Synergies Between Waste Reduction, Resource Efficiency and Energy Systems Decarbonisation

An input to COP31

International Energy Agency



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Abstract

Current patterns of production and consumption have far-reaching consequences for global resources, greenhouse gas emissions and waste generation. Transitioning to a more sustainable, circular and zero waste economy requires action across entire value chains, from preventing waste generation to improving the management of unavoidable waste. This report, prepared by the International Energy Agency (IEA) at the request of the Türkiye COP31 Presidency, examines how action at the intersection of waste reduction, circularity and energy systems decarbonisation can contribute towards the Presidency's target to halve the projected growth in global municipal solid waste generation by 2035 while strengthening circularity. It focuses on three high-potential action areas: waste prevention and material efficiency; collection, sorting and recycling; and sustainable energy recovery from unavoidable residual waste. Together, measures in these areas could reduce global greenhouse gas emissions by more than 1.5 gigatonnes of carbon dioxide equivalent annually by 2035, including considerable reductions in potent methane emissions. The report concludes with policy options to help governments accelerate progress in these areas.

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Executive summary

Transforming how we produce and consume resources and improving waste management can accelerate progress towards a net zero emissions and zero waste economy

Current patterns of production and consumption have far-reaching consequences for global resources, greenhouse gas (GHG) emissions and waste generation. Each year, the world generates around 2.6 billion tonnes of municipal solid waste (MSW) – enough to cover New York City under ten metres of waste. The disposal, treatment and incineration of waste alone accounts for about 4% of global GHG emissions, including nearly 20% of global anthropogenic methane emissions, a greenhouse gas that is much more potent than carbon dioxide (CO_2). The emissions footprint of waste and inefficient resource use is even greater when full value chains and production systems are taken into account. Tackling waste is thus a key opportunity to slow near-term global warming and contribute to global net zero goals.

Transitioning towards a zero waste economy requires rethinking how goods and infrastructure are designed, produced, consumed and treated at end-of-life. Doing so would mean that fewer resources are used, products last longer, materials are reused and recycled, and what was once waste is instead turned into a valuable resource wherever possible.

Raising waste reduction and circularity on the international climate agenda can help accelerate global progress

More strongly incorporating zero waste and circular economy objectives into the international climate agenda has strong potential to accelerate progress. The Türkiye COP31 Presidency has announced an ambitious goal to reduce the projected increase in global annual MSW generation by at least 50% by 2035 and to boost circular economy approaches. Achieving this goal requires businesses to redesign and innovate across the life cycle of products, buildings and infrastructure, and governments to rethink how policies can enable such a transformation.

Achieving the COP31 Presidency's goals will require economy-wide action, including preventing food waste and encouraging more sustainable consumption;

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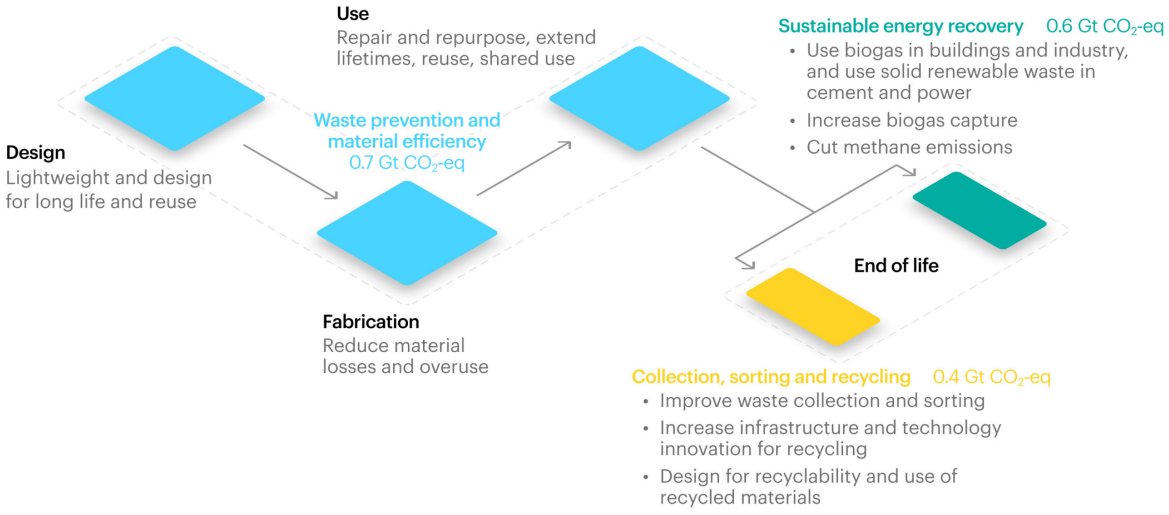
designing products and buildings that use materials more efficiently and avoid generating waste; expanding reuse and recycling; and improving waste collection and treatment systems.

Three high-potential action areas at the intersection of zero waste and energy systems offer significant potential for decarbonisation

There are considerable synergies between waste reduction, circularity and energy systems decarbonisation. This report identifies three key areas where GHG emissions reductions and improved resource efficiency outcomes can be achieved together: waste prevention and material efficiency; collection, sorting and recycling; and sustainable energy recovery from residual waste streams.

Implementing a comprehensive package of actions in these areas could cut global GHG emissions by more than 1.5 gigatonnes of carbon dioxide equivalent (Gt CO_2-eq) annually by 2035, comparable to bringing the emissions from half the global car fleet to zero. Additionally, they would ease pressures on resources, improve health and local environmental outcomes, create new economic opportunities, generate additional jobs in value-added sectors, and enhance global energy security, including through the use of organic waste as fuel. Most of these measures can be achieved using proven technologies and practices. Priorities will vary by country depending on the national context, the maturity of existing waste management systems, institutional capacity and access to finance.

Figure ES.1 Actions along the full value chain to prevent waste, support circularity and reduce emissions, and their emissions reductions potential in 2035



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Material efficiency, from improved design to shared use, can prevent waste at the source and reduce emissions

Five energy-intensive materials-based sectors – steel, cement, chemicals (including plastics), aluminium and paper – account for nearly 20% of global energy-related CO_2 emissions today. Using these materials more efficiently in buildings, vehicles, packaging and other value chains can reduce energy use and emissions associated with their production while cutting waste at its source. Product and infrastructure design is a key leverage point, helping optimise material inputs while enabling longer lifetimes, repair, reuse and recycling. Opportunities also exist across value chains, from minimising losses during construction to expanding shared-use models. Illustrative examples include the Quay Quarter Tower in Sydney, Australia, where an existing building was redeveloped rather than demolished and rebuilt, retaining over 65% of its structural elements and avoiding about 7 300 tonnes of embodied CO_2; and the city-wide REUSABLE system in Aarhus, Denmark, where the same takeaway cups are returned and reused across multiple participating businesses, reducing the need for single-use packaging. Actions in this area have the potential to reduce emissions by around 0.7 Gt CO_2-eq annually by 2035.

Improved collection, sorting and recycling can recover materials and turn waste into a valuable resource

Stronger end-of-life waste collection and sorting are essential to improving waste management, opening up opportunities to recover value from materials while reducing emissions. Maximising recycling potential can keep waste out of landfills and reduce demand for virgin materials and the energy needed to produce them. While large-volume metals like steel and aluminium already have relatively high recycling rates, further efforts are especially needed for plastics: through stronger collection and sorting and continued innovation on recycling methods, global plastics recycling could double by 2035. An illustrative example is Seoul, Korea, where households are required to collect transparent PET bottles separately from other plastics, enabling higher-quality recycling into new products such as clothing and bags. Stronger efforts in this area across all materials have the potential to reduce emissions by at least 0.4 Gt CO_2-eq annually by 2035.

Sustainable energy recovery from residual waste can curb methane emissions and expand low-emissions fuel supply

Even in a transition towards zero waste, some residual waste will remain difficult or uneconomic to recycle. Energy recovery from organic waste – while simultaneously maximising efforts to prevent organic waste where possible – can

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tackle two challenges at once: avoiding methane emissions from disposal and increasing the supply of low-emissions fuels and valuable by-products. Global production of biogases – derived from feedstocks such as crop residues, manure and MSW – could quadruple by 2035. Emerging market and developing economies (EMDEs) account for more than half of the associated emissions reduction potential. Production of biogases can enhance energy security by using resources produced close to where they are consumed: the energy from quadrupling the production of biogases is equivalent to all the liquid natural gas exported via the Strait of Hormuz in 2025. The city of Indore in India illustrates how biomethane production can be integrated into waste management: its largest plant converts 550 tonnes of organic waste each day into biomethane, fuelling more than 400 city buses. Biogases production could be complemented by the use of organic waste as a solid fuel in power generation and parts of industry. Increased global action on sustainable energy recovery from waste has the potential to reduce emissions by at least 0.6 Gt CO_2-eq annually by 2035.

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Policy priorities at the intersection of zero waste and energy systems decarbonisation

Achieving the COP31 Presidency's goals for zero waste will require governments to put in place the policy conditions for a step change towards a circular economy. Governments may wish to prioritise the high-impact areas identified below, with the right mix and sequence depending on the national context. Robust monitoring and reporting are important to ensure progress towards national and international objectives.

1. Place value on resource efficiency across government policies: Resource efficiency is often not the default choice as it may require higher upfront planning, labour costs, investment in infrastructure or behavioural shifts. Yet it can pay dividends over time, both in environmental outcomes and in driving higher value economic activity. Governments can examine the full spectrum of major policies to strengthen the value placed on resource efficiency, including through progress indicators, taxation, public procurement and permitting. Doing so could better align incentives towards productivity, competitiveness, repair, reuse, recycling and less waste, ultimately helping decouple economic growth from material use. Governments may also consider integrating circular economy and waste-reduction objectives and measures into their emissions reductions policies, plans and reporting frameworks, such as their Nationally Determined Contributions.

2. Examine design regulations to prioritise circularity: Product and buildings design is a key intervention point as many aspects of material inputs, use patterns and end-of-life outcomes are partially pre-determined during this stage. Revisiting design rules can ensure that product and building design considers material inputs and is easier to use for longer, repair, reuse and recycle. Starting with design regulations for the largest end-uses of energy-intensive materials – including buildings, vehicles and packaging – could have the largest impact on reducing GHG emissions. Policy options include extended producer responsibility, repairability and durability standards, and whole-life carbon rules.

3. Allocate sufficient funds for better collection, sorting and recycling and establish robust waste governance: Finance for collection, sorting and recycling – both infrastructure investment and ensuring ongoing operations are sufficiently funded – is integral to keep materials in use and reduce uncontrolled disposal, both of which also substantially reduce emissions. Public finance is key

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and when used well can leverage additional private finance. Extended producer responsibility schemes can also enable funding by placing responsibility for end-of-life management on those who shape product design. The focus of intervention depends on a country's current stage of waste management and may range from expanding MSW collection to offering separated organic waste collection to funding innovation for plastics recycling. Institutional or financial barriers may need to be overcome, especially where waste collection and controlled disposal are limited. Strengthening waste governance – including greater stakeholder inclusivity, financial sustainability, robust institutions and clear lines of responsibility – is also important. Collaboration among local and national governments can help, including sufficient funding allocated to local governments.

4. Incentivise the use of organic waste as bioenergy: Reducing, collecting and managing organic waste is a priority stream for reducing GHG emissions, as poor management leads to methane emissions while energy recovery can displace fossil fuels and support energy security. Investment in separated collection or sorting for organics, alongside targeted incentives for biogases and solid bioenergy use, can support the sustainable use of organic waste. Policies include tax credits, renewable energy quotas and streamlined permitting for relevant facilities demonstrating low leakage rates and fume treatment, all the while prioritising waste prevention.

5. Make resource efficiency and sustainable waste management part of core curricula and professional training: Embedding resource efficiency in curricula and training for designers, engineers, architects, construction site managers and waste sector executives would help build the capabilities to deliver circularity and maximise response to policy incentives. The highest impact awareness interventions can target those who design and build systems (including the policies referenced in the first priority action), in turn making resource efficiency the easier and automatic choice for society. Topics to cover could include life cycle emissions, material-efficient design, repairability, and how resource efficiency can improve productivity and capture higher value-added markets. Capacity building could also extend to municipal officials, operational staff and waste workers, particularly where practical skills are needed in service delivery, maintenance, financial management and community engagement.

