $450 billion annually.[13]

The bulk of the work to recycle, and the risks and health impacts of doing so, are currently borne by the estimated 20 million informal waste pickers globally.[14] In many countries these workers are the backbone of the waste management system, and reportedly collect up to 60% of all the plastic waste recycled globally.[15] The ILO estimate that up to 85% of waste workers operate in the informal sector, working with few, if any, safeguards and are subject to unpredictable working patterns and remuneration.[16] Any solutions seeking to reform waste management must consider the role of waste workers.[17] In the context of the Global Plastics

4. UNEP. (2024). *Global Waste Management Outlook 2024*
5. Kaza, S., et al. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.* World Bank.
6. ITU. (2020). *Global e-Waste Monitor.*
7. Circle Economy Foundation. (2023). *The Circularity Gap Report 2023.*
8. Kaza, S., et al. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050.* World Bank.
9. Wilson, M. et al. (2021). *Digital Dividends in Plastic Recycling.* GSMA.
10. ITU and UNITAR. (2024). *Global E-waste Monitor 2024*
11. IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services.*
12. The Pew Charitable Trusts. (2020). *Breaking the Plastic Wave.*
13. UNEP. (2023). *Turning off the Tap: How the world can end plastic pollution and create a circular economy*
14. Zolinkov, T.R., et al. (2021). *A systematic review on informal waste picking: Occupational hazards and health outcomes.* Waste Management
15. International Alliance of Waste Pickers (2022) Submission to the secretariat for the Intergovernmental Negotiations Committee for the prospective Plastics Treaty at the United Nations Environment Programme.
16. ILO. (2013). *Sustainable development, decent work and green jobs.*
17. Circle Economy, ILO and World Bank. (2023). *Decent Work in the Circular Economy*

Treaty negotiations, The International Alliance of Waste Pickers have set out nine components to include in a just transition for waste workers.[18] Mismanaged waste also poses health threats to the wider population. This is particularly clear in the case of faecal waste and public health, but also includes industrial pollutants and contaminants and the air quality impacts of waste burning.

The impacts of the waste sector on climate change are profound, with organic waste, plastics and faecal waste all major sources of emissions. In 2019, the production and incineration of plastics resulted in over 850 million tCO2e, which is about 2.5% of the global total.[19] Every tonne of plastic burnt will emit 2.9 tCO2e, and given the limited options for safe management, the emissions from plastics could rise sharply in the coming years. The food system accounts for over 20% of global greenhouse gas (GHG) emissions,[20] and food waste alone 6-10% of global GHG emissions.[21,22] The bulk of these emissions are from organic waste being landfilled; composting or biogas emit far less, and can even result in net reductions for CO2 emissions. Faecal waste also emits huge amounts of GHGs if not properly managed. The water sector as a whole uses resources or emits GHGs equivalent to around 10% of global emissions, with wastewater treatment accounting for over 60% of that total.[23]

Decarbonising the waste sector holds great potential for reducing the near-term temperature increases. The waste sector is a major source of methane emissions, which are both more potent than CO2 but also have a shorter atmospheric half-life. Meaning action to reduce methane emissions have a comparatively rapid impact on reducing warming. A recent global analysis of waste management's mitigation potential found the waste sector will exceed 1.5 degree thresholds by 2028 under a business-as-usual path, but with action there is a pathway for the sector to become carbon negative.[24]

Beyond decarbonisation, the waste sector makes important contributions to climate resilience and adaptation, with flooding in particular presenting high risks.[25] An estimated 218 million people are at risk from plastic-aggravated flooding worldwide as solid waste clogs the drainage system of cities.[26] Faecal and solid waste present health hazards in the wake of floods, where inadequate infrastructure leads to outbreaks.[27] Beyond preparing for more frequent and extreme weather events, adequate waste management contributes to long-term resilience in the population through improved health, and in the case of the waste pickers working in the sector, greater economic resilience where they are recognised and more formally integrated into the system.

Momentum is building behind policy reform, both global and national, that is set to reshape markets and create new ones. Extended Producer Responsibility (EPR) rules and legislation, whereby the producers of certain waste streams become responsible for their end-of-life disposal, is one of the most powerful policy tools available. Countries are increasingly enacting these globally, albeit at a slow pace, and new market opportunities are created as value is attached to the waste through compliance requirements. EPR legislation to date has most commonly targeted e-waste and plastics. Additionally, in 2022, 175 nations agreed to develop a global legally binding agreement to address the full lifecycle of plastic, including its production, design and disposal.[28]

There is also a vibrant, growing and dynamic innovation ecosystem in waste management that is increasingly attracting sizable investments across LMICs. Digital innovations are enabling more effective service delivery and giving policy makers and regulators greater oversight and enforcement mechanisms. Innovation is happening at all stages of the value chain, from connecting households to informal collectors and ensuring waste pickers work in safe conditions and are fairly remunerated, to tracking waste through the value chain, and innovations in processing that allow the cycling of materials back into use. Digital solutions developed for one purpose or one waste stream often have applications across others, although these synergies are more limited at the processing stage of the value chain where materials are cycled back into use via processes to the waste stream. The ILO estimate that the transition from a linear economic model to a circular one has the potential to generate eight million new jobs globally.[29]

18. IAWP. (2023). *IAWP's Vision for a Just Transition for Waste Pickers under the UN Plastics Treaty*.
19. Center for International Environmental Law. (2019). *Plastic & Climate: The Hidden Costs of a Plastic Planet.*
20. IPCC. (2022). *Climate Change 2022: Mitigation of Climate Change, Summary for Policy Makers*.
21. Poore, J., & Nemecek, T., (2018). *Reducing food's environmental impacts through producers and consumers.* Science, 360, 987-992.
22. FAO. (2022). *Tackling food loss and waste: A triple win opportunity.* (blog, accessed March 2024).
23. GIZ. (2020). *Report on Water and Climate Change: Stop Floating, Start Swimming: Water & Climate Change*.
24. Hoy, Z.X., et al. (2023). *Curbing global solid waste emissions toward net-zero warming futures.* Science, 382, 797-800.
25. C40 Cities. (2020). *Reducing climate change impacts on Waste Systems*.
26. Tearfund and Resource Futures. (2023). *Plastic pollution and flood risk*.
27. Wang, P., et al. (2023). *Floods and Diarrhea Risk in Young Children in Low- and Middle-Income Countries* JAMA Pediatr. 177(11): 1206–1214.
28. UNEP. (2022). *Historic day in the campaign to beat plastic pollution: Nations commit to develop a legally binding agreement.* (blog, accessed March 2024).
29. ILO. (2019). *Skills for a Greener Future: a global view*

1.1 Scope and focus of this report

This report takes stock of the digitalisation of waste management across four key verticals: organics, plastics, e-waste and sanitation/ wastewater, with a focus on the start-ups delivering these in low- and middle-income countries. The insights draw heavily on the recently completed GSMA Innovation Fund for Digital Urban Services, which included four organisations working on digitalising waste management (see Spotlight 16), and the GSMA's past innovation funding to sanitation providers. These insights were supplemented with interviews from across the ecosystem, with a focus on the start-ups and early-stage companies working in Sub-Saharan Africa, South Asia and Southeast Asia. The report aims to provide an overview of the landscape of emerging innovations, the companies driving these forward, and what is needed for these to scale to meet the challenge. The remainder of the report is structured as follows:

— Chapter 1 outlines some of the key concepts underpinning this report;

— Chapter 2 takes stock of the waste management challenges across four key waste streams and where digital solutions can address these;

— Chapter 3 presents detailed insights from the four organisations in the recent GSMA Innovation Fund cohort; and

— Chapter 4 discusses the key trends defining the sector and makes recommendations for action.

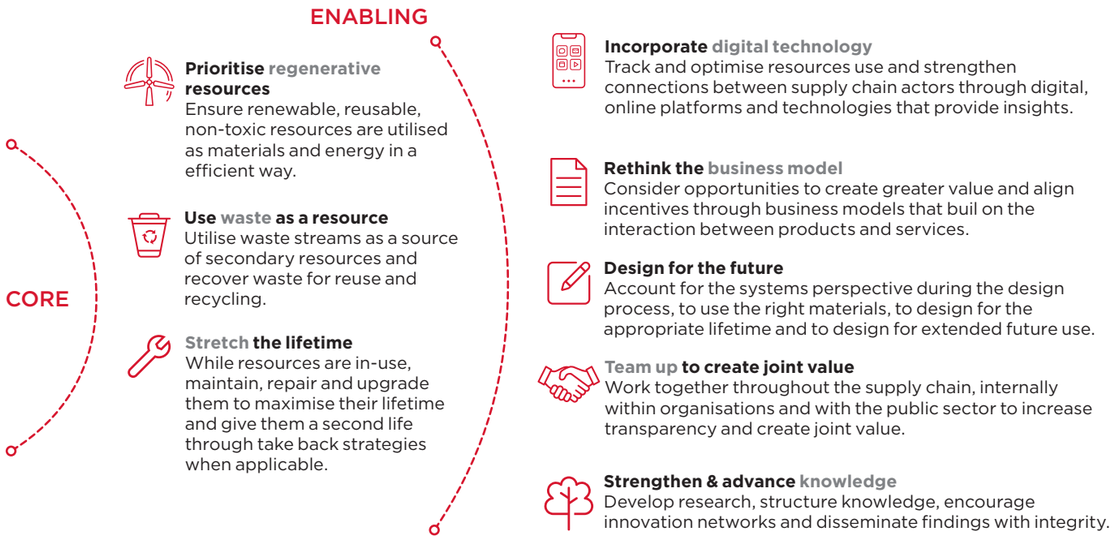
The report has some key notable limitations. First, many of the companies working to digitalise the sector focus on addressing issues of what happens to waste after it has become waste, as such there is less of a focus on the elements of the circular economy principles related to overall waste reduction or waste reduction in production processes. Secondly, the focus of this research is on municipal solid waste and only some of the waste streams within municipal solid waste. This implicitly excludes sectors that make a significant contribution to global consumption and waste, notably construction waste, textiles, and industrial production and pollutants.

1.2 Circular economy models and principles

At the core of most circular economy models is the decoupling of prosperity from the use of finite resources. In the last 20-30 years, circular economy ideas and principles have moved from being a fringe concept to the centre of global and national policy making. With that has come a phenomenal growth in the use of the term, though often without clarity surrounding exactly what is meant. The Circularity Economy Foundation identify eight key elements that define most approaches: three core elements that relate to material and energy flows, and five further enabling elements that support these core elements; these are detailed in Figure 1. Similarly, the Ellen MacArthur Foundation identifies the three principles of i) eliminating waste and pollution, ii) circulating products and materials at their highest value, and iii) regenerating nature. A second critical concept of the waste hierarchy (Figure 2) provides a framework for guiding actions to move towards circularity, with the highest impact actions at the top, centred on preventing waste by design in the first instance, and the lower impact actions at the bottom.

Figure 1

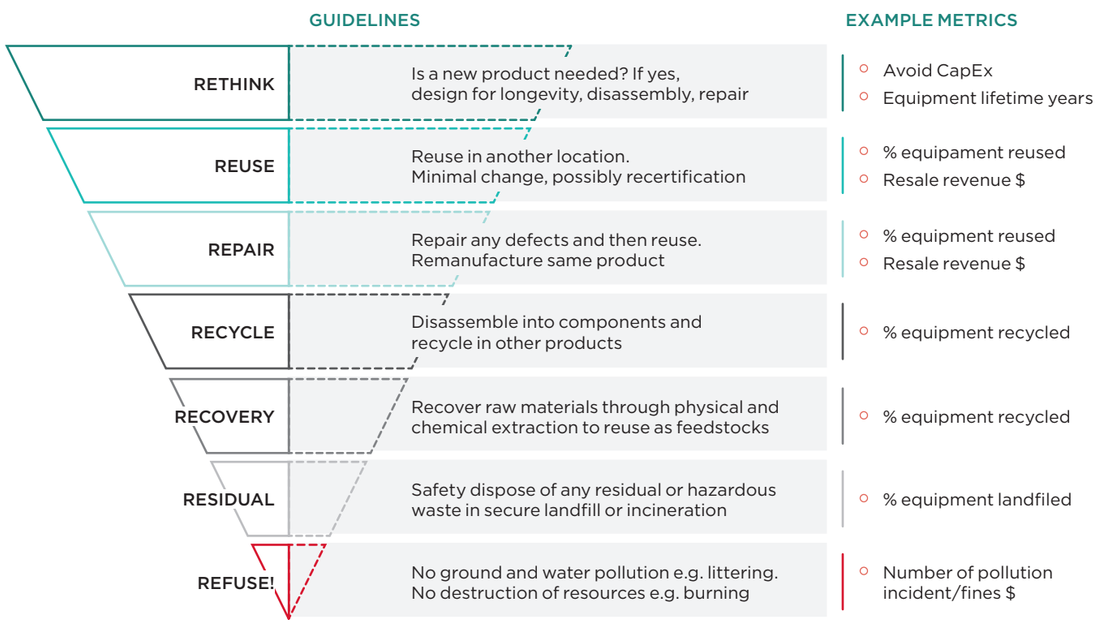
Defining the key elements of circular economy approaches



Source: Adapted from Circle Economy Foundation's Key elements of the circular economy

Figure 2

GSMA waste hierarchy for mobile devices and network equipment



Source:GSMA

2 Waste management challenges and the offer of digital

2.1 The key waste streams considered

This chapter sets out some of the key challenges in the waste streams examined in this report, before turning to the opportunities that digital provides to address them. The opportunities for digitalisation are presented through the lens of the function the technology performs. Figure 3 outlines a generic value chain for waste management, which will look very different across different waste verticals and market contexts. Nonetheless, most waste will pass through three key stages: collections, transport and aggregation, and processing.