6. Strengthen international collaboration, knowledge exchange and access to finance: Countries are at different stages of developing circularity and waste management strategies, creating valuable experience-sharing opportunities. Participation in international platforms can support knowledge exchange, capacity building and technology collaboration, particularly for EMDEs, while international finance and technical assistance can help bridge funding and institutional capacity gaps and support design and implementation of effective policies. Collaboration is also important among governments, the private sector and civil society.

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Introduction

Patterns of production and consumption shape global resource use, energy demand, waste generation and GHG emissions. Waste creates climate, environmental and health impacts and represents the monetary loss of the products, materials or food that end up being thrown away. Addressing these challenges requires action across entire value chains. Consistent with the waste management hierarchy, priority should be given to preventing waste, using materials more efficiently, and keeping products and materials in use through reuse and recycling, followed by responsible management of and, in some cases, energy recovery from, unavoidable residual waste.

Türkiye's leadership in advancing a zero waste and circular economy[1] has helped heighten international attention to the links between waste prevention, resource efficiency, emissions reductions and environmental protection. As highlighted in the Third Letter from the COP31 President-Designate to Parties, "prioritizing waste prevention alongside methane reduction and circular economy approaches" can tackle "emissions at their source while improving resource efficiency, strengthening resource security and reducing pressure on ecosystems". Elevating this agenda could encourage governments and businesses to rethink and innovate across the life cycle of products, infrastructure and materials.

This report, prepared by the IEA at the request of the Türkiye COP31 Presidency, examines three high-potential action areas where the zero waste and energy systems decarbonisation agendas intersect: **waste prevention through material efficiency; collection, sorting and recycling; and sustainable energy recovery** from unavoidable residual waste streams. Together these approaches can reduce demand for primary materials and the energy required to produce them, lower emissions across value chains, reduce the volume of waste destined for disposal, and manage unavoidable residual waste through energy recovery pathways that can also displace fossil fuel use.

The opportunities examined in this report represent only part of the broader action needed to address rising waste generation and advance circularity. Achieving the wider COP31 waste objectives – including the Presidency's proposed goal of "reducing the projected increase in global annual municipal solid waste generation by at least 50% by 2035" – will require action across a broad range of sectors and

[1] Throughout this report, "zero waste", "circularity" and related terms refer broadly to efforts to prevent and minimise waste and resource use and to keep products and materials in use for as long as possible, including through reuse, repair and recycling. "Zero waste" denotes an ambition to minimise waste generation rather than necessarily the literal elimination of all waste.

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stakeholders. This includes changes in production and consumption patterns; reductions in food loss and waste; broader adoption of reuse, repair and other waste-prevention measures; and expanded access to reliable waste collection, appropriate treatment and environmentally sound disposal. Progress will depend on co-ordinated efforts among governments, industry and international partners.

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Waste, circularity and impacts on greenhouse gas emissions

Volumes of waste generated globally continue to rise

Waste consists of materials or products that are discarded or intended to be discarded. It can be categorised in a variety of ways: by material type, ability to biodegrade and source. Distinctions can also arise between waste and residual material streams considered to be valuable secondary raw materials, co-products or by-products, depending on how they arise and are subsequently used. Sources of waste include homes and businesses, construction and demolition, industry, agriculture, healthcare, and mining. Analysis based on available data estimates that more than 23 billion tonnes of waste are generated each year,[2] including around 2.6 billion tonnes of municipal solid waste (MSW).[3] MSW is the waste that homes and businesses discard daily and is closely linked to public health and methane emissions. The volume of MSW generated is enough to cover New York City under ten metres of waste every year.

Waste generation is closely linked to population growth, urbanisation, rising incomes and changing consumption patterns, and varies considerably between countries and regions. The future trajectory of global MSW generation will also depend heavily on actions taken over the coming decades. Scenario analyses from the United Nations and the World Bank suggest that, without significant changes in policy or practice, MSW generation could increase by around 60-65% by 2050.

Prioritising waste prevention and reuse can significantly slow or even reverse waste growth, while increasing refurbishment, recycling and composting alongside improved collection and sorting systems can reduce landfilling as well as uncontrolled burning and disposal. In the most ambitious scenarios, global waste generation peaks in the 2030s and returns to roughly today's levels by

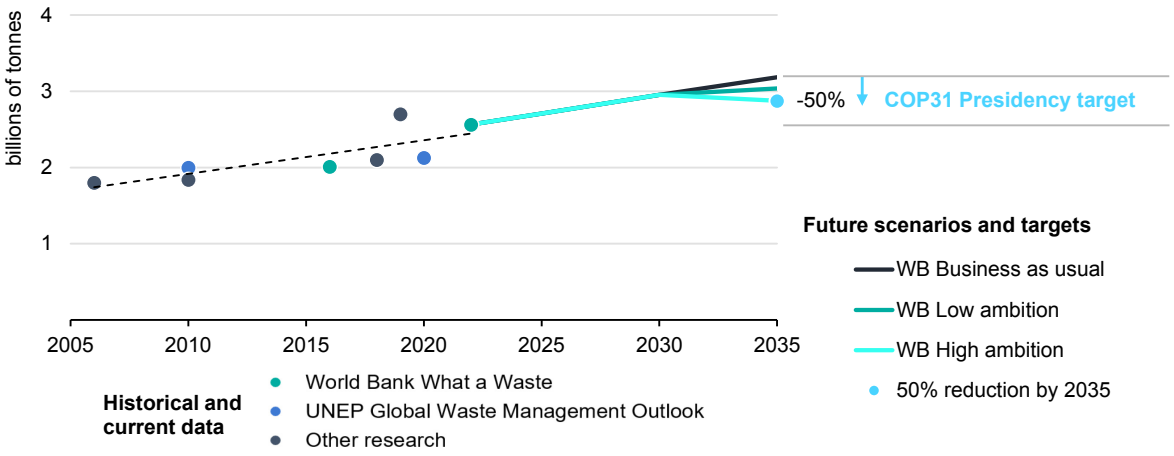
[2] This total excludes waste from mining, electronics and medical waste. This figure is based on IEA analysis of Eurostat (2022), Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (database); World Bank (2026), What a Waste Global Database; United Nations Office for Disaster Risk Reduction (2025). Mining is one of the largest sources of waste globally, with estimates suggesting that mine tailings alone amount to roughly 7-13 billion tonnes (Araujo et al. [2022], Recycling and Reuse of Mine Tailings: A Review of Advancements and Their Implications. Geosciences, 12(9), 319; ICMM [2025]) annually, while total mining waste including waste rock may exceed 100 billion tonnes per year. According to UNITAR (2024), Global E-Waste Monitor 2024, waste generated from electronics in 2022 was 62 million tonnes.

[3] Based on the latest available values (2022) in World Bank (2026), What a Waste 3.0. Estimates of waste generation and management are subject to considerable uncertainty, reflecting differences in definitions, reporting practices and data availability across countries and waste streams. MSW is generally the best-documented waste category because it is often managed through formal collection systems. By contrast, industrial, construction and demolition and agricultural waste are typically less consistently measured, and may be reused, recovered or disposed of without being systematically recorded. As a result, global estimates are generally more robust for MSW than for other waste streams, but reported quantities can still vary considerably between sources and methodologies.

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mid-century, supported by widespread adoption of circular approaches, universal waste collection and improved waste management infrastructure. These scenarios deliver environmental and social benefits and can reduce the long-term economic costs associated with rising volumes of waste as well as with unmanaged waste. A high-ambition waste reduction scenario relies on strong waste prevention measures, particularly reducing food waste; cutting single-use packaging; and expanding reuse, repair and circular business models to decouple waste generation from economic growth.

Figure 1 Historical municipal solid waste generation and projected future growth



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Notes: World Bank (WB) analysis notes that increases in historical estimates of MSW generation can be due to both real increases in generation amounts and improvements in data coverage. A 50% reduction by 2035 = reduce the projected increase in global municipal solid waste generation by at least 50%, relative to the business-as-usual trajectory from a 2022 baseline (2022 being the latest published data available).

Sources: **Historical:** UNEP (2015, 2024), Global Waste Management Outlook 2015, Global Waste Management Outlook 2024; World Bank (2021, 2024), What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050, What a Waste 3.0. Other research - Waste Atlas (2013); Maalouf, A.and A.Mavropoulos, Re-assessing global municipal solid waste generation, Waste Management & Research: The Journal for a Sustainable Circular Economy, 2023;41(4):936-947; From Waste to Resource A World Waste Survey (2009); Verisk Maplecroft (2019), Waste Generation and Recycling Indices. **Future:** World Bank (2026), What a Waste 3.0 scenarios.

The target announced by the Türkiye COP31 Presidency to: "[reduce] the projected increase in global annual municipal solid waste generation by at least 50% by 2035" is aligned with the World Bank's "High ambition scenario" (Figure 1), which sees waste grow from approximately 2.7 billion tonnes in 2022 to 2.9 billion tonnes in 2035, compared with the "business-as-usual scenario", which sees 3.2 billion tonnes of MSW generated in 2035.

The waste hierarchy prioritises preventing waste and promotes circularity

Waste management practices should follow the waste management hierarchy wherever possible, where preventing and reducing waste is the priority, followed by reusing, recycling and composting; then energy recovery; and finally controlled disposal in landfills (Box 1).

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Collecting and sorting waste is a prerequisite for effective waste management and is required for recycling, composting and most forms of energy recovery. While collection services are nearly universal in many advanced economies, some regions struggle to provide basic waste collection. World Bank analysis estimates that around 30% of MSW globally is either openly dumped or left uncollected, highlighting the scale of the remaining challenge. Where waste is collected, much of it is still disposed of rather than recovered. Many materials with high economic value, such as metals, are routinely recycled, in some countries through the informal[4] waste sector, while organic and mixed waste streams often continue to be sent to landfills or dumpsites. As a result, large quantities of potentially valuable materials are lost from the economy each year.

Box 1 The waste management hierarchy and circular approaches

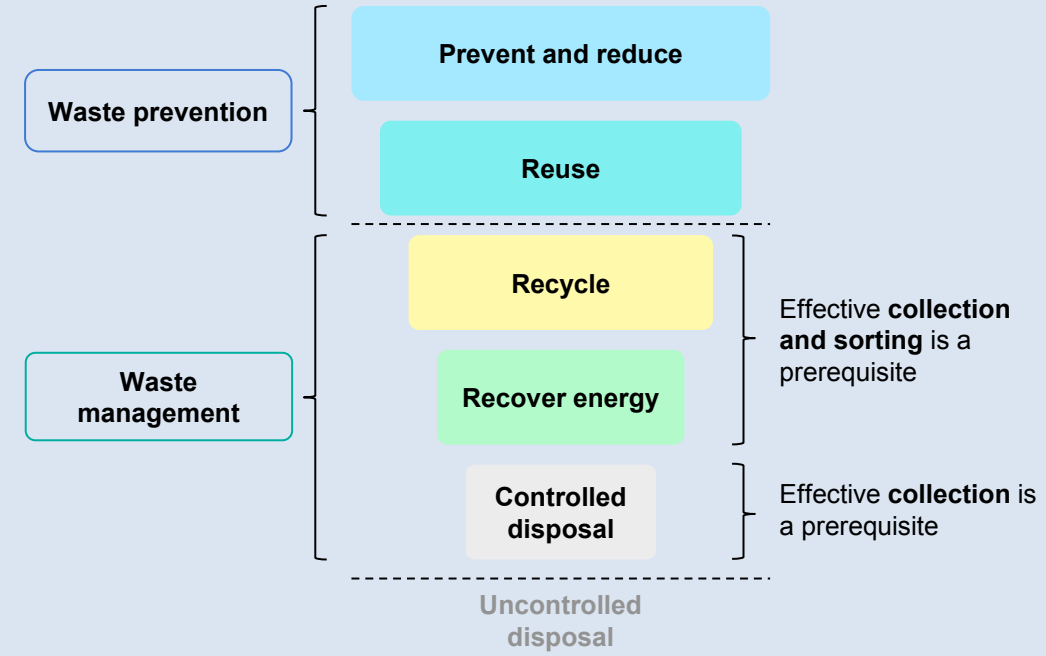
The waste management hierarchy (or simply 'waste hierarchy') is a well-established guiding principle for waste-related policy. It prioritises preventing and reducing waste, followed by reusing, recycling and composting; then energy recovery; and finally controlled disposal (Figure 2).* Legislation such as the European Union's Waste Framework Directive interpret the hierarchy through a circular economy lens, seeking to keep materials and products in use for longer through measures such as product design, reuse, repair and remanufacturing before end-of-life recycling or recovery. By reducing demand for primary material production and diverting waste from disposal, these approaches can improve resource efficiency while lowering energy use, emissions and other environmental impacts. Energy recovery remains an important option for unavoidable residual waste, particularly anaerobic digestion for organic waste streams and landfill gas collection, but should avoid displacing higher value prevention, reuse and recycling options.

While the waste hierarchy provides a useful general guiding principle and countries and regions should broadly aim to move up the hierarchy over time, it is not a strict rule and there is ultimately a role for multiple waste management solutions within an effective system. The most suitable option may vary in some cases depending on the specific waste material, the relative weight of different priorities (e.g. impact on land use, GHG emissions, local air pollutants), as well as the specific local context (e.g. investment and operational costs, transport distances, infrastructure availability, what is possible in the near term versus what is ideal in the longer term). Therefore, policy makers may tailor approaches to national and local contexts and priorities.

[4] The informal waste sector comprises workers and enterprises engaged in the collection, sorting, recovery, recycling and trade of secondary materials outside formally regulated waste management systems. These activities often provide an important source of livelihoods while contributing significantly to material recovery and recycling.

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Figure 2 The waste management hierarchy



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* This version of the waste hierarchy was agreed by parties to the 2011 Basel Convention to give a sense of generalised priority based on environmental performance. In practice, actual environmental outcomes for each treatment option – and therefore priority – will depend on the specific practices used in each case and should consider life cycle impacts across relevant environmental indicators.
Note: Separate collection should be prioritised where it is necessary to achieve high-quality recycling, but should not preclude effective mixed-waste sorting, which can complement separate collection and increase overall material recovery.

Global activity on reducing waste and its associated emissions has been growing in recent years

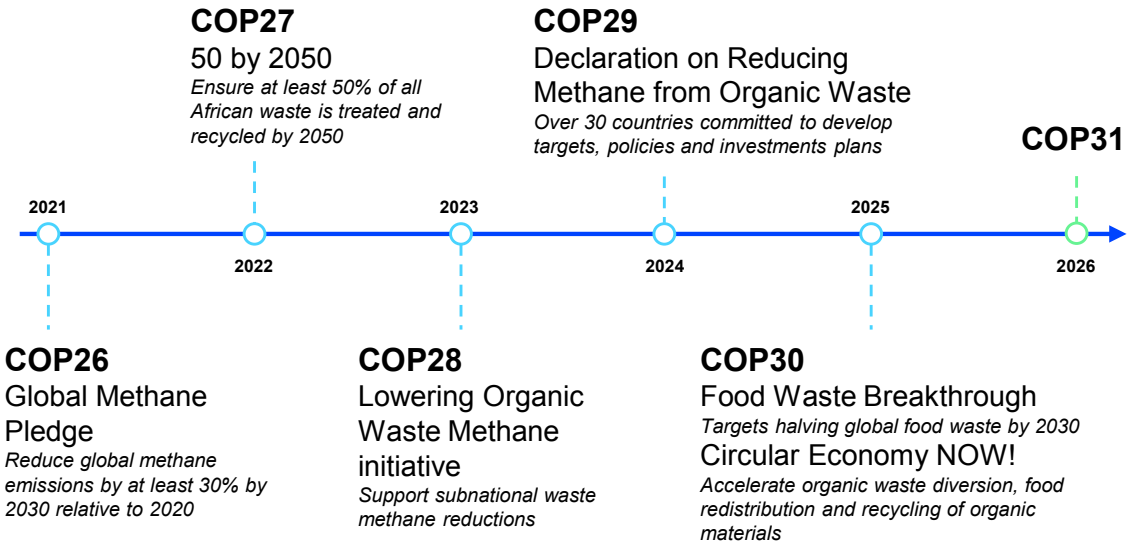
The Sustainable Development Goals (SDGs) provide the broadest global framework for waste reduction and management. In particular, SDG 12 on sustainable consumption and production includes a target to halve per capita global food waste and reduce food losses by 2030 (SDG 12.3). Waste management is also reflected in SDG 11 on sustainable cities, which tracks the share of MSW collected and managed in controlled facilities.

Efforts to reduce food loss and waste are among the most developed areas of waste policy, owing in part to the methane emissions associated with organic waste disposal. Under the Global Methane Pledge, launched at COP26, Participants committed to take voluntary action towards reducing global methane emissions by at least 30% below 2020 levels by 2030. The Global Methane Pledge's Waste Pathway, launched in 2022, focuses on reducing emissions across the waste value chain through measures such as food waste reduction, separate collection of organic waste, anaerobic digestion and landfill methane

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capture. Subsequent COPs have seen a growing number of waste-related methane initiatives focused on organic waste, food waste and circular approaches (Figure 3).

Figure 3 Selected recent waste-related initiatives and pledges announced at COPs



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Sources: 50 by 2050 initiative; Lowering Organic Waste Methane initiative; COP29 Declaration on Reducing Methane from Organic Waste; Circular Economy NOW! (no organic waste) initiative; Food Waste Breakthrough.

Circularity has received less direct focus to date, with a limited number of recent initiatives, such as the Building Circularity into Nationally Determined Contributions Toolbox, launched at COP28, and the Global Circularity Protocol and ICLEI Circulars global network, both launched at COP30. Alongside the above-mentioned waste-related initiatives, successive COPs have also highlighted complementary topics such as sustainable mineral extraction, recycling and industrial decarbonisation, including the COP28 announcement of a UN Panel on Critical Energy Transition Minerals and the Climate Club.

Plastics have also become a growing focus of international governance. Following a 2022 United Nations Environment Assembly resolution, the Intergovernmental Negotiating Committee has been leading negotiations on a legally binding international instrument on plastic pollution, although a final treaty has yet to be agreed upon.[5] Existing agreements, such as the Basel Convention's Plastic Waste Amendments, also address specific issues such as transboundary movement of plastic waste and environmentally sound management.

These developments provide the context for the COP31 waste agenda. Türkiye has played a visible role in promoting zero waste internationally, including through the UN General Assembly resolution that designated 30 March as International

[5] Following the most recent negotiating session in Geneva in August 2026, the next formal negotiation session is expected in 2027.

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Day of Zero Waste. In the Third Letter from the COP31 President-Designate to Parties, published in August 2026, the Türkiye COP31 Presidency announced a target to: "[reduce] the projected increase in global annual municipal solid waste generation by at least 50% by 2035".

Waste is associated with significant GHG emissions, alongside local environmental and health impacts

Waste can pollute air, water and soils; create public health risks; and contribute to GHG emissions, especially when disposal is uncontrolled. Its impacts vary across waste streams, ranging from methane emissions from decomposing organic waste to the release of air pollutants, plastics, hazardous chemicals and other contaminants. Poorly managed waste can expose nearby communities and waste workers to health risks from toxic substances, poor sanitation and disease vectors while damaging ecosystems and contributing to biodiversity loss. Improving waste management, and preventing waste generation in the first place, therefore delivers important environmental, health and climate-related benefits.

If organic waste – such as food waste, garden waste and paper – is disposed of in uncontrolled landfills or dumpsites or if wastewater is managed under anaerobic conditions (i.e., in the absence of oxygen), the decomposition of organic matter can generate methane. Consequently, organic waste contributes disproportionately to waste sector GHG emissions despite representing only a subset of waste generated. Collecting and managing organic waste through alternatives such as composting and anaerobic digestion can reduce emissions substantially while recovering nutrients and/or energy.[6]

Methane is a powerful, short-lived climate pollutant, remaining in the atmosphere for approximately 12 years once emitted (compared with centuries for CO_2). The warming impact of methane is typically compared to CO_2 by considering the warming that occurs over a 100-year period, where methane causes approximately 30 times more warming than CO_2. However, when warming is considered over a 20-year period, methane causes approximately 80 times more short-term warming than CO_2. This means that cutting methane emissions from waste can help to lower near-term peak global temperatures, shorten the period of overshoot above 1.5 °C, and therefore reduce the risks faced by people and ecosystems. But rapid action is needed, particularly before 2035, to unlock the significant potential for methane emissions reductions from waste.

The Intergovernmental Panel on Climate Change's (IPCC) GHG accounting includes four main categories of emissions sources for the waste sector: 1) solid

[6] Composting and anaerobic digestion can substantially reduce the GHG footprint of organic waste management, particularly by avoiding methane emissions from uncontrolled anaerobic decomposition in landfill and dumpsites, but they are not emission-free. While the CO_2 released is largely biogenic, methane, nitrous oxide and other life cycle emissions can still occur.

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waste disposal; 2) wastewater treatment and disposal; 3) biological treatment of waste (including composting); and 4) waste incineration and open burning. Solid waste disposal and wastewater treatment and disposal produce the largest emissions, where methane is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites and wastewater treatment facilities, respectively. Smaller amounts of methane are also emitted during the biological treatment of waste, as well as during incineration[7] and open burning of non-renewable waste. In the waste sector, nitrous oxide (N_2O) is produced primarily during denitrification and nitrification by bacteria during wastewater treatment and disposal, with smaller amounts produced during biological treatment of waste and waste incineration and open burning (during which CO_2 is also produced).

Incomplete combustion during the open burning of waste also generates black carbon, commonly known as soot, a component of fine particulate matter air pollution (PM2.5)[8]. Estimates suggest that open burning of waste contributed around 5% of anthropogenic black carbon emissions in 2019. Once released into the atmosphere, black carbon acts as a short-lived climate pollutant,[9] and contributes to global warming. Because black carbon remains in the atmosphere for only a matter of days or weeks, but its warming effect can be many times greater than CO_2, reducing emissions can quickly slow warming and improve air quality. Furthermore, black carbon deposited on ice and snow can decrease albedo[10] and exacerbate ice melting.

Many emissions associated with waste generation and management are, however, accounted for in other sectors. Emissions from waste-to-energy incineration – which were estimated to be approximately 0.15 Gt CO_2-eq in 2025 – are reported under the energy sector, while many of the emissions benefits of waste prevention, material efficiency, and reuse and recycling occur outside the waste sector through reduced demand for energy, materials and agricultural production. Waste sector emissions therefore capture only part of the climate impacts associated with waste and resource use. Moreover, changes in waste sector emissions do not necessarily correspond to changes in the amount of waste generated. This is because emissions can shift between sectors, for example through incineration with energy recovery, and because different waste streams have very different emissions profiles, with biodegradable waste generating more direct waste sector emissions than non-biodegradable materials such as plastics.

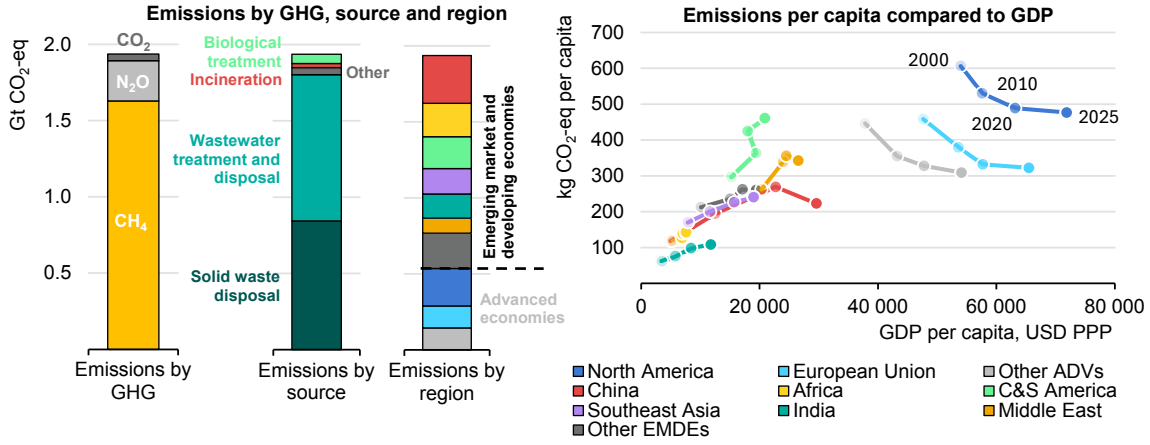
Waste produced nearly 18% of anthropogenic methane emissions in 2025. While in absolute terms methane emissions from waste are lower than those from the energy sector (36%) and agriculture (47%), waste methane has seen the strongest

[7] Incineration of waste with energy recovery, e.g. in waste-to-energy plants, is included in the IPCC energy category.
[8] Particulate matter with a diameter of less than 2.5 microns.
[9] Other short-lived climate pollutants include methane, tropospheric ozone precursors and fluorinated gases. Improper disposal of cooling equipment can also release fluorinated gases, although these emissions are generally accounted for outside the IPCC waste sector.
[10] Albedo is a measure of how much solar radiation is reflected by an object or surface.