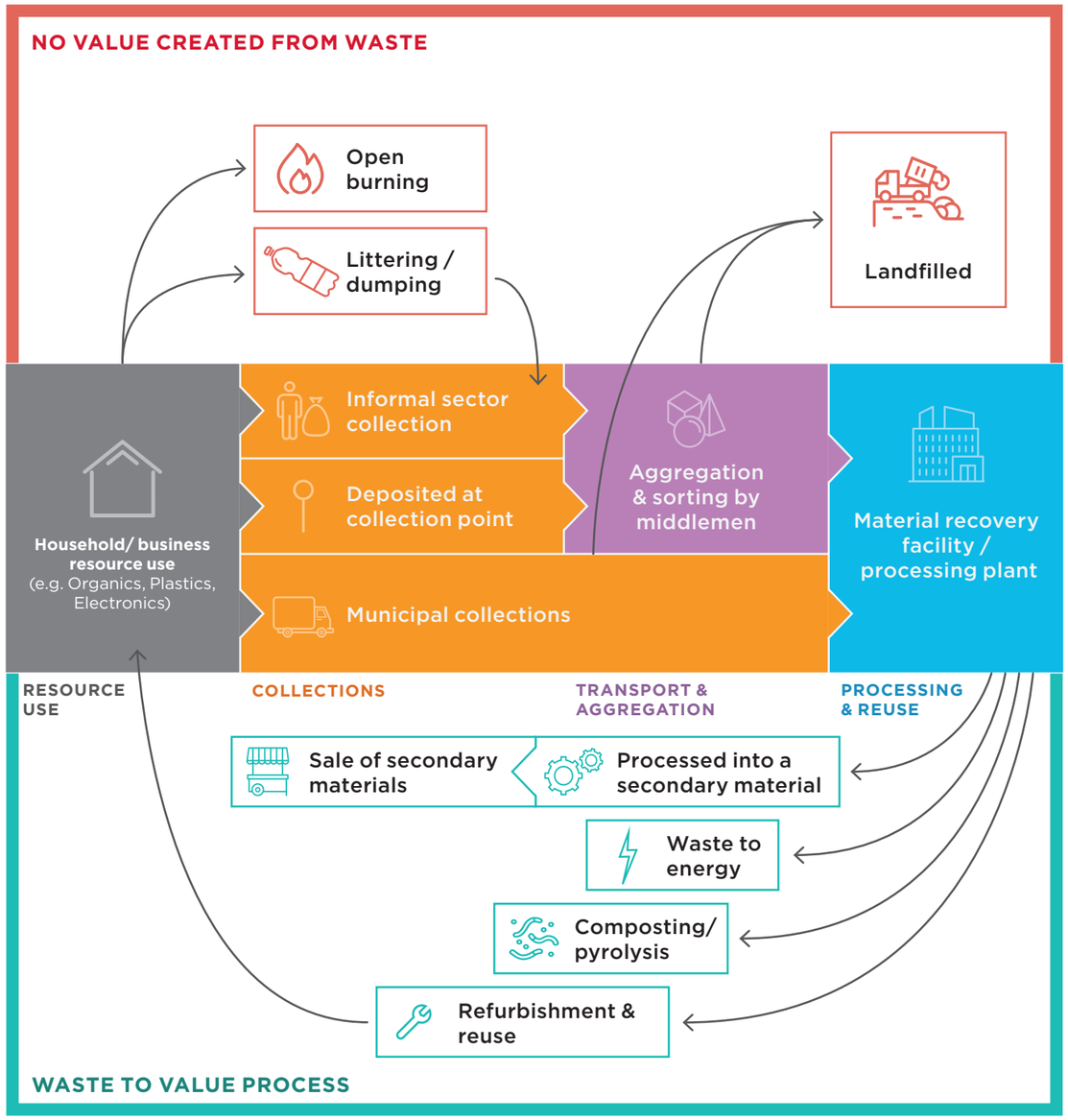
Organic and food waste

In all regions, organic waste is the highest single waste category by volume and accounts for 44% of municipal solid waste globally, with food waste accounting for a large proportion of this. A third of all food produced is wasted, with 13% lost between harvest and retail and 17% wasted within households,[30] which is equivalent to 1.3 billion tonnes of food. For reference, the World Food Programme estimates that this is enough to feed two billion people and represents over $1 trillion in value.[31] That food waste is such a high proportion of waste makes it critical to address in the issue of urban planning and management. Cities around

30. UNEP. (2021). *Food Waste Index Report 2021.*
31. World Food Programme. (2020). *5 facts about food waste and hunger.* (blog, accessed March 2024).

Figure 3

Waste management value chains



the world are rapidly running out of landfill space and have very few alternatives for management. For example, Jakarta's Bantar Gebang landfill is the size of 200 football fields, 50 metres high, and grows by 7,000 tonnes a day despite this. Similarly, Delhi's 'trash mountain' in Ghazipur reached capacity in the early 2000s, but grows by 10,000 tonnes a day and is 60 metres high and several miles wide. The concentration of organics in these landfills contributes to massive methane build-up, with methane 'super-emitter' events monitored from space identifiable to specific landfills.[32] This methane can also contribute to landfill fires, which pose serious health concerns for the many millions living close to them.[33]

The waste sector is critical in addressing GHG mitigation and offers one of the most effective paths to slowing global heating. The food system accounts for a quarter of global GHG emissions, not including on-farm waste, almost exclusively in the form of methane.[34] This is driven by the presence of organic matter in landfills. A tonne of organic waste in a landfill will generate roughly 400 kg of CO2e, equivalent to the per passenger emissions on a four-hour flight. Composting it, however, will result in a reduction of 41 kg of CO2e and biogas also represents a reduction in net emissions.[35] Methane is a far more potent GHG than carbon dioxide, but it also has a shorter atmospheric half-life, meaning any action taken to reduce methane production will result in a slowing of heating more quickly. The 'waste pathway' of the Global Methane Pledge outlines the actions needed and that are already being taken in the sector. Additionally, recent research has mapped the waste sector's path to decarbonisation, which rests heavily on properly managing organics, as composting all organics has a comparable CO2 impact to halving all waste (Figure 4).

Figure 4

Waste sector pathways to decarbonisation

Source: Hoy, Z.X., et al. (2023). Curbing global solid waste emissions toward net-zero warming futures. Science, 382, 797-800

32. NASA. (2022). *Methane 'Super-Emitters' Mapped by NASA's New Earth Space Mission.* (blog, accessed March 2024).
33. The Guardian. (2024). *'It's impossible to breathe': Delhi's rubbish dumps drive sky-high methane emissions.* (article, accessed March 2024).
34. Poore, J., & Nemecek, T., (2018). *Reducing food's environmental impacts through producers and consumers.* Science, 360, 987-992.
35. Nordahl, S., et al. (2020). *Life-Cycle Greenhouse Gas Emissions and Human Health Trade-Offs of Organic Waste Management Strategies.* Environ. Sci. Technol. 54, 15, 9200–9209.

Plastics

In 2019, over 460 million tonnes of plastic waste was produced, with the global plastics market valued at over $700 billion in 2023 and expected to cross the $1 trillion mark within the next 10 years.[36,37] The OECD estimate that without action, the volume of plastic waste will reach over a trillion tonnes by 2060.[38] Fewer than 10% of the world's plastics are currently recycled, around half of all plastics end their life in landfill, just under 20% are incinerated and the remaining 20% is mismanaged in other ways.[39]

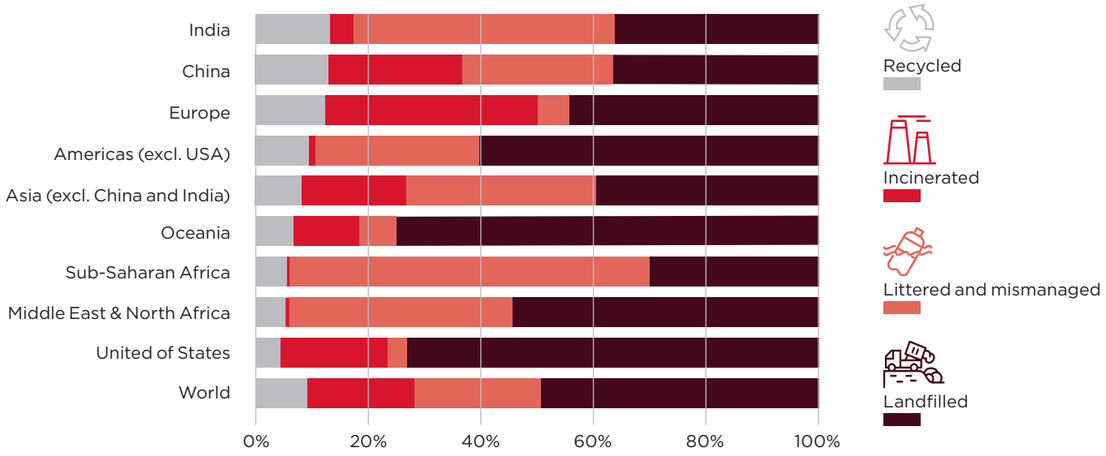
Much of this has to do with cities and nations' ability to manage waste. Plastic Overshoot Day have constructed an index that estimates a country's ability to manage the plastics they receive, and accounts for plastics imported and exported. The index estimates country capacity based on the level of plastics imported and exported combined with the volumes that are mismanaged (littered, uncollected, or improperly disposed of in unsanitary landfills or dumpsites).[40]

While there is enormous variation between countries and context, a clear trend emerges with respect to income group. The median capacity of low-income countries to manage plastics was 2.7%, while for high-income countries this figure was 83%. For lower-middle and upper-middle income countries, the figures are 11% and 26% respectively.

This management issue is compounded by the fact that many high-income countries export large volumes of their waste to lower income countries. For example, in 2019 the EU's then 28 member states exported nearly two million tonnes of plastic waste to countries predominantly in the Asia-Pacific; that figure was nearly twice as high four years earlier.[41] Similarly, the US was the world's largest exporter and shipped over a million tonnes of plastic abroad in 2018, 78% of which went to countries that lack safe waste management legislation.[42] One result of this combination of historic exports and mismanagement is that 90% of all ocean-bound plastic comes from just 10 rivers (eight in Asian countries and two in African countries).[43]

Figure 5

Plastics end-of-life fate by region (2019)



Source: Author's analysis of OECD.Stat data

36. OECD. (2022). *Global Plastics Outlook: Policy Scenarios to 2060*.
37. Future Market Insights. (2022). *Plastic Market Snapshot 2023 to 2033*.
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39. For details see: GSMA. (2021). *Digital Dividends in Plastic Recycling*.
40. Plastic Overshoot Day. (2023). *Plastic Overshoot Day Methodology guide*.
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42. rePurpose. (2019). *US Waste Exporting Explained.* (blog, accessed March 2024).
43. Schmidt, C., et al. (2017). *Export of Plastic Debris by Rivers into the Sea*. Environ. Sci. Technol. 51, 21, 12246–12253.