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relative growth over the last 25 years[11]. In total, waste accounted for around 1.9 Gt CO_2-eq of GHG emissions in 2025 (Figure 4).[12] Of this, around 85% are methane emissions, alongside smaller amounts of CO_2 and N_2O. The emissions impact from the waste sector is subject to substantial uncertainty[13] due to incomplete, inconsistent and unevenly reported data across regions, affecting estimates of quantities of waste generated, waste disposal that ends up in landfill, and wastewater generation and treatment coverage. Data uncertainties should not be reason to delay action, and efforts are ongoing to improve the measurement of waste emissions, including through the United Nations Environment Programme's Methane Alert and Response System (MARS).

Figure 4 Direct emissions from the waste sector by greenhouse gas, source and region, 2025



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Notes: ADVs = advanced economies; *Other ADV* includes Australia, Chile, Colombia, Costa Rica, Japan, Korea and New Zealand; *Other EMDEs* includes the Middle East, Eurasia, non-OECD Asia Pacific and EMDEs in Europe; C&S America = Central and South America (developing nations only); Mt CO_2-eq = million tonnes of carbon dioxide equivalent.

Source: IEA analysis of emissions from the EDGAR (Emissions Database for Global Atmospheric Research) database (2026).

Today the majority of global GHG emissions from waste (56%) come from emerging markets and developing economies (EMDEs), excluding the People's Republic of China (hereafter "China"). Advanced economies are responsible for some of the highest emissions per capita.

[11] With the exception of industrial emissions from the chemical industry (category 2B) and metal industry (category 2C) which represented less than 0.5% of methane emissions globally in absolute terms in 2025.

[12] Global emissions from the waste sector in the Emissions Database for Global Atmospheric Research (EDGAR) in 2024 are estimated to be approximately 59 million tonnes of methane (Mt CH_4) per year, 0.48 Mt N_2O per year and 13 Mt CO_2. Assuming global warming potentials over 100 years of 28 CH_4 and 265 N_2O (consistent with the IPCC Fifth Assessment Report values used in the *EDGAR database*), this leads to overall GHG emissions of 1.8 Gt CO_2-eq. This report's analysis on emission relies on data from the *EDGAR database*, as it provides a robust and well-documented source of emissions estimates, disaggregated between different regions and emissions sources and aligned to IPCC 2006 emissions categorisations. While the *EDGAR database* does not include large-scale biomass burning with Savannah burning, forest fires, and sources and sinks from land-use, land-use change and forestry, preliminary estimates are available.

[13] The range of overall uncertainty in waste emissions estimates in the EDGAR database, used as the underlying data for the discussion of waste emissions in this report, is between 35% and 134% for CH_4 and 10% and 490% for N_2O, which are some of the largest uncertainty ranges of any IPCC emissions sector.

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Global GHG emissions from the waste sector have been growing steadily since at least the 1970s, but rates of change in emissions from waste vary significantly among regions. In advanced economies, such as the European Union (EU) and North America, emissions from the waste sector have been declining since around 1990, including due to improved waste management practices, which have diverted organic waste away from landfills. However, some of this diversion has been to waste-to-energy incineration, whose emissions are reported under the energy sector rather than the waste sector. In the European Union, for example, landfilled municipal waste fell from 112 Mt in 2000 to 48 Mt in 2024, while incineration with energy recovery grew from 36 Mt to 61 Mt over the same period.

More recently, changes to waste management practices in China, including a rapid expansion of incineration, have steeply reduced waste sector emissions, reversing a significant upward trend in waste emissions since the early 2000s. However, as with the trends seen in the European Union mentioned above, some of this reduction reflects a reallocation of emissions to the energy sector rather than an absolute reduction. The reduction of waste emissions in China has led to a global plateau in waste emissions in recent years. In other EMDEs, however, emissions from the waste sector continue to rise, with some of the strongest rates of growth between 2000 and 2025 seen in Africa, India, the Middle East, and some Central and South American countries, particularly Brazil and Mexico. Growth of waste sector emissions in these regions indicates that without improved waste management practices, the current plateau in emissions is not likely to be a long-term effect.

The emissions benefits of reducing waste and pursuing resource efficiency extend far beyond direct emissions from waste disposal

A large share of the emissions associated with waste and wasteful resource use are generated earlier in value chains through activities such as raw material extraction, agricultural production, manufacturing, transport and product use. For example, when emissions from agricultural production, processing, distribution and consumption are included, food loss and waste account for around 6-8% of global GHG emissions, much greater than the 4% of global GHG emissions from the waste sector. Additionally, consumption and waste generation for plastics, metals, construction materials and electronics are generally associated with emissions from resource extraction and manufacturing, which fall outside the IPCC definition of waste sector emissions.[14] In these areas, material efficiency, reuse and recycling offer large opportunities for reducing emissions, meaning that the emissions benefits extend well beyond direct waste-related emissions.

[14] Initiatives such as circular activity sheets for Nationally Determined Contributions published by GIZ have advanced efforts to think about emissions reductions using a circular and cross-sectoral approach.

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Three high-potential action areas at the intersection of waste reduction, resource efficiency and energy systems decarbonisation

Progress on the zero waste agenda requires a diversity of actions across many value chains. This includes a combination of upstream interventions that avoid waste generation and prevent unnecessary consumption and measures that keep materials in productive use for longer, as well as downstream approaches to manage residual waste that cannot be prevented or recycled. The waste management hierarchy (see Box 1) provides a framework for prioritising actions that can reduce waste generation and its impacts.

The IEA has identified three key areas where strong synergies exist between waste reduction, circularity and energy systems decarbonisation. Taking action in these areas has great potential to reduce GHG emissions, including direct emissions from waste and broader value chain emissions associated with methods of production and consumption. Table 1 provides a summary of these opportunities.

Table 1 Summary of emissions reductions associated with the three high-potential action areas explored in this report, within and beyond the waste sector

Action area	Emissions reductions within the waste sector	Emissions reductions beyond the waste sector
Waste prevention and material efficiency	Reduces waste disposal and associated emissions from landfills, dumps, incineration and open burning	Reduces demand for materials and, in turn, associated energy use as well as energy and process emissions from the industrial sector
Collection, sorting and recycling		Reduces demand for primary materials and associated extraction, processing and industrial emissions
Sustainable energy recovery		Displaces fossil fuels and reduces emissions from energy use and manure management

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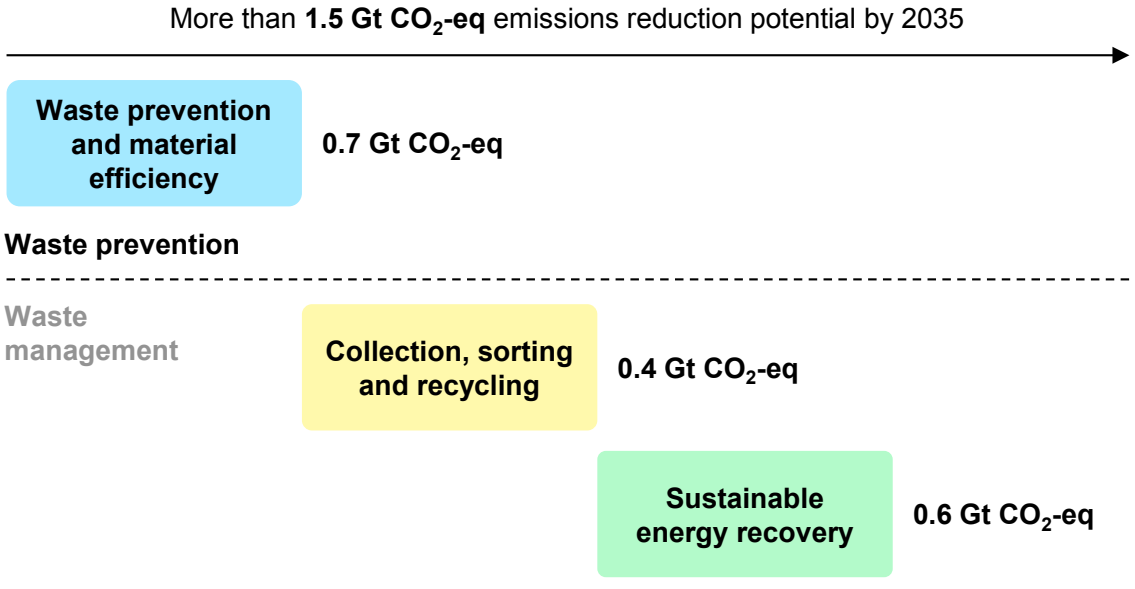
The first area examines **waste prevention and material efficiency** measures across the design, production and use phases of selected value chains. These actions reduce the demand for materials, thereby preventing "wasteful" use of materials and avoiding waste before it is generated. This area could make the largest contribution, with the potential to reduce around 0.7 Gt CO_2-eq annually by 2035.

The second area explores opportunities to improve **collection, sorting and recycling** so that materials can remain in productive use for longer, contributing at least 0.4 Gt CO_2-eq in emissions reductions.

The third area considers **sustainable energy recovery** for unavoidable residual waste, including opportunities to reduce methane emissions and displace fossil fuels through the use of organic waste while recovering value from waste streams that cannot be otherwise utilised. This area has the potential to reduce annual emissions by at least 0.6 Gt CO_2-eq by 2035.

Collectively, these action areas could cut more than 1.5 Gt CO_2-eq of GHG emissions annually by 2035 (Figure 5).

Figure 5 Three high-potential action areas at the intersection of waste reduction and energy systems decarbonisation, and their emissions reductions potential in 2035



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Waste prevention and material efficiency

There are many opportunities to prevent waste and use materials more efficiently throughout the life cycles of products, buildings and infrastructure. In particular, actions in the design, production and use phases – referred to in this report as "material efficiency" – are integral to transitioning to a circular economy. They support the highest priorities of the waste management hierarchy – prevention, reduction and reuse – serving to enable more sustainable production and consumption and to avoid waste generation in the first place. By reducing demand for material production, material efficiency measures can also reduce the energy consumption and emissions due to producing materials and associated resource extraction.

Energy-intensive materials value chains present the greatest opportunities to reduce emissions through material efficiency

From the perspective of energy consumption and emissions, the largest opportunities for material efficiency come from the most energy- and emissions-intensive materials. As mentioned previously, just five materials-based sectors – steel, cement, chemicals (including plastics), aluminium, and pulp and paper – account for 65% of industrial energy consumption and 75% of industrial CO_2 emissions[15] today. Together these sectors represent around 25% of total final consumption and just under 20% of total energy-related CO_2 emissions on a direct basis.

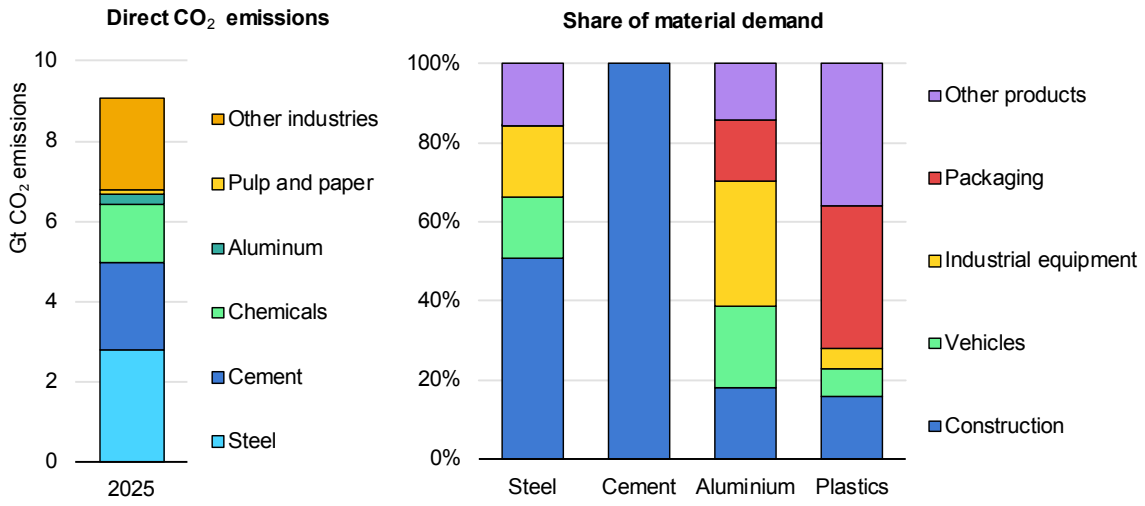
The greatest material efficiency opportunities are in value chains that use large volumes of these materials (Figure 6). Buildings and infrastructure are particularly important because they account for major shares of materials use, including essentially all cement and approximately half of steel used globally. Material demand is particularly shaped by the design and lifetime of buildings. Vehicles – including cars, trucks, ships and airplanes – are also a significant source of material demand, accounting for about 20% of aluminium demand and 15% of steel demand. Vehicle design, size and patterns of use all shape material demand. Packaging, consumer products and textiles are important value chains for plastics, together accounting for over 70% of demand; they also account for about 30% of aluminium demand. Here, product design and consumer habits have a considerable impact on material demand and, in turn, waste generation. Industrial machinery and electrical equipment are also substantive users of metals, in

[15] Includes direct industrial fuel combustion emissions and industrial process emissions.

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particular accounting for about 30% of aluminium demand led by electrical applications (including electrical cables and solar photovoltaic panels).

Figure 6 Global CO_2 emissions by industry and end-use consumption shares of selected bulk materials



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Notes: Construction includes buildings and other infrastructure. Vehicles include road vehicles, ships, and airplanes. Industrial equipment includes machinery and electrical equipment (cables, solar panels, etc.). Other products include (when relevant) consumer products, domestic appliances, textiles and miscellaneous uses.

Material efficiency should be viewed as complementary to, rather than a substitute for, industrial decarbonisation. Even with ambitious demand-side action, large quantities of steel, cement, aluminium, chemicals and other materials will still be needed, particularly in EMDEs. Technologies needed for energy transitions will also push up demand for some materials in certain segments, such as aluminium for electricity grids and solar photovoltaics. However, by reducing unnecessary material demand and keeping existing materials in productive use for longer, material efficiency can make an important contribution to emissions reductions and make the remaining task of decarbonising material production more manageable and less costly.

Opportunities for material efficiency exist at all stages of the value chain, from design to end-of-life

Across value chains, material efficiency opportunities arise at different life cycle stages. The largest impacts often come from decisions taken early, before products are produced or structures are built. In the **design stage**, material efficiency strategies can apply to individual products or structures, and their components – aiming for less material-intensive design or to make them easier to maintain, repair, adapt, reuse or recycle later. It can also include material substitution towards lower emissions and more recyclable materials. Moreover, a

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broader systems-design perspective can also save money, such as by designing the built environment to facilitate the use of public transport and vehicle sharing rather than private vehicle ownership, or redesigning product delivery models around less packaging through standardised, reusable and refillable containers.

In the **manufacturing, construction and assembly stage**, material efficiency strategies focus on reducing material losses and overuse of materials and making efficient use of emissions-intensive input materials. Some strategies apply to material and product manufacturing plants, such as improved and more precise process controls to improve yields and reduce scrap generation in steel production or vehicle manufacturing plants. Other strategies apply to construction, such as prefabrication or using ready-mix concrete to better control processes, and improved logistics to reduce over-ordering or damaging materials. Additionally, manufacturing decisions can make more efficient use of emissions-intensive materials and, in some cases, create opportunities for industrial symbiosis and cross-sector resource efficiency. For example, greater blending of supplementary cementitious materials in cement production can make more efficient use of emissions-intensive clinker, while in some cases also deriving value from industrial co-products such as slags from steel production.

In the **use stage**, material efficiency strategies aim to increase the amount of service provided by existing products, buildings and infrastructure before they are replaced. This includes maintenance, repair, refurbishment, upgrades and repurposing that extend useful lifetimes. Such **lifetime extension** in buildings has one of the largest potentials to reduce material demand, given the large quantities of materials used and that in some regions buildings are often demolished well before the end of their theoretical useful lives. Life cycle emissions should be considered when applying this strategy, so that lifetime extension does not lock in emissions-intensive technologies that would have otherwise been replaced with low-emissions technologies, such as in the case of vehicles. When longer use or reuse of full products has been exhausted, reuse of components or materials may be another possibility. Another key use-phase strategy is more intensive use of existing assets, such as through car sharing, higher office space occupancy, other product-as-a-service or rental services, and improved logistics in commercial settings. Other strategies include using material inputs more efficiently, such as through more efficient use of fertilisers in agricultural systems (including nitrogen fertilisers derived from ammonia, an energy-intensive chemical), and more selective consumer choice, such as by choosing smaller products or products with less packaging.

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Table 2 Illustrative examples of material efficiency measures across value chains

Life cycle stage	Illustrative material efficiency measures
Design and planning	• Optimise design: structural efficiency, lightweighting, right-size products and packaging, avoid over-design. • Substitute with lower emissions and/or recyclable materials. • Robust and modular design: design and choose materials for durability, repair, adaptability, repurposing, disassembly and recycling. • Redesign systems to facilitate shared use, reusable products and reduce overconsumption. • Renovate or repurpose before building new.
Manufacturing, construction and assembly	• Reduce material losses: improve yields and reduce scrap or spillage, including through better process and site control. For scrap generated, separate alloys at source to facilitate closed-loop recycling. • Match quantities of materials ordered and used to actual needs. • Use prefabrication, ready-mix concrete and standardised components for improved process control. • Make more efficient use of emissions-intensive materials by complementing them with lower emissions inputs, such as increased use of supplementary cementitious materials or scrap metal.
Use and lifetime extension	• Extend lifetimes: maintain, repair and repurpose to maximise longevity. • Recover components and materials for direct reuse. • Increase use: shared-use models, higher capacity use, logistics optimisation. • Reduce overconsumption and consumer choice of smaller and lower impact products.

For policy makers, the implication is that material efficiency is not a single technology, but a set of practices that require action across ministries and sectors, with potential implications ranging from building codes and procurement strategies to waste management policies. The final section of the report provides further details on policy options.

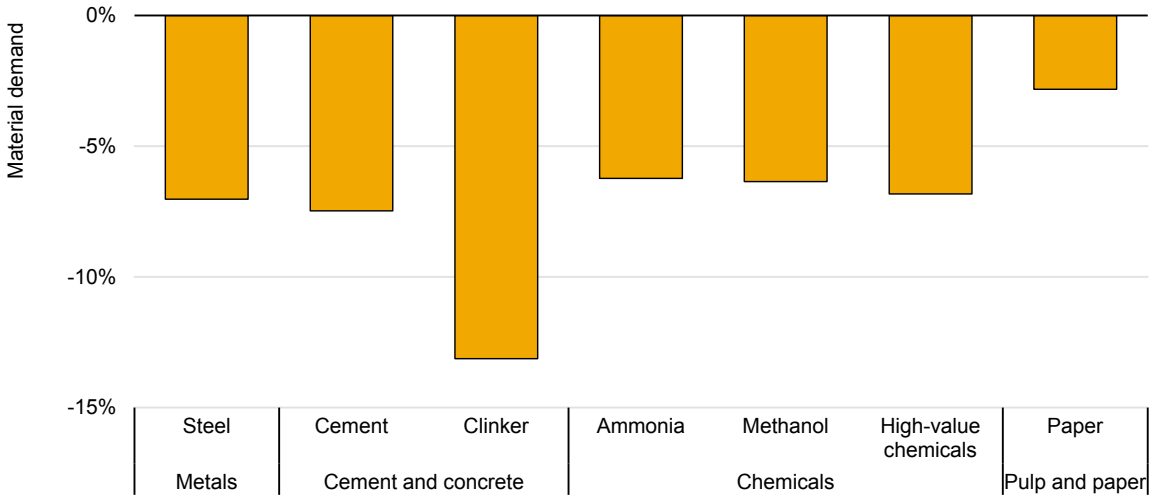
Ambitious pursuit of material efficiency can considerably reduce material demand and emissions

Material efficiency strategies can considerably reduce material demand. In the IEA's Net Zero Emissions by 2050 Scenario (NZE), global demand for key energy-intensive materials is reduced by around 6% on average in 2035 relative to a baseline scenario with minimal material efficiency in the same year. The actual reductions vary by material, including reductions of about 7% for steel, high-value

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chemicals and cement, and about 3% for paper. While these changes may appear modest at the aggregate level, they are significant in sectors where global material flows are very large and where each tonne of avoided production can considerably reduce energy demand, emissions and waste generation. Additionally, the clinker-to-cement ratio falls by about 8% by 2035 relative to 2025 (from an estimated 0.71 to 0.65)[16] through increased use of supplementary cementitious materials, an important step to make more efficient use of emissions-intensive clinker (Figure 7).

Figure 7 Reduced global material demand in 2035 in the Net Zero Emissions Scenario relative to a scenario based on stated policy settings



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Total aluminium demand, on the other hand, increases marginally (by less than 1%) as energy transitions drive additional demand in applications such as electricity grids and solar photovoltaics. This increase more than offsets the reductions achieved through material efficiency in other end uses. For other materials, although energy transitions also increase demand in certain end uses, these increases do not outweigh reductions from material efficiency.

The material efficiency savings achieved offer a variety of benefits, with GHG emissions reduction being paramount among them. In the IEA's NZE by 2050 Scenario, material efficiency in key industrial value chains reduces industry sector emissions by around 0.7 Gt in 2035, equivalent to almost 2% of today's annual global energy-related CO_2 emissions, or close to Indonesia's total current annual energy-related emissions. The largest contributors to these emissions reductions are the steel, cement and chemicals sectors, given that they account for the largest portion of industrial emissions. Value chains that account

[16] The clinker to cement ratios are IEA analysis based on GNR-GCCA in Numbers (database), complemented with county-specific statistics and national industry data for selected countries.

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for considerable reductions include buildings, vehicles and packaging, via their demand for the material outputs of the aforementioned sectors.

Material efficiency can also have benefits related to lower resource use and costs. Reduced material demand can reduce the extraction of raw materials and ease pressure on raw material supply chains while ultimately leading to less waste generation. In some cases, material efficiency can reduce costs for households, firms and governments, including by reducing material input costs, extending the lifetime of assets and improving utilisation rates. It can also reduce exposure to volatile commodity markets and prices. These resource use and economic benefits are particularly important where demand for buildings, infrastructure and transport services is growing rapidly. Additionally, material efficiency can improve the affordability of clean energy transitions by reducing the scale of investment needed to decarbonise material production.

Indicative progress metrics for waste prevention and material efficiency:

- Emissions reduction potential: around 0.7 Gt CO_2-eq annually by 2035.
- Reduced global material demand – while providing the same services – in 2035 in the NZE Scenario relative to in 2035 in a scenario based on stated policy settings:
  - steel: more than 5% demand reduction (from around 2 050 Mt to around 1 900 Mt)
  - cement: more than 5% demand reduction (from around 4 000 Mt to around 3 700 Mt)
  - high-value chemicals (key precursors to plastics, largely ethylene, propylene and aromatics): more than 5% demand reduction (from around 550 Mt to around 510 Mt)
  - paper: less than 5% demand reduction (from around 470 to around 460 Mt).

Collection, sorting and recycling

After material efficiency opportunities have been exhausted, improved end-of-life management is the next lever that can deliver further emissions savings and contribute to circularity. Collection rates, the effectiveness of sorting systems and the availability of suitable recycling technologies – which vary by waste stream and material – all influence the extent to which materials can be recovered and returned to productive use (which may include recycling or use as energy; see the next section for a discussion on use as energy). Measures to improve collection, sorting and recycling therefore play a central role in advancing circular material systems – turning what would have otherwise become waste into a potentially valuable resource.

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Robust collection and sorting systems underpin material recovery

Waste arises from a range of sources, including municipal, industrial, construction and demolition, and agricultural activities. These streams differ considerably in composition, collection coverage, and ease and economics of material recovery.

Globally, around 83% of MSW is collected, but there is considerable variation in collection rates[17] across countries and regions: collection is close to universal in many advanced economies while in some developing economies it is around 30%, with even lower rates in rural areas. Further efforts are needed to expand collection in underserved regions. Where municipal waste is collected, there is also considerable variability in the extent to which it is subsequently managed in an environmentally sound manner and its resources recovered for further use. With regards to the latter, on average globally, around 18% of collected waste is recycled and a further 7% is composted or sent for anaerobic digestion, with the remainder managed through landfills, dumpsites and incineration.