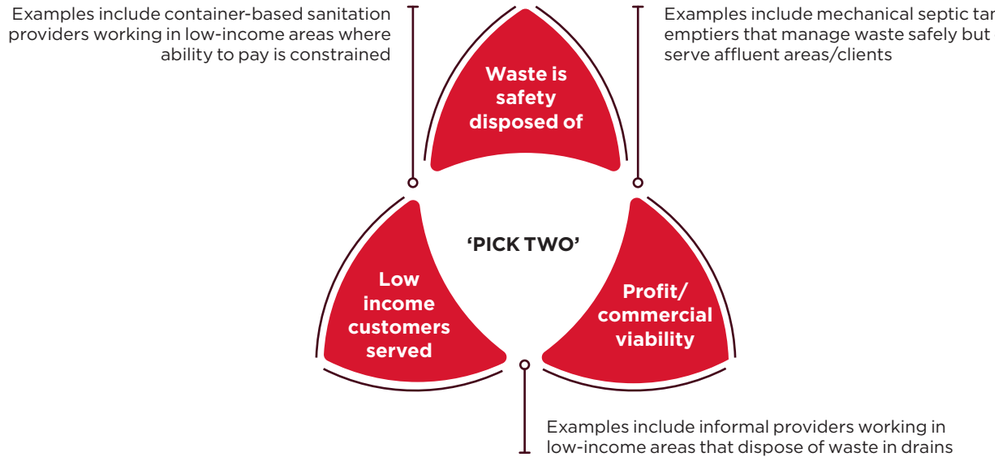
Sanitation

Few waste streams are more hazardous to human health than poor sanitation and faecal waste entering the environment. The malnutrition costs from poor sanitation in African and Asian countries are estimated at a staggering 9% of GDP.[44] The contaminants in wastewater (from both industrial and human waste) pose serious environmental challenges, from endocrine-disrupting compounds from pharmaceuticals entering the food chain to microplastics and high levels of nitrogen and phosphorus causing algae blooms that choke aquatic life.[45,46] The global data on wastewater treatment is extremely limited, but current best estimates suggest that only 32% of wastewater flows receive some form of treatment.[47] Properly managed wastewater can dramatically reduce its impact on human health and the environment. As an example, secondary and tertiary wastewater treatment processes remove 88% and 94% of microplastics.[48]

We are also only just beginning to fully understand the relationship between sanitation and climate, and all signs point to a serious underestimation of the impacts. On-site sanitation alone (i.e., excluding emissions from sewer access) is estimated to generate around five per cent of global methane emissions.[49] The proportion of emissions from sanitation is also particularly high in cities. A recent analysis in Kampala, Uganda, suggests sanitation may represent more than half of their total city-level emissions.[50] A radical rethink of how to manage faecal waste from cities is needed, as mismanagement and poor onsite storage results in high methane emissions, while proper conventional management is energy intensive.[51] Add to this the need to rapidly expand services and it is clear new and innovative models are needed for rapidly growing cities. Sanitation is also all too often cripplingly underfunded, meaning one of three aims—profit/commercial viability, serving low-income customers and disposing of waste safely—must be sacrificed. Collecting and safely disposing of waste is a widespread service, but only where residents can pay for this. Providers working in low-income areas and the safe disposal of waste often face commercial challenges, while those serving low-income areas and making a profit often do so by not incurring the costs of safely disposing of the waste.

Figure 6

The pick two problem in urban sanitation



44. UN-Habitat. (2023). *Global Report on Sanitation and Wastewater Management in Cities and Human Settlements*.
45. Kapelewska, J., et al. (2022). *Endocrine-Disrupting Compounds in Water Environment: Analytics and Impact on Living Organisms.* In: Buszewski, B., & Baranowska, I. (Eds) Handbook of Bioanalytics. Springer.
46. Sun, J., et al. (2019). *Microplastics in wastewater treatment plants: Detection, occurrence and removal.* Water Research, Vol 152, 21-37.
47. UN-Water. (2021). *Progress on Wastewater Treatment*.
48. Ahmed, R., et al. (2022). *Critical review of microplastics removal from the environment.* Chemosphere, Vol 293, 133557.
49. Cheng, S., et al. (2022). *Non-negligible greenhouse gas emissions from non-sewered sanitation systems: A meta-analysis.* Environmental Research, Vol 212, Part D, 113468.
50. Johnson, J., et al. (2022). *Whole-system analysis reveals high greenhouse-gas emissions from citywide sanitation in Kampala, Uganda.* Communications Earth & Environment, Vol 3, 80.
51. GWI. (2022). *How do we fix wastewater's big carbon problem?* (blog, accessed March 2024).

E-waste

In 2022, an estimated 62 million tonnes of e-waste was produced, which is equivalent to around seven kilograms a year for every person on earth.[52] E-waste is also the fastest growing major waste stream, outstripping population growth by a factor of three. The ITU estimate that by 2030, the volume of e-waste will increase by nearly 50% to just under 82 million tonnes annually. E-waste, tonne for tonne, contains approximately 90 times more gold than the ore.[53] In 2022, the value of the raw materials in global e-waste was estimated at $91 billion. E-waste contains particularly harmful chemicals and contaminants. The World Health Organization highlights adverse neonatal outcomes, neurodevelopmental learning and behavioural outcomes, and reduced lung capacity and function as some of the impacts of e-waste exposure.[54] Children are particularly vulnerable due to their stage of neurological development, among other factors.[55] There are an estimated 30 million adults and children currently experiencing adverse health impacts from informal e-waste recycling.[56]

Mineral and metal production is highly concentrated in a few countries, creating supply chain risks, and electronics manufacturing costs have risen sharply in recent years.[57] A smartphone commonly will contain up to 50 different metals, and for many of these the virgin production of the raw material is concentrated in just a few countries. The DRC mines around 75% of the world's cobalt, South Africa mines two-thirds of the world's platinum, and Australia mines over half of the world's lithium.[58,59] China produces over 80% of solar-grade polysilicon and mines 70% of the world's rare earth elements. There is an even higher concentration in the processing of these minerals, with, for example, China having high concentrations for graphite (>99%), rare earths (90%), cobalt (74%), and lithium (64%).[60] COVID-19 exposed the vulnerabilities in supply chains and led to a sharp increase in input costs within the electronics market.[61] In 2021, over 90% of electronics manufacturers reported increasing material costs.[62]

Spotlight 1

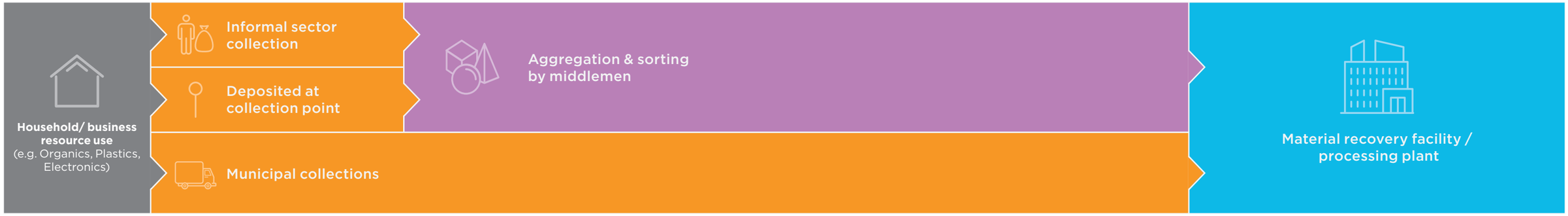
MNO e-waste reduction initiatives

In 2020, GSMA reviewed waste management legislation in 85 countries in Africa, South Asia and Southeast Asia, the results of which are published in an E-Waste Legislative Framework Map. In the same markets we reviewed the e-waste management efforts of MNOs and identified 67 cases across 40 countries. These included 38 customer awareness programmes; 43 programmes based on collecting different types of e-waste; 30 programmes based on specifically collecting mobile phones; and 25 related to management of e-waste from MNO towers and office locations. Further information on these can be found in a summary blog, and a blog series profiling some leading initiatives.

The high metallurgical content and growing prevalence of unused electronics has led to a growing interest in 'urban mining', where unused devices become a source for material inputs for new products. Much work is still needed to realise the potential, with the principal challenges of centralising the waste and developing effective extraction processes. E-waste recycling processes remain relatively crude for the most part, although significant investment and advances are now being made in e-waste recovery processes, notably in battery recycling, with companies such as Attero and Umicore developing processes that can lead to much higher levels of resource recovery. As the electric vehicle industry proliferates, many expect the battery recycling industry to grow in scale and sophistication, with some forecasts projecting that the waste from an electric car battery could be reduced to about 30 kg.[63]

52. ITU and UNITAR. (2024). *Global E-waste Monitor 2024*
53. Bookhagen, B., et al. (2020). *Metallic resources in smartphones*. Resources Policy, Vol 68, 101750.
54. WHO. (2023). *Electronic waste (e-waste)* (webpage, accessed March 2024).
55. WHO. (2021). *Children and digital dumpsites: e-waste exposure and child health*.
56. GSMA. (2022). *Strategy Paper for Circular Economy: Mobile devices*.
57. PACE and WEF, (2019). *A New Circular Vision for Electronics*
58. CMCC. (2023). *From waste to resource: the rise of urban mining* (article, accessed March 2024).
59. World Economic Forum (2023) *This chart shows which countries produce the most lithium* (article, accessed March 2024).
60. IEA. (2023). *Critical Minerals Market Review 2023*
61. S&P Global Market Intelligence. (2021). *Global electronics industry faces continuing supply disruptions.* (article, accessed March 2024).
62. IPC. (2021). *The Current Sentiment of the Global Electronics Manufacturing Supply Chain*.
63. Transport & Environment. (2021). *From dirty oil to clean batteries*.

2.2 Opportunities for digitalisation



RESOURCE USE | **COLLECTIONS** | **TRANSPORT & AGGREGATION** | **PROCESSING & REUSE**

Tools for citizen engagement and behaviour change campaigns

Digital tools, games and campaigns can help raise public awareness of why and how people are able to recycle or avoid waste, helping to drive behavioural change and increase collection and segregation rates. Solutions can also enable the identification of pollution hotspots, or report illegal dumping.

Connecting waste producers and collectors

Many start-ups working in the space have offers related to app-based systems for arranging the collection of waste from households. Incentivising both households and waste collectors to use the service and ensuring that these incentives are strong enough to guarantee continued use is critical to these services.

Delivering the incentivising behaviour change

Mobile payments and tracking allow for the delivery of incentives for behaviour change. In the case of solid waste, this is most often the case for segregating waste or even just recycling in the first place. Digital payment and virtual currencies are used by many of these apps, which can reward customers for segregating and cleaning waste. Similarly, these digital channels can be a means to return value to waste pickers from the reselling of upcycled materials or the benefits from the sale of plastic credits.

Digital tools to boost the welfare of waste pickers

Similar to household incentives, many of the app offerings for collections focus on the welfare of the waste pickers. Examples include premium payment amounts when using a digital app, micro health insurance, or the channelling of EPR payments to waste pickers. Digitalising payments can itself be of value to waste pickers in creating a credit history and accordingly access financial services.

Tracking and tracing of waste through the value chain and compliance with EPR legislation

As accountability measures in waste management become stronger through EPR legislation, a vital offer of digital is in the tracking and tracing of waste. In the case of legislative compliance, the use of tokenisation or blockchain technologies can add much needed credibility to claims. These technologies are also important for those solutions that have the potential to generate either carbon credits or voluntary plastic credits.[64] These same digital tools also offer efficient monitoring and enforcement mechanisms for tracking cross-border movements of waste, which is particularly important in the context of the forthcoming Global Plastics Treaty, for example.

Data acquisition on waste location and status

IoT and other sensing devices are increasingly being deployed to determine the fill levels of waste containers and their status. This data is important for the effective logistics in collecting the waste as well as ensuring a higher level of service for customers by emptying full containers promptly. Combined with GIS and vehicle tracking, the data can also be used for route optimisation.

Identification of resources for urban mining and reverse logistics

Reverse logistics describes the activities required to retrieve a used product from a customer or end user. This is particularly important in the case of e-waste and recovering value from devices or extending their life through refurbishment and sale on the secondary market. The offer of digital is in the tracking and identification of these products and providing a communication channel for their recovery. The most advanced form of this is digital product passports (DPPs), a digital twin of the product which can share data on a product's entire lifecycle, including information on the material contents, production processes, and end-of-life disposal.[65] For example, the EU have advanced proposals on DPPs and are in the midst of building the required digital infrastructure. Proposals include the use of QR codes as identifiers and that information is stored on the EU Blockchain.[66]

Advanced analytics and robotics in waste sorting

A fast-growing use case for AI and machine learning is in the identification and analysis of waste stream components and patterns, and combined with robotics at centralised facilities to fully automate waste segregation. These analytics are vital when deployed to estimate the value of waste, particularly in e-waste where estimating the value of components can be challenging to do at scale effectively.