Industrial, construction and demolition, and product-specific (such as for vehicles and major appliances) waste streams can have higher rates of reuse and recycling when they contain large volumes of relatively homogeneous materials, such as metals or mineral waste, and especially when those materials have considerable economic value, as in the case of metals. In fact, in sectors such as steel and aluminium, well-established markets for scrap illustrate how end-of-life material streams can have considerable value as secondary raw materials, rather than being viewed simply as waste. Agricultural waste is often suited to composting or energy recovery because of its high organic content, its relative homogeneity and its concentration in farms.

Separation at source, sorting and pre-treatment are also key enabling steps across waste streams and materials, helping to increase recovery rates and maximise higher value recycling. Ideally, separating materials at source, or when that is not possible through effective downstream sorting, can increase the quantity and quality of material available for recycling (or for use as energy, particularly in the case of organic waste – see the next section) and reduce the processing costs. For example, sorting organics from municipal waste streams offers the possibility to use them for purposes such as bioenergy or organic fertiliser production. For plastics, sorting by polymer type and colour can raise yields and improve the quality of recycled resin. Similarly for aluminium, separation of alloy groups helps support closed-loop recycling. For steel, where separated

[17] "Collection rate" is defined here as the share of end-of-life material that is collected and enters a waste management pathway – whether for "recovery" (through recycling, direct reuse or energy recovery) or disposal. This contrasts with material that is not collected and is instead unmanaged, such as through open dumping or burning.

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collection is already common, operational techniques can be used to address the trace metals that are often used alongside steel in products, in order to maximise the quality of secondary steel products.

Measures to improve sorting include providing adequate infrastructure to enable consumers to undertake good sorting behaviours, deposit-return systems, improving demolition and dismantling practices, expanding the use of advanced physical separation processes in sorting facilities, and further innovation in separation technologies. Supporting and integrating existing sorting and recovery networks, including informal workers where relevant, can improve effectiveness and inclusivity. Additionally, designing products with end-of-life separation and recycling in mind can facilitate better separation and reduced contamination, while material identification and traceability tagging can enable better sorting through increased information on the material composition of products.

Current recycling rates vary across materials

Differences in collection and sorting systems, product composition, material value, and technology availability for recycling help explain the wide variation in recycling rates across materials.

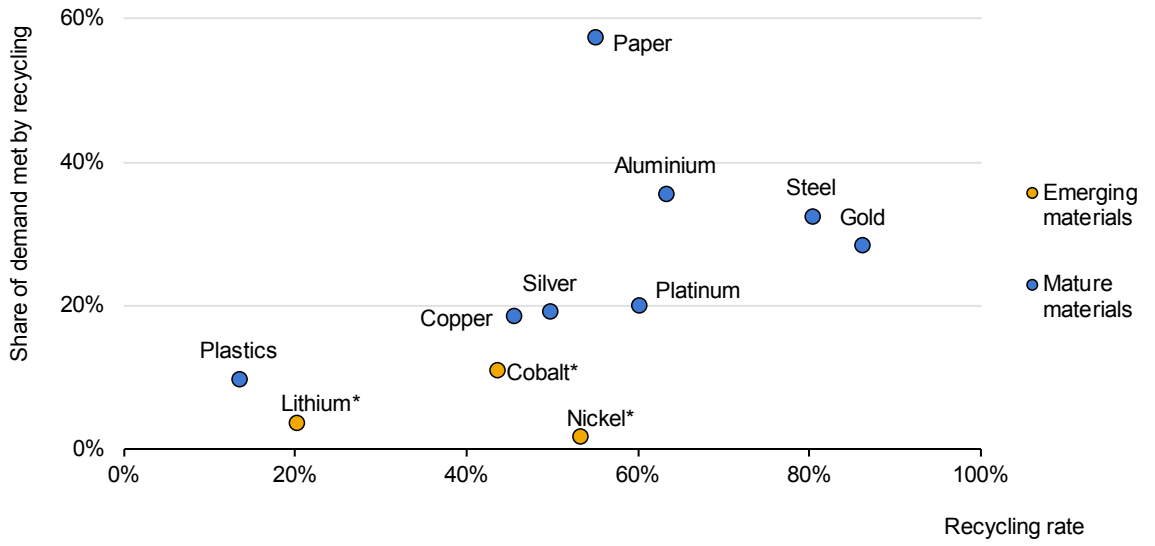
The most commonly used metals have some of the highest end-of-life recycling rates[18] – around 80% globally for steel and around 65% for aluminium – as scrap has clear economic value as an input to secondary production, basic sorting is relatively simple, recycling technologies are mature and material losses during recycling can be relatively low (Figure 8). The end-use also has an impact, with recycling tending to be lower for products that are smaller and where recycling may be more dependent on individual consumers' behaviour. For steel, larger end-uses such as automotive, construction and machinery have recycling rates of about 85-90%, whereas steel used in smaller end-uses like electrical and domestic appliances has considerably lower recycling rates, at about on average globally 50% (with regional variability depending on local collection, sorting and recycling practices). Similar patterns exist for aluminium, with recycling rates of 85% and higher for transport and construction and about 70% for beverage cans. Recycling of beverage cans varies considerably by region, with current recycling rates at just over 40% in the United States; 70% in Europe; and 90% or more in Brazil, China and Japan. There remains some potential to continue expanding recycling rates for these metals, particularly for end-uses and in regions with lower rates, but the overall potential is already relatively well exploited. This means that while there is

[18] "Recycling rate" is defined here as the share of end-of-life material that is collected for the purpose of recycling or direct use, and is subsequently incorporated into a new product. Due to yield losses, these values are generally somewhat lower than the "collection rate", which is simply the share of end-of-life material that is collected for the purpose of recycling or direct use.

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some room to expand the share of demand met by recycling,[19] production from new ores will still be needed for decades to come to meet total demand.

Figure 8 Global average share of demand met by recycling and recycling rates for select materials, 2025



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* Recycling rate refers to end-of-life recycling of batteries only for these materials.

Note: "Mature materials" are considered to be those with well-established recycling markets and substantial secondary production whereas "emerging materials" are those that have growing recycling rates but currently relatively low secondary production shares, as a result of demand increasing rapidly and the fact that dedicated recycling infrastructure has only recently started to develop.

Source: Adapted from IEA (2026), Energy Technology Perspectives.

Paper products also have relatively high recycling rates – around 55% on average globally – owing to well-established collection systems in many regions, strong markets for recovered fibre and technologies available to use recycled pulp in paper products manufacturing. Packaging and graphic paper have the highest recycling rates (over 60%), while household and sanitary paper products are generally not recycled. Barriers preventing higher recycling rates for paper include reliance on consumers to sort their waste streams; contaminants such as food residues, plastic layers and other non-paper materials; certain streams like sanitary paper being impractical to recycle; degradation of fibres as paper is recycled multiple times; and lower applicability of recycled paper to applications like graphic paper, where colour and texture are important.

Plastics, on the other hand, have much lower recycling rates. It is estimated that on average globally, around 20% of end-of-life plastics are collected for recycling.[20] However, a notable quantity of material is lost during sorting and the

[19] "Share of demand met by recycling" is defined here as the share of production from recycled inputs; in cases such as steel, where recycled and primary inputs can be mixed, this reflects the total share of recycled inputs.

[20] Data on total end-of-life plastics are subject to considerable uncertainty, and consequently collection and recycling rates are also somewhat uncertain.

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process of producing new plastic, such that the quantity that ends up being turned into new plastics is smaller than this (about 15%). Downcycling is also common for plastics, such that the quantity that ends up being used for a product similar to the original is even smaller still. The lower overall recycling rate reflects a combination of factors, including lower collection rates, higher levels of contamination, lower material value in some applications, the diversity of types of plastics and additives in use, and a lack of mature technologies available for recycling some types of plastics. There is also considerable regional variability; for example, in the European Union, just over 30% of plastics are collected for recycling. In general, plastics used for packaging have higher recycling rates than those used for other purposes, although there is also variability depending on the type of packaging. Together, there is considerable room for improvement, but several challenges will need to be overcome to increase the recycling rate.

Lack of mature recycling technologies for the wide of array of types of plastics is one of the key factors driving lower recycling rates. Mechanical recycling is well established for some relatively clean and homogeneous streams of some types of plastics, such as beverage bottles, but is more limited for mixed, contaminated or multi-material products. More advanced recycling techniques, including chemical techniques such as pyrolysis and solvent dissolution, are helping expand the range of plastics that can be recycled, but these remain at different stages of technology readiness and commercial development (as the IEA is monitoring in the Clean Energy Technology Guide) and some face economic and technical barriers. As a result, higher plastics recycling will depend not only on expanding collection but also on improving product design, sorting, pre-treatment, and developing and deploying a range of necessary recycling technologies.

Across materials, policy and public investment can help through multiple levers, including by expanding collection coverage, investing in sorting infrastructure, setting quality standards for recycled outputs, creating incentives for the use of secondary materials in products, and incentivising innovation in advanced recycling and sorting technologies for materials with lower recycling rates. See the final section of the report for further details on policy options.

Box 2 Recycling opportunities for emerging materials and clean energy technology

Recycling is also important for the materials and minerals used in clean energy technologies like electric vehicles, batteries, solar panels and wind turbines, and will become increasingly so as growing numbers of these technologies reach the end of their operational lifetimes. Much of the metal content can already be recovered using established processes. Beyond aluminium and steel discussed above, precious metals such as gold, silver and platinum have long-established recycling

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value chains, particularly through jewellery, industrial applications and electronic waste, while copper and nickel also have significant secondary supply streams. Meanwhile, recycling for lithium from batteries is increasing rapidly, from just 4% in 2015 to around 20% today, but still remains well below the rate seen for many other metals. Additionally, some components – particularly composite wind turbine blades and certain solar panel materials – remain more challenging to recycle, highlighting the importance of continued innovation and investment in recycling infrastructure. Thinking of future end-of-life management during the design and planning stages can help ensure optimal outcomes.

Plastics have the strongest potential for increased recycling

Improving collection, sorting and recycling can deliver sizeable emissions and energy savings. In the NZE Scenario, increased recycling contributes around 400 Mt CO_2 of emissions reductions in 2035. This reflects higher collection and recycling rates across a range of materials.

The largest increase in recycling is for plastics, where the share of demand met by recycling roughly doubles from around 10% today to 20% in 2035 (Figure 9). While all plastics recycling reduces demand for fossil feedstocks and most reduces emissions at least to some degree, the quantity of emissions reductions is quite variable depending on the type of recycling and end-of-life treatment. Mechanical recycling typically requires much less energy than producing virgin polymers, particularly where clean, well-sorted streams of common polymers are available. Chemical recycling – which may be used for mixed, contaminated or harder to recycle plastics – is generally more energy-intensive than mechanical recycling and its net benefits depend on the technology, feedstock quality and energy source. Furthermore, at end-of-life, emissions would generally be lower for recycling than incineration, but not necessarily much lower for recycling than landfilling given that plastics hardly decompose and thus the embedded carbon does not return to the atmosphere. This makes the details of the waste management system and technologies used central to the magnitude of the emissions reductions.

High-volume metals including steel and aluminium see smaller increases in recycling rates, given the already relatively high recycling rates in many markets. However, the global share of demand met by recycling still rises by just over 20% by 2035 relative to today for both steel and aluminium. For steel, this is in large part due to increasing scrap availability resulting from higher growth in products reaching end of life relative to growth in new demand for products (rather than due

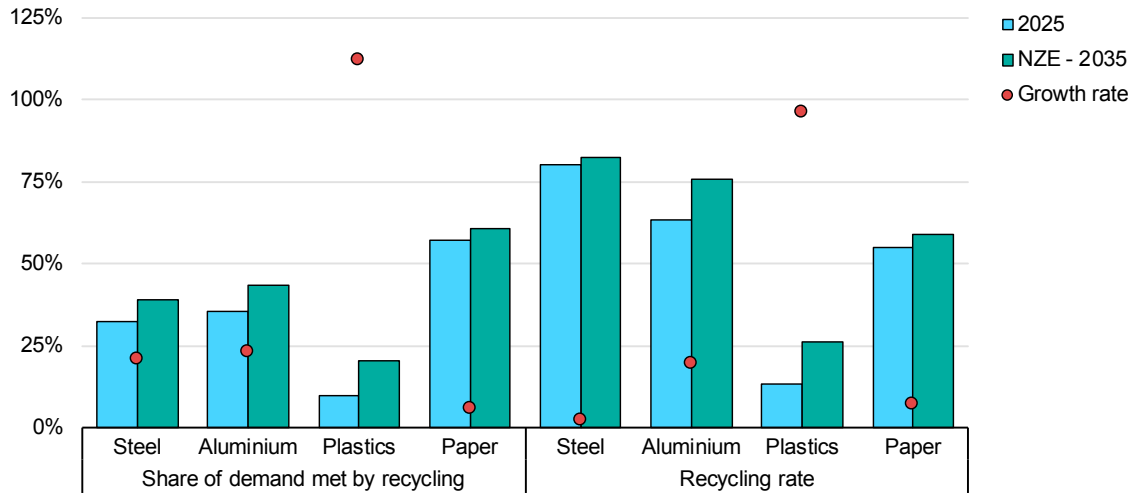
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to a substantial increase in recycling rates). Steel scrap use increases from around 32% to 39% of metallic inputs and secondary aluminium production from around 36% to 44%.