Data for planning and policy development

Data scarcity is a major constraint for many urban bodies across LMICs in urban planning and service delivery. Additionally, a lack of data at the national level inhibits the development of effective policies and regulation. Remote sensing data, payment data or the data from digitising collection processes can begin to build the necessary foundations for data-driven decisions. Additionally, data-sharing partnerships between the public and private sector can bridge this gap.[67]

Marketplaces for secondary materials

Though a more nascent area, specific digital platforms for the sourcing of secondary materials are beginning to emerge. Such marketplaces, when combined with traceability tools and regulatory requirements for certain percentages of products to be made from recycled materials, may come to play a more prominent role in the sector.

64. See: Verra's Plastic Waste Reduction Standard as an example.

65. WBCSD. (2023). *The EU Digital Product Passport shapes the future of value chains: What it is and how to prepare*.
66. European Commission. (2023). *Recording of the Digital Product Passport (DPP) webinar on the draft standardisation request.* (Accessed 23 March 2024).
67. Kong, J., et al. (2021). *Innovative Data for Urban Planning: The Opportunities and Challenges of Public-Private Data Partnerships*. GSMA.

This remainder of this chapter examines how digital innovations have been deployed across the three stages common to most waste management value chains. It considers the issues specific to each stage of the chain, where digital innovations address these, and highlights the business models needed to support these. Throughout this chapter, examples of leading companies and initiatives are included to bring these to life.

2.3 Collections

The collection of waste itself is a value-add stage, yet the unit economics of running these services can be challenging. Households often do not pay for the service at the point of delivery, as these services are generally either provided as a municipal service or performed by the informal sector. Municipal collections may involve private operators working to contract, but these will be funded via taxation. In the case of solid waste and the informal sector, it is common that households do not pay for this service, but rather the waste pickers generate value from the segregation and on-selling of the collected waste. This market dynamic is important as start-ups operating in the space cannot assume there will be a willingness to pay for collections at the household level.

For many app-based solutions, it is not a strong enough value proposition to simply connect users and collectors; relatively strong incentives need to be in place to ensure user stickiness. This applies both to the households using the solution as well as those collecting the waste. In some cases, such as Bekia in Egypt, these incentives are purely financial, with a proportion of the sale of waste further along the value chain returned to the household or waste collector. Similarly, ReCircle in India generate plastic credits and return the value to partners in the value chain in the form of premium prices paid. Other key examples of app-based platforms in this space include TakaTaka Ni Mali in Kenya, Zaidi Recyclers in Tanzania, The Kabadiwala in India, and Wahu in Indonesia. Financial incentives are not the only mechanisms available for driving use, as safer working conditions and predictability can also be used as offers to engage with app-based solutions for waste pickers. For example, Mr. Green Africa have an app-based loyalty programme which provides life and business skills training, health assistance, access to microcredit, protective clothing, and mobile phones. Bundling services can also be another incentive; for example Soso Care in Nigeria offer health insurance where the premium can be paid in recyclables.

A second critical value-add process that can take place at the household is the segregation of waste. For most waste-to-value processes, this segregation will have to happen at some stage and there can be significant benefits to this taking place at the household, especially when it comes to organics. Organics mixing with dry waste (paper, plastics, metal and glass) causes contamination that is challenging and costly to address at later stages. This mixing is also a key contributor to the overall GHG emissions produced by landfilling waste, as methane from these organics is the key source of emissions at this stage. In all previously mentioned solutions, segregation is part of the value position in using the apps. Segregation also increases the value of the waste at the point of collection, meaning that it can be more worthwhile for a waste picker to go to a collection if they know there will be segregated waste there. For organisations working with organics, there is the additional important step of safe and hygienic containment. Companies like Rekosistem in Indonesia and Freetown Waste Transformers in Sierra Leone have containment with app-based collections. Safety and hygiene is even more of a concern in sanitation and the collection of faecal waste, and companies like Fresh Life, Loowatt, and Mosan have all developed specialised containment for household collections and conversion to value via biogas or composting.

The business models that support sustainable services vary by solution type, waste stream and context. Insights from companies operating financial incentives indicate that relatively high volumes need to be transacted to ensure that these financial incentives can be strong enough to have a meaningful impact on behaviour. Companies offering the digital solution to other players in the ecosystem also must achieve scale, which can take time. The waste-to-value process, the waste stream dealt with, and the degree of vertical integration also impact unit economics significantly. Many companies struggling with the unit economics of just operating collections signalled that vertical integration was a key strategy for commercial sustainability. Finally, the unit economics are often the most challenging in reverse logistics for packaging, as there are not only additional steps in the value chain to cycle into use, but also that the cost of virgin materials in packaging is so low.

Spotlights

2. The Zero Waste Living Lab building the reuse ecosystem

The Zero Waste Living Lab (ZWLL) in Indonesia is a programme by international start-up studio Enviu. It is focused on launching 'reuse businesses' that drive systemic change towards a true circular economy for plastics. Their active ventures include Allas, who focus on returnable food packaging solutions, and Alner, a venture focused on providing reusable replacements for sachet packaging. ZWLL previously explored models for takeaway food, but found the unit economics were not feasible, given how artificially cheap virgin plastics are. Key learnings from their experimentation are that financial incentives are needed in many cases (subsidy for reuse or tax for single use), and bans are required for some of the most problematic materials. The other key challenge for ventures focusing on reuse is building the entire ecosystem for an extended value chain. For a product to have a second life, additional steps needed to retrieve packaging from consumers and a process for sanitising the product and preparing it for reuse. Here, digital technologies have two key offers: the tracking and tracing of the packaging through RFID, QR codes or IoT devices, and app-based services for managing communications with customers and resellers.

3. Aligning incentives for segregation at source, Bekia in Egypt

Founded in 2019, Bekia is an app-based service that allows users to receive digital payments directly to their wallets in return for segregating their waste. Bekia users are guided by the app to separate their waste into categories. Household collections are then ordered through the app where third-party independent drivers collect the waste and deposit it at a Bekia aggregation facility where it is sold to recyclers. Bekia's clean and segregated waste can command a higher premium from the recycling processors, and this extra value can be returned to the customer. These proportions vary by waste source but are around 45% of the onward sale price for cardboard and 30% for PET plastics. Bekia estimate that the average household can earn up to $12 a month through segregating, and 95% of their customers are women. Since launching, they have activated 25,000 mobile wallets and currently collect 120 tonnes of waste per month. Bekia's model as a digital broker and aggregator in the market means that they operate within a complex web of partnerships and relationships. A key insight from the early stages of the company's growth is that these partnerships took many years to form and required a significant pre-revenue investment.

4. KCCA's on-demand pit emptying service

In 2017, the GSMA Innovation Fund supported the Kampala Capital City Authority (KCCA) to upgrade the pilot GIS tracking system and deploy an app to be used by the nearly 100 pit emptiers who collect faecal waste from onsite facilities. The application works as a platform to connect customers to pit latrine emptying services, and then tracks service delivery to ensure safe disposal. The app was well received by pit emptiers, 71% of whom reported it was 'very easy' to use and 63% reported increased earnings. Similarly, 84% of customers reported an improvement in the quality of service they received. Over the course of the grant, there were several cholera outbreaks across the city. The GIS data revealed a strong correlation between areas reporting disease outbreaks and low pit emptying activities. KCCA used these data and insights to coordinate their behaviour change promotion following the outbreaks. More on the GSMA grant to KCCA can be found in a blog summarising the grant outcomes.

5. Scrapays' IoT-enabled collection model

Nigeria-based Scrapays is an app for connecting waste collectors and households in Nigeria. Agents collecting waste are onboarded and provided with the materials they need to conduct household collections, including an IoT-enabled weighing scale. Both the agents and the households are paid per kilogram for the waste collected within the app's digital payment ecosystem from which cash can be taken out via agents. In 2023, Scrapays received an investment from pre-seed venture-builder Catalyst Fund. They currently operate in Lagos, with plans to expand across Nigeria in 2024.

2.4 Transport and aggregation

It is at this stage of the value chain where the informal sector will begin to engage with larger organisations and the ecosystem expands. Informal waste pickers will sell to middlemen in the value chain aggregating waste and performing other value-add processes. In the case of dry waste, this will usually include the segregation of waste and the baling or crushing of waste so that it can be easily transported. As with household collections, digital tools that mediate these (especially related to weighing and payments) can boost efficiency in operations and allow for the tracking of waste from the point of origin.

It is at this stage of the value chain where the tracking of waste itself becomes a value-add service, particularly where this is needed as part of EPR compliance, demonstrating impact, or in the case of hazardous waste ensuring that it is safely managed. Being able to track waste reliably through the value chain from the point of collection is essential for generating plastic credits, to be used in regulatory compliance or on a voluntary basis. In some cases, plastics organisations interviewed also highlighted that the tracking of payments to waste pickers was itself of value as it demonstrated their impact. ReCircle, Attero, Recykal, and Let's Recycle all offer digitised EPR compliance, thanks in part to the Indian government's tightening legislation. These companies have all made significant capital raises recently, with Let's Recycle closing a $18 million Series C in 2020, Recykal a $22 million Series A in 2022, Attero a $16 million Series C back in 2014, and ReCircle closed a pre-Series A round in 2023 with investment from Flipkart Ventures, 3i Partners and Acumen Fund Inc. This significant investment, with participation from global actors, highlights the significant role regulation can play in stimulating the market. While there are initiatives in the voluntary sector such as Verra's Plastic Standard and the rePurpose platform, these have yet to see the scale achieved by companies working with EPR compliance.

Another critical aspect is efficiently managing collections through sensing devices. The operating expenditures of managing collections are often a large cost component for organisations, and efficiently managing aggregation through route optimisation or only collecting full loads of waste is a critical aspect for efficiency. Smart bins are increasingly being deployed across Africa and Asia, and at a minimum these bins usually have sensors for fill levels, but may also have other sensing capabilities, or functions related to sorting or compacting. In many cases, these will be large communal collection points serving many people. Early stage companies like Circularity Space in Kenya are developing the hardware and software, communal smart bins at markets have been piloted in Nairobi,[68] and established companies like Bigbelly have deployed in over 60 countries. While these bins can contribute to maximising efficiency, they also have a role in ensuring quality of service through timely emptying.

Data services are important at this stage, particularly where it relates to urban planning or efficiently running large-scale municipal services. Data scarcity is a major planning constraint for many municipalities, and the aggregation stage presents a particular challenge as waste may change hands several times as it makes it way from collection to processing. Weighing quantities at different stages is an essential component of both vertically integrated businesses and when transacting. For example, in moving to 100% household collections, the city of Indore equipped all collection trucks to monitor route compliance and as part of the behaviour change campaign, citizens were encouraged to report collection issues through the city's '311' municipal app.[69] South African Kudoti are an example of a start-up building the digital tools and platforms needed for full traceability.

Many of the digital solutions used at this stage of the value chain are waste stream agnostic. Solutions developed for one purpose can have applications across different waste streams, contexts or markets, and sectors. Though as noted above, specific regulations for types of waste and waste-to-value processes can govern the unit economics of doing so. In 2018, GSMA supported Loowatt and the Container Based Sanitation Alliance to develop an EPR solution to manage the collection of faecal waste for dry toilets. This solution was deployed in Madagascar and South Africa, with the Antananarivo municipality currently exploring its applications in the solid waste management sector.[70] Similarly, as part of managing their collections of organic waste, Freetown Waste Transformers developed an app that has applications across waste streams, which is currently also being used by the Freetown City Council.[71]

68. The New Times. (2020). *Kigali to pilot 'smart' waste management system*. (Article, accessed March 2024).
69. Smart City Indore. (n.d.). *Solid Waste Management*. (Article, accessed March 2024).
70. GSMA. (2023). *Safe sanitation and solid waste management: Loowatt Madagascar's evolving partnership with the Antananarivo city authority* (Blog, accessed March 2024).
71. GSMA. (2024). *Sustainable Waste Management: Highlights on digitalisation and partnerships from Freetown* (Blog, accessed March 2024).

Spotlights

6. Ambient IoT, a gamechanger for traceability coming

A key constraint in many IoT deployments is battery life, which can be a major cost driver of deployments. Recent advances in energy harvesting have led to a new crop of IoT sensors that can operate powered entirely from energy provided in radio waves. Some of these technologies are already at commercialisation, for example Wiliot offer an IoT tag that, in their words, is "*a low-cost, small-size, flexible tag the size of a postage stamp, that contains a computer device and the technology to harvest energy from radio waves.*" Currently, these tags can sense a limited number of parameters (e.g. location, temperature and humidity), though these are more than enough for many logistics use cases. Current ambient IoT solutions in the market leverage Bluetooth or RFID connectivity, which can limit range in some circumstances. However, there is ongoing work to make ambient IoT a 3GPP standard solution, such that devices could leverage the cellular network and operate over a much greater distance.

7. Vintz plastics and deploying the Zaidi app in Kenya to track volumes and social impact

The Zaidi app was developed in Tanzania by Zaidi Recyclers Ltd to digitally manage the collection and aggregation of waste. They have scaled their solution regionally and in Kenya partnered with Vintz plastics to explore using the app to track social impact in Mombasa. Vintz is a recycling processor that recycles plastic for onward sale as an input to manufacturers; in Mombasa alone they process 150 tonnes a month. Vintz are exploring voluntary plastic credits and needed a solution for reporting volumes and social impact, with mobile money transactions to waste pickers the most viable and reliable way to do this.

8. Data insights, AI object detection and route optimisation from Circularity Space

Circularity Space are a start-up working in Kenya, developing tools for data insights into waste management. They provide data insights to waste collectors focused on assessing segregation and route optimisation. Circularity Space deploy IoT sensors on bins that are equipped with cameras and can assess fill levels and humidity. The data from these enable route optimisation as only full bins are emptied. They have trained an AI model for object detection with 40,000 tagged waste items.

9. Mr. Green Africa aggregation and fair payment practices

Mr. Green Africa is a technology-driven, for-profit organisation with a mission to create sustainable, long-term social, environmental and economic impact through managing post-consumer plastic waste. They focus on the processing end of the value chain, producing hot washed plastic pellets at their facilities. Mr. Green Africa engage informal waste pickers and pay them a fair, fixed, and above market price per kilogram for waste delivered to their facility. They also have an app-based loyalty programme, and provide several services to waste pickers, such as life and business skills, health assistance, access to microcredit, and protective clothing. In 2022, Mr. Green Africa closed their series B funding round, which included the participation of Dow, to expand their waste processing capacity in East Africa.

10. Takataka Ni Mali's Ecoloop platform

Takataka Ni Mali are a Kenyan start-up providing platforms that support innovation, green jobs and entrepreneurship in waste management. Their core offer is built on a mobile application connecting waste collectors, households and businesses. In 2023, they also launched 'Ecoloop', a platform that allows businesses and other waste producers to track and report on how the waste they generate is managed across the value chain. Takataka Ni Mali have partnered with several organisations in Kenya to deploy the solution, including the Kenya Alliance of Resident Associations.

2.5 Processing and waste-to-value

This stage is often the most crucial with regards to both getting value from the waste and ensuring that waste is not leaked into the environment. While the process of generating value will be dependent on the waste stream, what is common at this stage is a degree of centralisation, often with more substantial CapEx requirements, and that the secondary materials themselves will have to be marketed. Some of the most advanced applications of digital technology are in recovering value from e-waste through AI and robotics, though even for more analogue processes like composting there are still financing requirements where digital technology can play an important role. Similarly, digital marketplaces for secondary or refurbished materials are also increasingly common, and as in the aggregation stage, full traceability is still required right up until end of life or reuse.

Due to more centralised and specialised operations, it is also common for actors to specialise at this stage of the value chain. Organic and faecal waste is a relatively specialised area of processing. With biogas, composting and wastewater treatment, the biological processes must be carefully controlled, and in line with some of the inputs. The financing of these facilities also needs to build into the model. For example, Sistema.bio offer decentralised biodigester solutions on a pay-as-you-go basis to farmers, with remote monitoring of system performance. In 2022, they closed a $15 million Series C, bringing their total funding to over $37 million, and to date they have sold close to 100,000 digestors that have reached over half a million people with clean, renewable energy and organic fertiliser and processed 37 million m^3 of methane-producing waste.

All waste streams, but organics and faecal waste in particular, have the ability to avert significant amounts of GHG emissions, and as a result can benefit from climate finance. Sistema.bio are producing carbon credits with Gold Standard.[72] Sanitation also has the possibility to save significant emissions, and installing an onsite container-based toilet can avert approximately as much GHG emissions as a solar home system in many contexts.[73] Sanivation are one example of a sanitation provider specialised at the processing stage that could benefit from carbon finance. They partner with municipalities to establish waste-to-value plants for processing faecal waste and organics.

Segregation is a major process at this stage for waste that was not separated at source, with robotics and AI playing an increasingly prominent role. While the vast amount of waste sorting at material recovery facilities is currently done manually, there have been some recent sizable investments in companies seeking to automate the process. For example, London-based Recycleye recently secured a $17 million investment from deep tech investor DCVC,[74] Greyparrot closed an $11 million Series A in 2022, and India-based Ishitva closed a $1 million pre-series A in 2021. These companies are working to combine object detection AI with machine sorting. This is in addition to that used by global brands, such as Apple, for their own processes.[75] E-waste is a particularly significant waste stream as the components, if separated, are more valuable, increasingly rarer, and essential for the energy transition. Organic waste mixed with dry waste presents one of the more difficult challenges in segregation. To address this, Trashcon in India developed a patented method of automated mechanical sorting that can separate dry and wet/organic waste, and as such recover much more value.

Start-ups operating at earlier stages of the solid waste value chain, and in nascent ecosystems, can benefit from vertically integrating to capture value. In processing waste there are several intermediate value-add stages, from washing, billing and pelleting in the case of plastics, that significantly add value. This is significant as processes aimed at generating secondary materials as inputs are subject to commodity price changes, and in many countries these markets are concentrated around a few key players and prices are subject to volatility. For example, from Q4 2022 to Q1 2023, PET prices in South Africa dropped 30% and pulp-based packaging prices dropped 60% in the same period. Where a city or country has a significant deficit in processing infrastructure, it can be a necessity to invest in the vertical integration to justify operations at earlier stages of the value chain.

72. Sistema.bio. (2020). *Gold Standard: Sistema.bio strives for excellence*. (Accessed 23 March 2024).
73. CBSA. (2023). *Briefing Paper: Unlocking carbon credits for sanitation*.
74. TechCrunch. (2023). *Recycleye grabs $17M, calling plastic crisis a 'tremendous business opportunity'*.
75. Apple. (2022). *Apple expands the use of recycled materials across its products*. (Accessed 23 March 2024).

Spotlights

11. **Sanivation's evolving circular sanitation model in Kenya**

Sanivation began operating in Kenya in 2014 as a container-based sanitation provider, with a model of addressing the entire value chain from household collection to the treatment of faecal waste. Sanivation recently pivoted from managing household connections to being a partner for city municipalities and utilities to develop waste-to-value sanitation treatment facilities through planning and partnerships. Sanivation's treatment technology is based on combining faecal waste with organic biomass to create 'Superlogs' as a product in their waste-to-value treatment plants. These Superlogs can be sold as a solid fuel, and each tonne of Superlogs saves two tonnes of CO_2e, equivalent to 22 trees. The pivot has enabled Sanivation to focus on providing technical services across the value chain, specialising in managing the treatment facilities. You can read more about their evolving model in a recent GSMA blog.

12. **Wastezon in Rwanda building the digital tools for reverse logistics in e-waste**

Founded in 2019, Wastezon are seeking to address e-waste with two solutions: i) 'Wastezon2.0', a digital marketplace for electronics that extends their life through refurbishment and resale and ii) 'WastezonX', a digital platform that provides the traceability and tracking infrastructure needed for reverse logistics to source mineral inputs for manufacturing. For the Wastezon2.0 app, Wastezon vet and approve the sellers on the app and they also have a team of technicians to refurbish products. WastezonX aims to support the identification of end-of-life electronics for collection and use in manufacturing. Products in WastezonX are given a digital product passport, which contains information on the material content. Data on products are available in aggregate or for a specific product.

13. **REPARLE turning agri-processing waste into electricity**

REPARLE is a Uganda-based company seeking to build sustainable food systems while empowering smallholder farmers. To achieve improved food security, agricultural areas in Uganda need access to low-carbon affordable energy for mechanised agri-processing and storage facilities such as cold-chains. REPARLE works with farmers to process their grains at a cost, generating biomass waste from processing which they then convert to electricity to power the agri-processing unit. They also use the waste to make affordable briquettes to replace their farmers' inefficient wood cookstoves.

14. **Innovations in plastic reuse**

Nairobi-based Kubik are in the process of scaling their recycled plastic bricks. The company claims these bricks cost 40% less per square metre and the GHG emissions are at least five times lower than cement-based products. In 2023, Kubik closed a $3.3 million seed round and plan to establish manufacturing in Ethiopia. While similar products have existed for a long time and have been deployed in development projects, the key challenges Kubik address are lowering costs through localising manufacturing, and developing the capacity and sales channels such that these products can be used at scale. In 2023, Kubik was named 'Startup of the Year' at the Global Startup Awards.

15. **Safaricom's e-waste process at WEEE centre**

In 2008, the recycling facility Waste Electrical and Electronic Equipment Centre (WEEE Centre) in Nairobi was launched. E-waste is collected across Kenya and brought to the recycling centre for processing. Each month, the centre in Nairobi processes up to 10 tonnes of e-waste. Under the partnership, they began collecting waste from their retail centres and as of 2022 had collected more than 1,626 tonnes of e-waste to be processed back into use with WEEE Centre.

3 The GSMA Innovation Fund for Digital Urban Services

The GSMA Innovation Fund has supported several projects at the intersection of digital innovation and waste management and sanitation.

In May 2021, GSMA launched the GSMA Innovation Fund for Digital Urban Services with support from the UK Foreign, Commonwealth & Development Office (FCDO). The fund was open to start-ups and early-stage companies providing essential urban utility services who leverage digital innovations to make these services more accessible, reliable, sustainable and affordable.

The fund covered four key utilities sectors: waste management, energy, sanitation and water. Successful organisations were awarded between £100,000 and £250,000 in grant funding and were provided with technical assistance and dedicated support to facilitate partnerships with mobile operators and public sector organisations over an 18-month award period.[76]

Pitches were received from 335 organisations in 43 countries across Africa, South Asia and Southeast Asia, and from these, a cohort of nine organisations were selected. Four of these organisations – Freetown Waste Transformers, ReCircle, Regenize, and Soso Care - focused specifically on waste management and this section of the report takes stock of the learnings from the grant period for these organisations.

Spotlight 16
GSMA Innovation Fund support to digitalise waste management and sanitation

The GSMA Innovation Fund for Digital Urban Services:

- **Freetown Waste Transformers in Sierra Leone** turn organic waste into electricity, replacing diesel generators with green technology to reduce the cost of energy and increase the reliability of energy and heat. Their biogas digesters use organic waste collected from households in Freetown (grant implementation 2022-23)
- **ReCircle, based in India**, have built a traceable reverse supply chain and mint EPR credits to businesses. With its tech-enabled platform ClimaOne, ReCircle provides blockchain-assured traceability and complete visibility across the supply chain, from sourcing to disposal (grant implementation 2022-23)
- **Regenize deliver household recycling solutions in South Africa** through an app-based service with virtual currency and a network of decentralised recycling hubs (grant implementation 2022-23)
- **Soso Care work in Nigeria to deliver micro health insurance to customers and waste aggregators**, using waste as part-payment of premiums (grant implementation 2022-23)

Previous innovation fund rounds:

- **Coliba offers plastic recovery, collection and recycling services in Cote D'Ivoire and regionally**, where Coliba process the waste themselves and sell the plastic flakes as a secondary material (grant implementation 2018-20)
- **The Kampala Capital City Authority** are responsible for waste management in the city. GSMA supported them to launch a service connecting septic tank emptiers and customers with the tracking of vehicles and the waste they manage (grant implementation 2018-20)
- **Loowatt deliver scalable sanitation circular economy systems in Madagascar and South Africa**, based on an innovative dry toilet material (grant implementation 2018-20)
- **Sanergy deliver circular solutions in Kenya**. GSMA worked with them to test pit fill monitoring sensors (grant implementation 2017-19)

76. GSMA. (2022). *The Digital Utilities Partnership Hub*.

3.1 Freetown Waste Transformers

The context - Sierra Leone has one of the lowest energy access rates globally, with 76% of the population having no access to electricity.[77] Limited energy access and an unreliable grid have led to mass use of diesel generators, especially among MSMEs.[78] The waste management infrastructure in Freetown is also beset with inefficient collection processes. Only about 30% of the waste generated is safely disposed. The rest ends up in illegal dumpsites, on the streets and even flows into the Atlantic Ocean. Freetown Waste Transformers (FWT) aims to address these twin problems by providing a unique solution to waste disposal and enabling access to clean and affordable energy.