For these metals, the main emissions benefit comes from avoiding the most energy- and emissions-intensive stages of producing metals from ores (emissions are also saved from reduced raw material extraction and other upstream steps). Scrap-based steel production is carried out in electric furnaces and uses about 12% of the energy used for production from iron ore (on a final energy basis); its emissions benefit increases even further as electricity systems decarbonise. Secondary aluminium similarly avoids much of the electricity-intensive smelting process, thus using about 5% of the primary energy needed for primary production. However, as many steel and aluminium products often remain in use for decades, recycling rates are ultimately constrained by the amount of available scrap, even when recycling rates are maximised; primary production routes will, therefore, still be needed for many decades to come and will also need to decarbonise.

Likewise, there is a relatively small increase in recycling rates for paper products, of less than 10% on average. This is due to the aforementioned challenges and limits on the recyclability of various paper streams. Producing pulp (the main precursor to paper products and the most energy-intensive step of production) from recovered paper reduces the energy intensity of pulp production by about 45-65%. However, given that primary pulp production produces biomass waste that the sector self-consumes such that 45% of energy used in pulp production is bioenergy, the emissions savings of recycled production are considerably smaller.

Figure 9 Growth in the shares of demand met by recycling and recycling rates by 2035 in the Net Zero Emissions Scenario, relative to today



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In addition to emissions reductions benefits, stronger collection, sorting and recycling systems can reduce pressure on raw material extraction, improve resource security and reduce waste going to landfills. While recycling cannot remove the need for new primary supply, it can reduce the scale of new extraction required and improve resilience over time. Higher recycling of metals, paper, plastics and other materials reduces the need for mining, logging and fossil feedstock extraction, lowering associated land, water and air pollution impacts. It can also diversify sources of raw materials by creating more local secondary supply chains, which may be less exposed to some international supply disruptions than primary material imports. Moreover, recycling reduces the volumes of waste destined for landfills and thus, in turn, the associated local land-use and environmental impacts.

Indicative progress metrics for collection, sorting and recycling:

- Emissions reduction potential: at least 0.4 Gt CO_2-eq annually by 2035.
- Global share of demand met by recycling in 2035 in the NZE Scenario (and in 2025):
  - steel: around 40% (just over 30%)
  - aluminium: around 45% (around 35%)
  - plastics: around 20% (around 10%)
  - paper: just over 60% (more than 55%).

Sustainable energy recovery

Even with ambitious efforts to prevent waste, extend product lifetimes and increase recycling, some waste streams will remain difficult or uneconomic to avoid, reuse or recycle. Organic waste such as food waste will continue to be generated and some mixed, contaminated or low-value materials are not easily recovered through recycling. For these unavoidable waste streams, the waste management hierarchy recognises energy recovery as an important option to consider, provided it does not displace higher value prevention, reuse or recycling measures.

When integrated into broader waste management strategies, waste-to-energy pathways can help manage residual waste by recovering value from waste materials that would otherwise be discarded. They can reduce the volume of waste requiring final disposal, an important advantage where landfill capacity is constrained. At the same time, they can avoid methane emissions from waste decomposition in landfills and open dumps in the case of organic waste and displace fossil fuel use by converting waste into heat, electricity, or fuels. However, their environmental and economic performance should be weighed against available alternatives and take local conditions into account.

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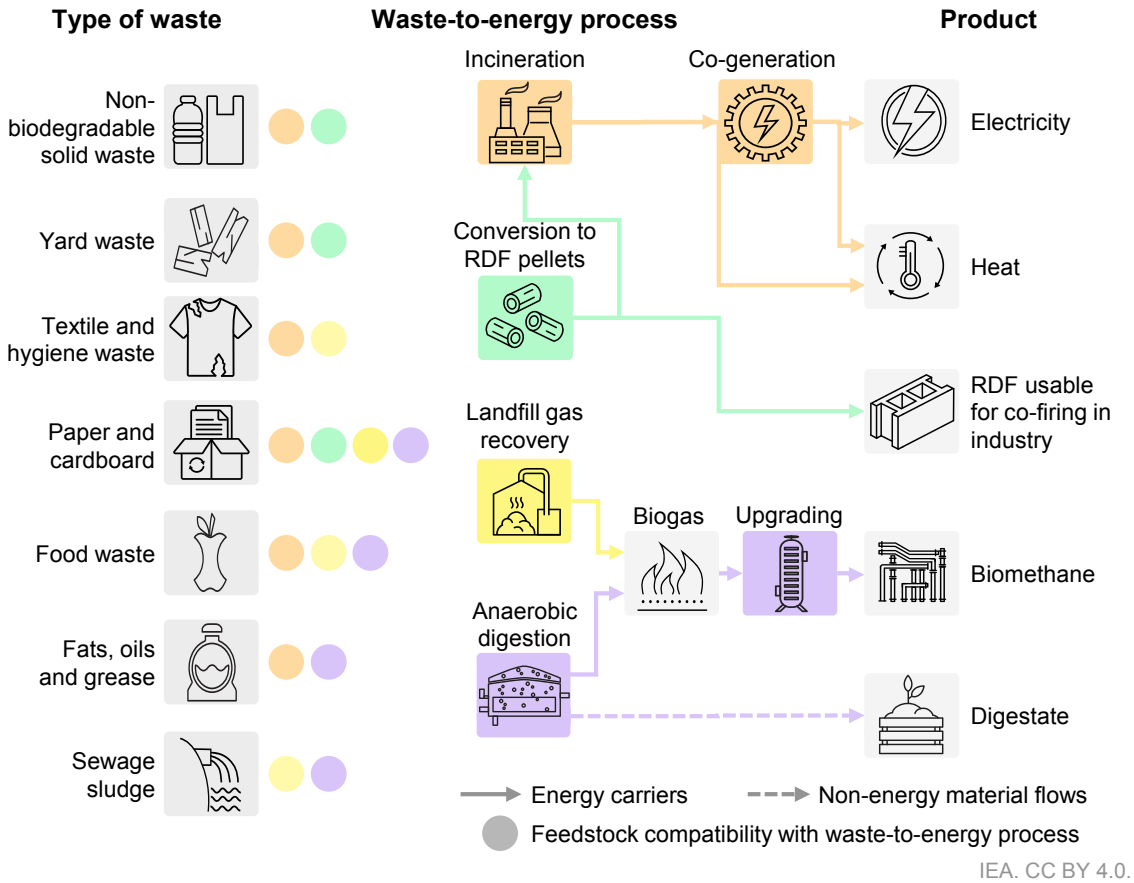
Mature technologies are ready to expand energy recovery from unavoidable waste

Waste-to-energy encompasses several pathways for recovering energy from residual waste streams (Figure 10). While some pathways require effective collection and sorting of waste, others can process mixed waste streams directly. These technologies are primarily distinguished by the moisture content of the feedstocks they can handle. Prior to energy recovery, waste can also be converted into refuse-derived fuel by sorting and shredding the dry combustible fraction, often followed by compression into homogeneous pellets. Refuse-derived fuel can be used directly, for example in cement kilns, or serve as intermediate feedstock for other waste-to-energy processes. These pathways vary in the energy products they deliver, their emissions reduction potential and their broader environmental benefits.

Incineration with energy recovery is the most widely deployed waste-to-energy pathway today, accounting for almost all waste-to-energy output outside of biogas production. Often coupled with co-generation systems, waste incineration can supply heat and electricity. The emissions impacts of incineration vary widely depending on waste composition and other local circumstances, while the possible displacement benefits decline as energy systems decarbonise. Beyond fossil CO_2, incineration may also emit black carbon – a potent short-lived climate pollutant – as well as other air pollutants, requiring appropriate emissions-control systems. Plastic waste, which makes up 12.5% of MSW by mass, emits more CO_2 per unit of energy produced than natural gas when combusted, making the climate value of energy recovery highly dependent on the facility's performance. Conversely, organic waste often offers greater emissions reductions, especially when diverted from landfills or dumpsites, although anaerobic digestion or composting may be better suited to wet organic waste. Similar forms of energy recovery take place in industry, where waste-derived fuels are combusted to provide process heat. In cement kilns, they account for around 10% of thermal needs, while the resulting ashes can be incorporated into cement.

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Figure 10 Mature waste-to-energy pathways



Notes: Non-biodegradable solid waste includes plastics and mixed waste such as tyres. RDF = refuse-derived fuel.

Other mature waste-to-energy pathways include the production of biogas from organic waste. In landfills, methane is released as organic waste decomposes and can be captured through landfill gas recovery, although much of the recovered gas is still flared. Anaerobic digestion is a more controlled approach, which converts organic waste into biogas in sealed, oxygen-free tanks using naturally occurring microorganisms. This gas, composed primarily of methane and CO_2, can be used for heat and power generation or upgraded to biomethane to use as a drop-in substitute for natural gas. Europe, the world's largest biogas-producing region, currently derives around 20% of its biogas production from waste feedstocks excluding agricultural residues, equivalent to 0.2 exajoules (EJ).

More emerging technologies, including thermal gasification, pyrolysis, and hydrothermal liquefaction and gasification, are promising pathways for converting waste into liquid and gaseous fuels, particularly for transport applications. However, their deployment remains limited by technology maturity, feedstock availability and costs.

Energy recovered from waste (including but not limited to MSW) contributed around 5 EJ in 2025, equivalent to around 1% of global energy demand. Yet around 30% of MSW is still landfilled, pointing to untapped potential where technically and economically viable. Several waste-to-energy pathways require

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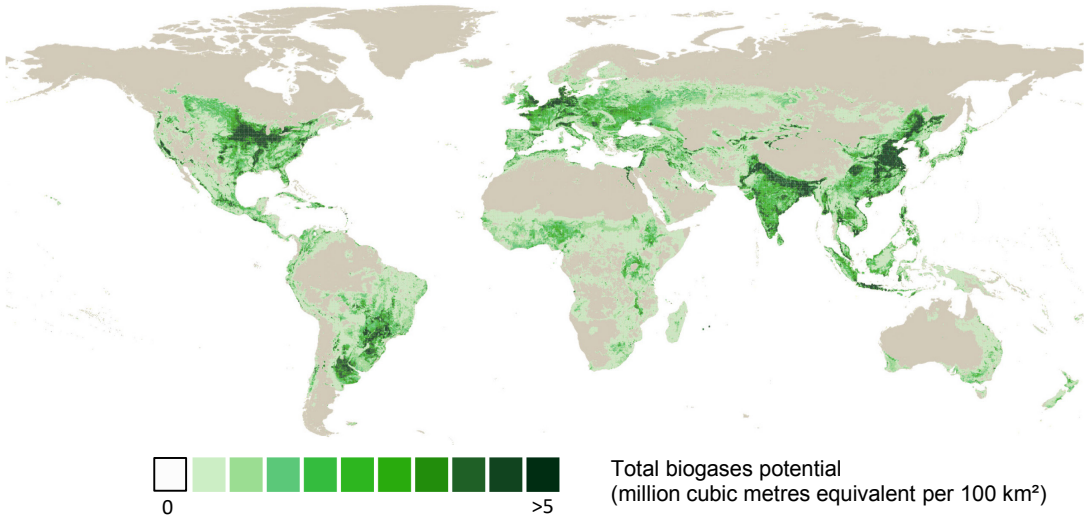
sorting and pre-treatment of the waste intake, potentially adding to costs and limiting their economic viability. For organic waste, anaerobic digestion stands out as a tried-and-tested solution that has been successfully integrated into a number of waste management systems worldwide, provided best practices are applied to limit methane leaks.

The IEA's detailed geospatial modelling reveals huge untapped biogas potential

As governments seek solutions that enhance energy security, cut emissions and support local economies, biogases – which encompass biogas and biomethane – stand out as a uniquely attractive option. Produced from organic waste, including crop residues, manure, wastewater and MSW, biogases are sustainable, secure, low-emissions fuels.