The company - FWT is an integrated waste-to-energy company operating in Freetown, Sierra Leone. They have successfully deployed a waste-to-energy pilot using proprietary technology (waste transformer) to convert organic waste into electricity, heat and fertiliser. On average, each installed transformer unit will generate up to 150 kVA of electricity and double that amount in heat. With this amount of electricity and thermal heat, MSMEs can potentially reduce their power bill by more than 35% and minimise their carbon footprint. The solution also provides more reliable energy than the grid, which is central for supporting businesses.

Purpose of the grant - GSMA supported FWT to digitalise the waste collection process by implementing a GPS mobile mapping app to improve the efficiency of existing waste coordination. To scale this solution, more organic waste will be required to feed FWT's anaerobic biodigesters, highlighting the need to better coordinate the collection of organic waste. The app will be used by waste collectors, in partnership with the Freetown City Council, to manage inputs from waste collection partners and provide live data.

77. World Bank Data. (n.d.). *Access to electricity (% of population) – Sierra Leone*. (Accessed 23 March 2024).
78. Kumar, C., et al. (2022). *Waste management in Africa: a review of cities' experiences*. ODI.

Key grant outcomes

- By the close of the grant, FWT had designed and launched the DortiBox app, and onboarded over 350 users to their platform. They had also trained and built the capacity of 322 waste collectors.
- Their services benefited 46,552 Freetown residents either through timely household waste collections, increased revenue for collectors or electricity provision from their Aberdeen Women's Centre waste-to-energy site.
- They diverted 11.85 tonnes of organic waste from landfills and generated 12,205 kWh of clean energy through their waste-to-energy solution.
- FWT has partnered with Africell Sierra Leone and Orange Money Sierra Leone to integrate their APIs with the DortiBox App. This enables users to transact using mobile money. Africell further deepened their collaboration with FWT by being one of the offtakes of the energy produced by the waste transformer units.

Key lessons

- **Strategic partnerships with key players are crucial for scaling**. FWT has partnered with the Freetown City Council to introduce digital waste management systems as the city plans to increase waste collection and safe disposal to 60%. The city will leverage the DortiBox app, mandating all households to sign up for automatic collections and make payments through the app. FWT has also been working with the Waste Collectors Management Association, which brings together waste collectors and has become a voice for its members, and has already trained and onboarded them onto the app.
- **There is an opportunity to track waste along the value chain**. FWT's circular approach to waste management presents the opportunity for households to track how much of their organic waste is collected, converted to electricity and fertiliser, and how much their efforts contribute to the reduction of carbon emissions. This data can incentivise more households to adopt DortiBox as a response to climate change and aid individuals to reduce their own carbon footprint.
- **The app has created household awareness on waste collection and best practices**. The majority of DortiBox users noted that the app helped them sort household waste and understand how organic waste can be reused to produce energy as well as how recycling and good waste management impacts health and the environment.
- **For maximum uptake of digital solutions, the usage gap needs to be reduced**. The uptake of the Dortibox app was lower than expected and this can be attributed to factors such as device ownership and the low penetration of mobile money in Freetown. Most waste collectors did not have smartphones and the number of women waste collectors with mobile devices was even lower. Device and data affordability remain great barriers to mobile internet adoption and use and these continue to disproportionately impact the underserved.

> "Freetown is prone to serious environmental hazards such as drought, flooding, coastal erosion, and landslides, which are exacerbated by ongoing climate change. Therefore, we place a premium on working with partners that deploy mitigative and adaptive initiatives towards climate change, and FWT's waste-to-energy initiative helps the city by increasing household waste collection while at the same time generating clean energy for businesses and minimizing the city's CO2 footprint by minimizing landfilling"
>
> **Yvonne Aki Sawyerr, Mayor of Freetown**

3.2 ReCircle

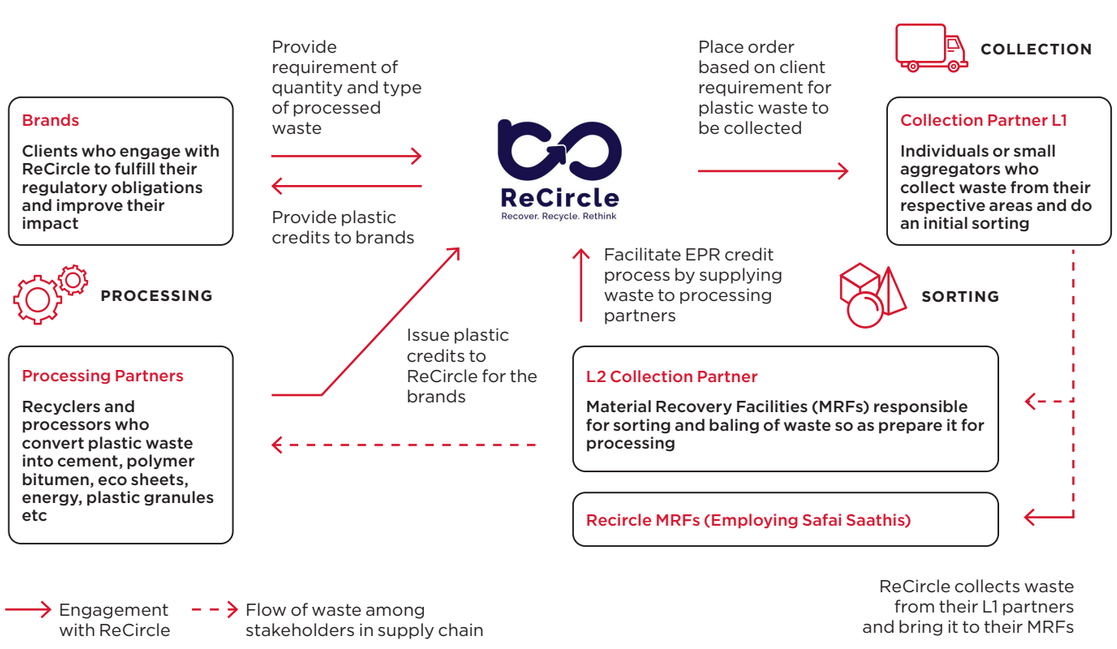
The context - In India, low-value and hard to recycle plastics—such as food packets, sachets and wrappers—are usually dumped in landfills as there is no or very limited value attached to collecting and processing this waste. EPR rules for plastics were first introduced in India in 2016,[79] requiring medium- to large-sized companies to recover the waste they produce. However, compliance and enforcement were both challenging due to a lack of mechanisms for tracking and reporting on waste. In 2022, the Government of India moved to tighten the legislation and ban some single-use plastics. This was much needed as between the period 2016-2020, India's plastic consumption increased from ~14 million tonnes to ~20 million tonnes, a compound annual growth rate of 10%,[80] with other estimates for 2019's plastic consumption putting it as high as 24 million tonnes.[81]

The company - ReCircle is building a digital platform that aggregates the collection and processing of dry waste to sell EPR credits to businesses. Their tech-enabled platform, ClimaOne, addresses existing challenges in the industry by building a unified, transparent platform that provides real-time tracking, backed by data analytics, and simplifies reporting and compliance. ReCircle partners with local waste collectors to collect, sort and pre-process recovered materials, after which the material is channelled to authorised recyclers/processors (see Figure 8 for details). ReCircle currently operate their own collection, sorting, and material recovery facilities in Mumbai, and have partnerships covering over 270 waste recovery sites across India.

Purpose of the grant - GSMA supported ReCircle to develop and launch their ClimaOne platform, which provides end-to-end traceability for plastic credits for businesses to track all plastic material collected on their behalf and close the loop by providing EPR plastic credits. The platform allows large plastic producers to take control of their sustainability targets at the click of a button and comply with India's EPR laws.

Figure 7

ReCircle's engagement across the plastics value chain



79. See: https://cpcb.nic.in/rules-4/.
80. Marico Innovation Foundation. (2022). *Innovation in Plastics: The Possibilities & Potential*.
81. Dhodapkar, R., et al. (2023). *National Circular Economy Roadmap for Reducing. Plastic Waste in India*. CSIRO.

Key grant outcomes

- The median monthly income range of the Safai Saathis (waste pickers) working at the material recovery facilities increased from Rs 5,001 - 10,000 to Rs 10,001 - 25,000. At grant closure, 80% of the workforce surveyed reported an enhancement in their quality of life after working with ReCircle.
- Over the course of the grant period, ReCircle onboarded 23 business clients to purchase credits to meet their EPR requirements; this has since increased to 32, including major brands such as Hindustan Unilever, Dabur, Hindustan Coca-Cola Beverages, and Nestlé.
- ReCircle's scaling was much quicker than anticipated, with the revenue targets set in the grant exceeded by a factor of 50, attributed to high demand from the tightening EPR legislation in India.
- In 2022-2023, ReCircle diverted 78,498 metric tons of waste from landfills and turned it into a resource. ReCircle now work across 270 cities and towns in India, with the help of over 45 processing partners, 400 collection partners and working with over 3,100 informal waste workers (Safai Saathis).
- At the end of 2023, ReCircle successfully closed a seed funding round with backing from Flipkart Ventures, Acumen, and 3i Partners.
- In 2022, ReCircle was recognised as one of the Top 30 Start-ups by the Ministry of Housing and Urban Affairs (MoHUA) at the Swachhata Startup Challenge.

Key lessons

- **The Indian EPR legislation has become central to their business model, as the sale of credits linked to EPR compliance now accounts for the majority of their revenues**. Over the course of the grant, the Central Pollution Control Board (CPCB) released updated EPR guidelines for plastic packaging, which mandated that producers, importers, and brand owners (PIBOs) register with the CPCB and adhere to the EPR Guidelines. These guidelines stipulate that brands must purchase plastic credits equivalent to the amount of plastic used in their products. This tighter legislation was market-making in that it created much more, and more reliable, demand for the credits.
- **ReCircle pivoted to focus on the B2B element of their business model**. ReCircle run their own waste collection and processing operation in Mumbai, but have chosen not to scale this element of their business, focusing instead on being the tech enabler for others in the ecosystem. Currently this is centered on ClimaOne and traceability, but ReCircle also have plans to develop a B2B2C offering whereby direct to consumer brands and platforms can, via an API, offer a ReCircle authenticated plastic offset for when customers buy plastic packaging.
- **ReCircle were able to channel a large proportion of the credit sale price to the partners and waste pickers, and this was central to incentivising their continued engagement**. As their model rests on the partnership and the continued engagement of Safia Saathis, ReCircle return about 90% of the credit sale price to the workers and processing partners.
- **In a recent upgrade, ReCircles MRF in Mumbai underwent upgrades, including the installation of a conveyor system**. The integration of this conveyor has led to a substantial increase in processing capacity from 5 to 8 metric tonnes per day.

Bijla Kapure, Safai Saathi at ReCircle MRF

"I feel good working at Recircle. Previously, I was engaged in the same sector as an informal waste worker. However, the working conditions and the quality of work have significantly improved since I joined Recircle. I am capable of maintaining bank balance since I started working here."

Arti Jadhav, Safai Saathi at ReCircle MRF

"I proudly share with people that I am employed in the waste management sector. My financial situation has improved significantly since I began working with Recircle. This improvement has allowed me to make contributions to my household, support my children's education, and maintain bank balance."

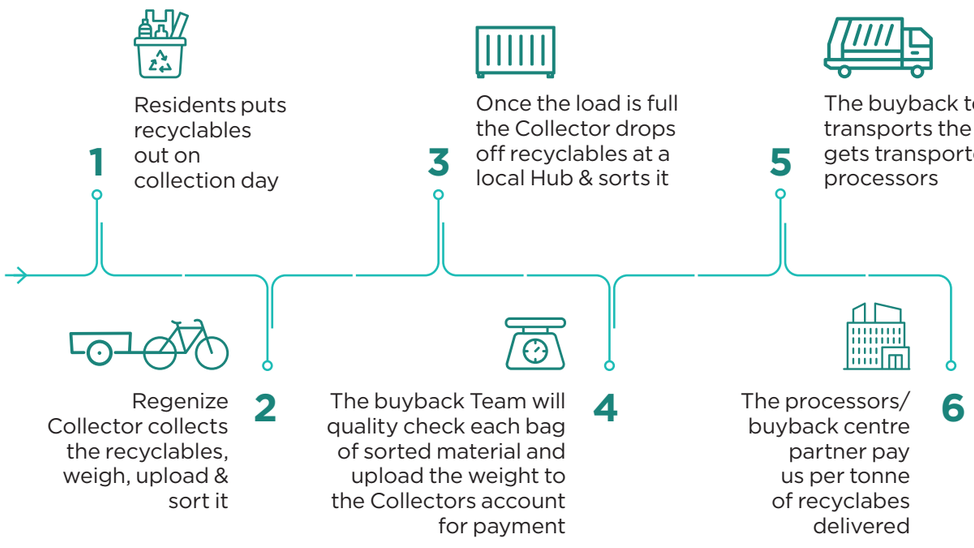
3.3 Regenize

The context - South Africa has high recycling rates for some waste streams; for example 63% of PET plastic bottles produced are recycled.[82] However, there are low segregation rates for household waste, with around 10% of urban households separating their waste at source.[83] The country's recycling sector depends on the 90,000 waste pickers that collect material from households and businesses. These waste pickers make huge contributions to the sector; as of 2016, it was estimated they save the government up to $50 million a year through landfill space and collect up to 90% of all paper waste.[84] Despite this, they work in hazardous conditions, many travelling between five to 20 miles a day by foot searching through bins or landfills as they do not have access to clean, separated recyclables.

The company - Regenize provide a free residential recycling collection service that incentivises residents for recycling and is operated by integrated informal waste collectors operating from decentralised recycling hubs (DRHs). They operate a freemium recycling collection service that incentivises residents with Remali, a virtual currency that can be redeemed for various rewards, such as airtime, data and grocery vouchers online (i.e., the Remali app) or offline (i.e., a local Remali convenience store). The free model ensures that Regenize reaches the majority of citizens (primarily the low/low-middle income groups) through their DRH operation that plants waste recovery infrastructure locally, ensuring service delivery and the ethical recovery of recyclable waste at source, integrates and supports waste pickers with PPE, fossil-fuel-free recycling tricycles, equipment, mobile devices, access to clean recyclables and a DRH. Regenize currently collect household dry waste (paper, glass, plastic and metal) and organics.

Purpose of the grant - GSMA supported Regenize to scale their solution through opening four new DRHs in low/low-middle income communities in South Africa used for sorting and storing recyclables as collected. Additionally, the grant supported the development and launch of Remali and the recycling service middleware that supports the front-end apps.

Regenize Recycling Process



82. Plastics SA. (2019). *South African PET recycling rates amongst the highest in the world*. (Accessed January 2024).
83. Samson, M., et al. (2022). *'Wasters, agnostics, enforcers, competitors, and community integrators': Reclaimers S@S, and the five types of residents in Johannesburg, South Africa*. World Development, Vol 150, 105733.
84. Godfrey, L., et al. (2016). *Integrating the Informal Sector into the South African Waste and Recycling Economy in the Context of Extended Producer Responsibility*. CSIR.

Key grant outcomes

- As of the grant closure, the new DRHs serve close to 7,000 customers/ households. These centres processed 556 tonnes of waste per year, and averted 1184 tonnes of CO2 from entering the atmosphere.
- Regenize are in the process of finalising a partnership with MTN South Africa to launch the app on the MTN Ayoba platform. MTN subscribers will be able to use the app without incurring any data charges, ultimately making it a cost-effective option for them.
- Regenize signed a partnership with PepsiCo to launch five DRHs serving 5,000 households, and with AB InBev to improve the activate rates, tonnage and users at the existing DRHs.
- 85% of users reported improved access to waste management service, and 50% of users used mobile money for the first time.

Key lessons

- **Large price fluctuations on the secondary materials market impacted DRH margins**. There are only a few companies in South Africa that buy and process sorted waste. Over the grant period, the price paid for some waste streams dropped by as much as 75%. Regenize are exploring vertically integrating to process plastic waste to washed flakes, which can increase their value by three times. Regenize is also exploring adding new revenue streams to ensure sustainability, which included advertising ad space using its existing infrastructure.
- **Instigating behaviour change required a significant effort**. In combination with the financial incentive (Remali), Regenize found that to successfully launch in an area and instigate waste segregation, door-to-door engagement was both needed and the most effective method. The drawback is that this is costly and time-consuming.
- **Price fluctuations impacted waste pickers**. Regenize operated a commission-based model with their waste pickers. As such, price fluctuations on the secondary market also impacted the waste pickers. Where material prices dropped substantially, some waste pickers would seek alternative employment, posing challenges for the continuity of operations. Regenize have recently moved away from the commission model through joining a government scheme where the waste collectors get paid a subsidised wage by the government, and become employees of Regenize.
- **The structure of the South African EPR legislation means Regenize has struggled to benefit from producer responsibility organisation (PRO) funding**. Under the South African EPR rules, importers of plastic pay a per tonne fee, which is then channelled to PROs to spend on supporting recycling. However, the operations of these PROs vary significantly, and each have different priorities and spend in different ways. As such, Regenize have struggled to work with PROs and are yet to benefit from any funding from them.

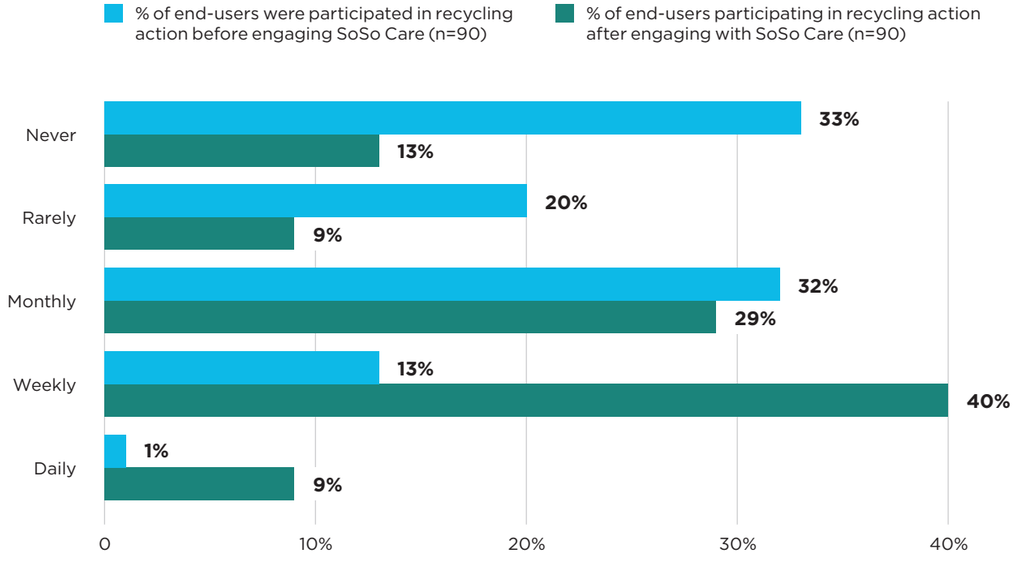
3.4 Soso Care

The problem - Nigeria generates approximately 32 million tonnes of waste annually,[85] of which 2.5 million tonnes are plastics, with less than 12% of this collected, sorted and recycled.[86] At the same time, there is pervasive poverty and poor healthcare financing, with fewer than three per cent of Nigeria's 200 million citizens having health insurance.[87] This means quality healthcare is out of reach for most Nigerians, or when people do seek care it can become a devastating out of pocket health expenditure. Out of pocket expenditures account for over 75% of Nigeria's total health expenditure, the fifth highest figure for any country in the world.[88] To address this, in May 2022 the Government of Nigeria signed into law the National Health Insurance Act, which made health insurance mandatory for all Nigerians.

The solution - Soso Care is a micro health insurance company with an innovative approach to providing health insurance to low-income populations in Nigeria. Households sell their recyclable household waste to intermediaries and recycling processors, and the proceeds are used to pay for Soso Care health insurance premiums. The service is delivered through a network of Soso Care agents, who both manage the collection of the waste from households, as well as their insurance policies. The majority of these agents are women from the communities in which Soso Care works. Households have the choice of 'cash or trash' when paying for their premiums, and they can also receive cash payments for the waste collection. Three to four kilograms of plastic waste per month provides the premium for the basic package of health insurance, which covers some pharmacy-related expenditures up to $15 per claim. Hospital packages are available with more waste, or blending cash and waste to pay the premium.

Grant summary - GSMA supported Soso Care to expand their current offering through developing and launching a mobile app and USSD services, and with funding to open two recycling facilities in Kaduna and Rivers State.

End-user's recycling behaviour before engaging vs. after engaging with SoSo Care



85. UNIDO. (2021). *Study on plastics value-chain in Nigeria*.
86. Babayemi, J.O., et al. (2018). *Initial Inventory of Plastics Imports in Nigeria as a Basis for More Sustainable Management Policies*. J Health Pollut. 8(18), 180601.
87. DHS Program. (2019). Nigeria Demographic and Health Survey 2018.
88. WHO. (n.d.). Global Health Observatory data repository: Out-of-pocket expenditure as percentage of current health expenditure (CHE) (%). (Accessed March 2024).

Key grant outcomes

- At grant close, Soso Care had over 3,000 direct users, 86% of whom were women. Eighty-nine per cent of those users reported they were new to using health insurance, 54% reported that the solution had positively impacted their income levels and 65% of those that took out insurance reported improved access to healthcare.
- In a grant endline survey of users and agents, all interviewees reported an increase in knowledge of insurance products. Eighty-six per cent of users reported a significant or slight increase in trust/confidence of insurance products, 13% reported unchanged levels of trust, and one per cent reported a decrease.
- Over the course of the project, Soso Care scaled from zero to processing 100 tonnes of plastic waste.

Key lessons

- **The digital tools were well received by both agents and end users, though a significant minority of users continue to favour traditional payment methods**. Sixty-three per cent of end users stated their payment preferences to be with the Soso Care USSD option or app (46% and 17% respectively), although 38% stated their preference as a bank payment or cash/offline payment. Agent payment preferences followed a similar pattern. Soso Care also first attempted to roll out all app functions at once, but later realised releasing features one at a time allowed Soso Care to gradually onboard agents without overwhelming them, which resulted in better digital engagement by the agents.
- **The option of using recyclables as insurance premium payments was widely taken up**. 82% of end users made their payments using the 'trash' option, 12% made payments with 'cash' and a further six per cent used a hybrid of both. The solution also provided a strong enough incentive to change recycling behaviours. The proportion of end users reporting that they 'never' or 'rarely' recycled fell from 53% before adopting the solution to 22% after.
- **The model was able to support the agents with a reliable source of income**. Of the agents interviewed at endline, 68% reported their incomes as consistent, 52% as 'very' and 16% as 'somewhat', while 16% reported their incomes working with Soso Care were 'somewhat inconsistent'. Prior to engaging with Soso Care, 44% of agents reported a monthly income of under NGN 30,000, and 32% reported an income of over NGN 50,000. At grant close, only 24% reported an income of below NGN 30,000 and the proportion reporting over NGN 50,000 had increased to 44%.
- **Soso Care faced sector and site-specific challenges in entering the plastics value chain**. Soso Care are, at their core, an insurance tech company. The recycling operations side of the business are designed to make their products more accessible. The sourcing of land, agreeing the leases, learning on the operational model what would work with the volumes and location of waste, and the decline in global secondary plastics prices over the grant period all posed challenges. Over the course of the project, and as operations scaled, Soso Care was able to command better plastics prices through selling at larger volumes to those higher up the aggregation process. Soso Care are now looking to export their plastics directly as this will again boost revenues.

4 Trends, triggers and tipping points

4.1 Drivers for change in the market

Tightening global and national policy and legislation

For many waste streams, effective policy can be market-making, and there is momentum building behind tightening national and international policy, which in most cases can enable companies working towards a circular economy. Traceability is central to both national EPR legislation and the international movement of waste, and brings digital tracking and monitoring to the fore. The bans for single use plastics and some of the most problematic materials are beginning to stem the flow of waste into the system, but all forecasts suggest that there is still need for further legislation to deal with the rapidly increasing flows of waste.

At the global level, the Basel Convention and the forthcoming Global Plastics Treaty govern waste flows between countries. In 2022, an amendment to the Basel Convention was adopted, recognising e-waste as hazardous and subject to tighter rules when moved between countries. The recognition of these transfers is significant where it intersects with EPR schemes as it will bring visibility to the trade, which is substantial, and lays the foundation for monitoring movements. Similarly, there is hope that the results of the negotiations of the Global Plastics Treaty will strengthen cross-border collaboration and monitoring. The aim is for the Treaty to be finalised by the end of 2024. In late 2023, a Zero Draft of the Treaty text was proposed and discussed, which included points related to identifying the waste to be covered, options for either mandatory or voluntary accompanying national EPR legislation, financing mechanisms and linkages to national plans.[89]

Though slow to emerge, there is growing impetus behind national EPR laws in Sub-Saharan Africa, South Asia and Southeast Asia. Emerging in the 1990s in Europe and North America as a prominent policy tool, countries are increasingly taking steps to accelerate national plans. On the African continent, South Africa, Kenya and Ghana have all either introduced or are in the late stages of introducing EPR legislation for e-waste or plastics. In South and Southeast Asia, India has the most advanced EPR policy framework, while Indonesia recently strengthened its EPR law and in 2022, the Philippines and Vietnam both passed new EPR legislation. Though different in structure and implementation, these laws generally: i) require large importers or manufacturers to report data and pay a fee based on volumes, ii) have provisions for how the funds are spent in relation to recycling, and iii) specify the role of PROs. These laws are potentially market-making for start-ups in the ecosystem and in many cases have digital monitoring integrated to the model.

While there is momentum behind national EPR adoption, there is currently limited cross-border collaboration. For example, the African continent is estimated to import from Europe second-hand electronics with European EPR fees equivalent to €340-380 million, with that value not reaching Africa as these fees are retained in Europe or waived as products are deemed to be reused (the second-hand car EPR fees are equivalent to a further €300-410 million).[90] This has led some to call for a policy framework based on 'Ultimate Producer Responsibility' that accounts for international flows and ensures receiving countries fairly benefit from taking on waste, or products very close to the end of their life that are soon to be waste.[91,92]

89. UNEP. (2023). *Zero draft text of the international legally binding instrument on plastic pollution, including in the marine environment*.
90. Arya, A., & Bhutani, A., (2023). *Study on items shipped for reuse and Extended Producer Responsibility fees*. Circular Innovation Lab for the EEB.
91. Renewable Matter. (2023). *Africa is working on an ultimate producer responsibility: Interview with Jocelyne Landry Tsonang*. (Accessed 23 March 2024).
92. Thapa, K., et al. (2022). *Brief: Blueprint for Ultimate Producer Responsibility*. Copernicus Institute of Sustainable Development, Utrecht University.

Spotlight 17
EPR mechanisms

EPR legislation differs significantly across markets but will generally utilise one or more of the policy tools below:[93]

- Fees, levies, or taxes: These can take the form of charges on the production or import of specific materials, advanced disposal fees levied on products purchased, deposit-refund schemes, or taxes on upstream producers.
- PRO-based models: PROs are organisations representing the producers of upstream materials that take on meeting the legislative requirements. They will do this either through fees or utilising funds raised through taxes or levies.
- Plastic credits: Producers are required to acquire credits certifying a given amount of waste was recycled that can be counted against the material they produced.

These are in addition to any specific regulations or bans on certain materials, or regulation around their handling.

The material requirements of the clean energy transition and rising demand for secondary materials

The International Energy Agency (IEA) projects rapid growth in demand for critical minerals for clean energy technologies, including electric vehicles, wind turbines, solar panels and electricity grids.[94] In the IEA's Net Zero Scenario, demand for critical minerals such as lithium more than triples, raising major risks of supply shortages and delays to achieving net zero. In their modelling for 2030 to 2050, solar capacity needs to increase 150-fold, and wind by 15-fold. By mass, 95% of solar components and 90% of wind components are recyclable, though at present only 10% of end-of-life solar products are recycled.[95] With the energy sector becoming a dominant share of mineral demand, there will be knock-on effects in the consumer electronics market. These supply shortages and risks present huge opportunities for those working in the recovery of materials for e-waste, which is already one of the higher margin waste streams. Though with different drivers, demand for recycled plastic is also growing quickly, driven in part due to brand commitments on recycling, taxes on the use of virgin materials, and EPR requirements.[96,97] Oil price fluctuations can undermine demand for recycled plastics when prices drop, and many companies interviewed for this research highlighted volatile prices on the secondary market as a challenge.

Accelerating investment in the sector and new financing sources

This report has highlighted the significant investment in tech-enabled waste management start-ups. The correlation between ambitious policy reforms and investment is notable, particularly in India and Indonesia. As highlighted above, the growing momentum behind further changes is a positive sign for the market. Also notable, and similar to some investment trends in the transport sector,[98] waste management start-ups are seeing investment from global brands. For example, the material sciences company Dow recently made an investment in Kenyan start-up Mr. Green Africa. Additionally, the digital tools that underpin many of these models—digital payments, accurate records and data, and digital identities—open the door to a wider range of financing instruments. Recent GSMA research has highlighted this opportunity for start-ups and some of the more promising instruments.[99] Pay-as-you go models for funding decentralised infrastructure, revenue share and results-based finance all have strong potential applications, and are either enabled or made more effective through digital adoption. Additionally, those solutions contributing to mitigating or sequestering carbon can also benefit from the carbon markets, which themselves are becoming increasingly digitalised with the emergence of new digital first standards in the voluntary market such as Cavex, CYNK, CarbonClear, and Puro.earth. In the compliance markets, the operationalisation of Article 6 of the Paris Agreement also presents new opportunities. Finally, the digitisation of waste collection and the creation of digital identities and credit histories for waste pickers means that there are a broader range of financial services that can be extended.

93. For further reading see: OECD. (2016). *Extended Producer Responsibility: Updated Guidance for Efficient Waste Management* or Dhodapkar, R., et al. (2023). *National Circular Economy Roadmap for Reducing. Plastic Waste in India*. CSIRO.
94. IEA (2023) *Energy Technology Perspectives 2023*
95. IEA. (2022). *World Energy Outlook 2022*.
96. McKinsey & Company. (2022). *Advanced recycling: Opportunities for growth*. (Accessed 23 March 2024).
97. S&P Global Commodity Insights. (2021). *Recycled plastics market becoming more liquid and globalized as demand soars*. (Accessed 23 March 2024).
98. Njoroge, B., & White, Z. (2023). *Powering Mobility: The rise of digital transportation in Africa*. GSMA.
99. Miles, S., et al. (2023). *Digitalising Innovative Finance: Emerging instruments for early-stage innovators in low- and middle-income countries*. GSMA.

Progress on multiple fronts building an ecosystem

There are few companies that can, or do, address the full value chain and partnerships are essential. How the value chain looks varies greatly between the waste stream and the country. In some cases, parts of the value chain will be saturated, while others, especially processing capacity, may be very limited. Encouragingly, much of the investment is targeted at innovations for the waste-to-value processing side and the capital requirements there. Creating sufficient value at this stage can make the segregation and collection stages viable. This is particularly the case in organics, where large-scale waste-to-value processing is nascent in many markets. Innovations in waste processing, combined with increasing demand for secondary materials and access to these markets, mean that start-ups can find their niche within the value chain rather than having to address all stages.

4.2 Recommendations to key stakeholder groups

While this report has explicitly focused on the solutions that seek to increase circularity through addressing the waste already produced, an overarching recommendation to actors at all levels is to work at higher levels of the waste hierarchy wherever possible. The recommendations below highlight the supporting actions that key stakeholder groups can take in increasing circularity by deploying digital solutions to address waste already produced.

Governments and regulators

National and global policy plays an essential part in the market and governments and regulators have a central role in brining about circularity. National EPR legislation is often an essential component of creating functioning markets and has the benefit of generating additional revenues for those working to address waste management. This can be particularly important where cities and countries have low baseline collection and recycling rates as it can act to stimulate a non-existent ecosystem, leveraging further private investment. The offer of digital outlined in this report grant policy makers new tools for gathering data and enforcing regulations. The recently past ERP legislation in Ghana, India, Indonesia, Kenya, and South Africa all

Spotlight 18
Mobile devices, network equipment and the circular economy

Approximately 1.5 billion mobile phones were sold in 2023, with 90% of the global population owning a device. In 2023, there were an estimated eight billion active phones worldwide, and this number is forecast to reach nine billion by 2030. Based on the limited data available, official take-back rates are likely below 15%, meaning that 85% of spent devices are not formally recycled, being either handled by the informal sector or improperly disposed of. The GSMA's circularity vision for mobile devices is driven by two core principles: i) extending the lifespan of devices as long as possible, and ii) achieving zero waste through the reuse of materials.

In 2022, GSMA published two strategy papers on the circular economy for network equipment and mobile devices.[100,101] The strategy paper on network equipment focused on parts or products along which data flows through the telecommunication infrastructure such as routers, antennas and data centre equipment. The mobile devices' strategy paper considered personal devices such as phones and tablets as well as customer equipment like Wi-Fi hubs and set-top boxes.

The average active lifespan of a phone today is two to three years, well below the technical lifespan of four to seven years for most phones. Extending the useful life of all smartphones in the world by a year would save over 21 million tonnes of CO2e, equivalent to taking nearly five million cars off the road. Additionally, there are promising trends in the used and refurbished phone market, with shipments growing by 10% in 2023, compared with a 3.5% decline in new phones.[102] The refurbished phone market is especially significant in supporting extending access for the 3.4 billion people globally without access to mobile internet.[103,104]

100. GSMA. (2022). *Strategy Paper for Circular Economy: Network equipment*.
101. GSMA. (2022). *Strategy Paper for Circular Economy: Mobile devices*.
102. International Data Corporation (IDC). (2023). *Worldwide Used Smartphone Forecast, 2023–2027*
103. GSMA (2023) *The State of Mobile Internet Connectivity Report 2023*
104. GSMA (2022) *Making internet-enabled phones more affordable in low- and middle-income countries*

offer learning surrounding the available policy mechanisms, and how digital can be integrated. Additionally, the outcomes from the negotiations of the Global Plastics Treaty are likely to clearly set the global framework in which national policy will work. In addition to EPR, bans on the most problematic packaging materials and single-use plastics are likely needed, and are increasingly being seen across countries.

Cities and municipalities

As highlighted in this report and other research, municipalities are often caught in the position of having to spend a large portion of municipal budgets on waste management, whilst at the same time struggling to provide an adequate service. Innovations in processing and reuse in particular offer some promise here, as they provide an additional revenue stream that can justify capital investment from private players and fill a much needed investment gap. Cities and municipalities can develop and enabling environment through developing partnership models that allow for the co-development of infrastructure and services, learning from other municipalities that have developed successful collaborations. Additionally, as municipalities often have service delivery mandate themselves, they occupy a central role in defining the relationship with the informal sector. This report has documented how digital tools can be used to monitor, engage, and empower informal workers within the waste sector.

Funders and investors

While this report has documented many successful cases of digital innovation thriving in in waste management, this is notably concentrated in a few key middle-income markets. In many countries, grant funding for early-stage companies will continue to be an important stimulus to the ecosystem. Similarly, and in relation to development finance institution lending, larger capital investments are needed in core infrastructure, especially in relation to processing and waste-to-value infrastructure. DFI financing can provide much needed certainty in the context of public-private partnerships, either through directly funding a portion of CapEx, indirectly through offering loss guarantees, or offering results-based finance or utilising credit-based models. In most cases these mechanisms have been piloted or have seen early deployment at scale.

Start-ups

Start-ups entering the market or looking to scale need to carefully examine product-market fit and their unit economics before scaling. The diversity between and within countries and waste streams as to how markets are structured means that there isn't a single playbook. Specifically, the waste-to-value process, either directly or indirectly, will govern the unit economics. In cases where there is a developed ecosystem of players, niche offerings within the value chain can thrive, but require a significant investment in relationship building. In other cases, where there is a fragmented ecosystem, or access to the secondary market for materials is governed by just a few players, vertical integration may be needed to ensure that start-ups can capture enough value from the sale of secondary materials. Regardless of the specific solution, integrating digital payments to the model can often prove a quick win, as it opens the door to a much wider range of financing instruments for funders and financial institutions.

Mobile operators

Mobile operators have a central role in addressing e-waste within their own sphere of influence. The GSMA strategy papers on mobile devices and network equipment together identify 17 key actions operators can take.[105,106] These focus on keeping equipment or devices in use for longer, the steps that can be taken to identify where and how secondary materials can be used, and the steps that can be taken to build necessary relationships. Additionally, the digital solutions highlighted in this paper all leverage mobile solutions. Existing MNO tracking and fleet management solutions have potential applications in waste management sectors, and with increasing demands for traceability, they present a strong use case for IoT.

105. GSMA. (2022). *Strategy Paper for Circular Economy: Network equipment*.
106. GSMA. (2022). *Strategy Paper for Circular Economy: Mobile devices*.

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