The IEA has been closely tracking the development of biogases for several years and recently released a first-of-its-kind global spatial analysis of the potential for developing biogases from today's organic waste streams. Our latest modelling finds that nearly 900 billion cubic metres (bcme, or 32 EJ) of biogases, measured in natural gas-equivalent terms, could be produced sustainably each year – enough to meet more than 20% of today's global natural gas demand (Figure 11). MSW alone could yield almost 100 bcme (3.5 EJ) of biogases, leveraging waste already being collected and sent to landfills or other disposal routes, without improvements in waste collection or changes to current recycling, composting and incineration rates. Around 70% of this MSW potential is located in EMDEs, led by China, India and Brazil.

Figure 11 Geographic distribution of supply potential for biogases derived from organic waste streams



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Notes: Potentials include agricultural feedstocks and municipal waste.
Source: IEA (2026), Interactive map of global biogas and biomethane potential.

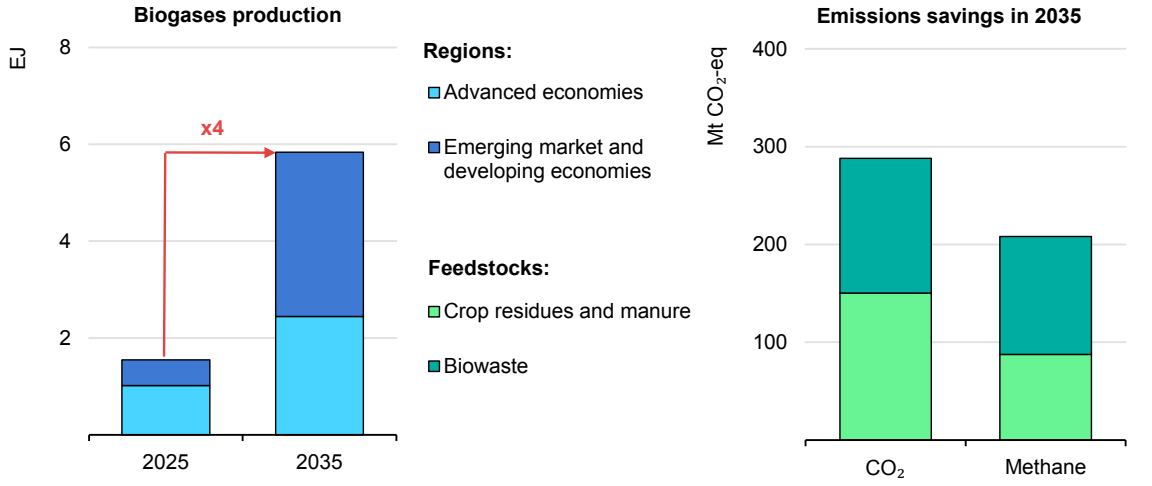
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Biogases production is around 1.6 EJ today, and an ambitious yet achievable goal would be to quadruple global waste-derived production to nearly 6 EJ by 2035, in line with the COP30 Belém pledge to quadruple sustainable fuels. Achieving this goal would require maximising biogas production from organic waste through anaerobic digestion, which enables efficient energy recovery while producing nutrient-rich digestate that can be used as a biofertiliser. However, practical constraints related to waste collection, sorting, costs, infrastructure and social acceptance are likely to prevent the full diversion of organic waste from landfills. For the waste that continues to be landfilled, landfill gas recovery offers an important additional source of biogas while reducing methane emissions, although gas collection efficiencies vary widely (13-86% in Denmark) depending on landfill cover, system performance and waste characteristics.

Biogases connect waste and energy

Achieving a quadrupling in biogas production would deliver around 0.5 Gt CO_2-eq in annual emissions savings (Figure 12). EMDEs account for 70% of this emissions reduction potential. Emissions reductions would come from redirecting manure, municipal and industrial waste, as well as crop residues into anaerobic digesters, which produce biogas that can be upgraded into biomethane. This delivers a double dividend: avoiding some of the methane emissions that would otherwise occur in the agriculture and waste sectors while displacing the use of fossil fuels. Exploiting the full potential of MSW alone could avoid 0.3 Gt CO_2-eq of emissions annually.

Figure 12 Biogases production in 2025, acceleration potential to 2035 and associated emissions savings in 2035



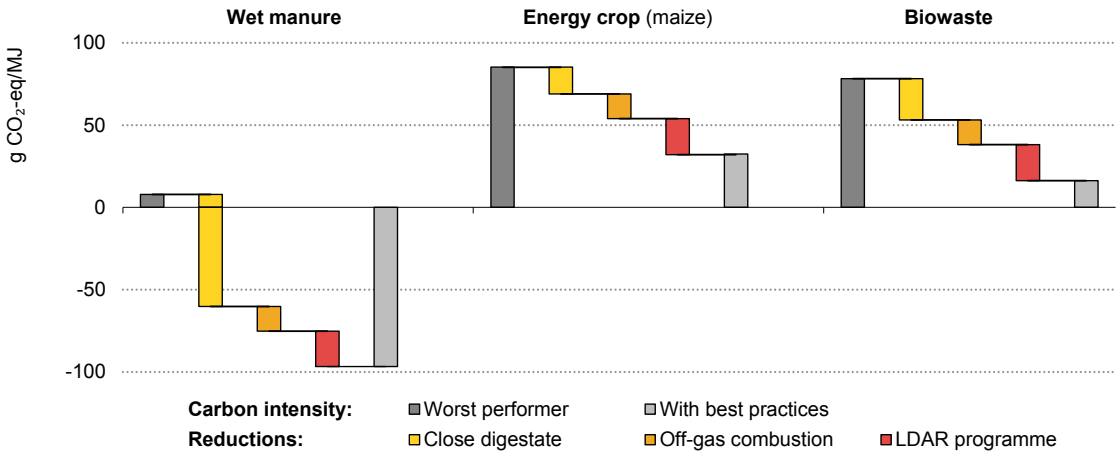
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Notes: CO_2 emissions reductions from fossil fuel displacement are estimated using life cycle emissions intensities and a fossil fuel displacement model. Avoided methane emissions are estimated using feedstock- and region-specific credits, expressed as a share of biomethane production (17.5-25% for manure, 0-15% for biowaste, 0% for crop residues), while accounting for an assumed 2.5% methane leakage rate during biogas production and upgrading. Compared with current practices, lower methane leakage rates are assumed, reflecting broader adoption of best practices in 2035.

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The full emissions reduction potential of biogases depends crucially on how the biogas and biomethane is produced (Figure 13). Methane leaks from anaerobic digesters, upgrading units and related infrastructure can undercut or eliminate entirely the GHG emissions benefits of biogases. Evidence suggests that, on average, biogas plants emit methane emissions equivalent to 6% of their output. There are many ways to reduce these methane leaks, and the concerted application of best practices – notably through closed digestate storage and the combustion of off-gases during upgrading processes – is essential to make the environmental case for biogases. While these measures require additional investment, recovered methane can offset or even exceed their cost. Their uptake is growing, particularly where supported by regulation. For example, in Denmark, average methane losses were measured at 2.5% in 2021, prompting the introduction of regulations to lower it further.

Figure 13 Life cycle carbon intensity of biomethane production, by measure and feedstock type



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Notes: LDAR = leak detection and repair. The value for worst performer using wet manure includes a methane avoidance credit. Negative values reflect avoided methane emissions from field decomposition of manure and biowaste. g CO_2-eq/MJ = gigatonnes of carbon dioxide equivalent per megajoule, based on a 100-year global warming potential.
Source: IEA analysis based on data from the EU RED, Annex VI, updated with methane values from European Commission, JRC (2024), Methane emissions in the biogas and biomethane supply chains in the EU.

When responsibly developed, biogases can deliver multiple co-benefits across energy, environmental and agricultural objectives. Their production and use embody the idea of a more circular economy, bringing benefits through reduced emissions, improved waste management and greater resource efficiency. Biogas and biomethane can also create new economic opportunities for rural communities and industries while helping to expand domestic energy supplies, which can strengthen energy security.

Despite their potential, biogases continue to face numerous challenges. Production costs remain relatively high while logistical hurdles, complex permitting procedures and insufficient policy support have held back deployment in many

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countries. At the same time, improved measurement and reporting from existing plants, alongside robust carbon accounting standards, are essential to fully demonstrate their environmental performance. Social acceptance can also be a barrier. Because wet organic waste is costly to transport over long distances and waste-to-energy facilities often rely on access to district heating networks, plants are frequently required to be located close to population centres, where concerns about noise, odours and local environmental impacts can arise. Targeted policy support can help address these challenges and unlock the full potential of biogases. The final section of the report offers more details on policy options.

Beyond biogases, additional emissions savings are achieved through the use of solid waste, by displacing fossil fuel in industry and power generation. The cement sector accounts for a significant share of these reductions, as kilns can utilise a range of waste streams, including low-quality ones that have few alternative uses.

Indicative progress metrics for sustainable energy recovery:

- Emissions reduction potential: at least 0.6 Gt CO_2-eq annually by 2035:
  - from biogases: 0.5 Gt CO_2-eq, including CO_2 reductions from displacing fossil fuels and avoided methane from waste decomposition
  - from use of organic solid waste in industry and power: at least 0.1 Gt CO_2 reductions from displacing fossil fuels.
- Increased use of biogases: quadrupling to 6 EJ in 2035.
- Increased use of renewable wastes in cement: tripling (from about 6% of thermal energy requirements today to about 18% in 2035).

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Policy options to accelerate emissions savings through waste reduction and circularity

Governments have an important role to play in helping reduce GHG emissions by reducing waste generation, boosting productive use of waste, and enhancing overall resource efficiency and circularity. A variety of policy options are available to meet governments' objectives, and the ideal policy package will vary across countries. Key factors impacting a country's policy priorities and suitable solutions include the maturity of its waste management system, the availability and quality of waste streams, the current emissions intensity of and demand for materials and energy, the distribution of responsibilities across national and local governments, institutional capacities, and access to finance.

This section outlines a two-phase approach for governments aiming to reduce emissions through waste reduction and resource efficiency. First, governments may wish to assess their current context and map the opportunity space, including setting clear short- and long-term objectives, outlining the range of potential actions and technologies that could meet those objectives, and identifying possible barriers to their implementation. This would enable determining in which areas additional policy efforts could be the most effective and have the greatest impact across objectives. Second, governments may choose from a variety of targeted and cross-cutting policy options to help enable the key intended changes identified in the first step. In sum, governments would determine "what" they would like to happen in step one and "how" they could help make it happen in step two. Meanwhile, international collaboration and experience sharing can help all countries advance more quickly.

Identify the main opportunities, objectives, solutions and barriers

A practical starting point is for policy makers to assess where waste reduction and resource efficiency strategies can deliver the largest emissions and waste management benefits in their particular context. This includes looking across full chains – from design to end-of-life – and across key economic sectors and activities, to understand current emissions, gaps in policy coverage and opportunities for improvement. As discussed above, diverse decisions – ranging from building design to infrastructure planning, product standards to procurement, or industrial production to consumer markets – can all affect material demand and

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future waste generation, and thus should be examined. Policies should, therefore, identify the main sources of waste and emissions and the value chains with the largest material impacts. Robust data can help enable this step, and efforts can be taken to improve monitoring. Where detailed data are currently lacking and institutional capacity to improve data is limited, a high-level scan using available information can be a proportionate approach to provide an initial indication of priorities. Waste composition analysis could be another tool to help identify waste streams or materials with significant potential for intervention. This stage should also consider multiple priorities, including emissions reductions objectives, but also be balanced against other waste management, social and economic goals. While this report helps provide general context for possible opportunities to consider with synergies connected to the energy system, the specific opportunities will vary by country and may include other actions not strongly intersecting with energy system decarbonisation. It will, thus, be important for each country to assess their own situation.

With opportunities in mind, a next step is to set clear objectives – such as goals covering emissions reductions from particular sectors, waste generation reduction, increases in waste collection or recycling rates for particular materials, or increases in energy produced from organic waste. Such objectives will again vary by context. Governments may consider integrating these objectives and associated measures into their Nationally Determined Contributions and other national climate planning and reporting frameworks, helping to align waste reduction and resource efficiency with broader climate goals, as well as to track their contribution to emissions reductions. Additionally, it is important to consider both near- and long-term objectives, so that policy interventions maximise near-term benefits while ensuring initial steps are consistent with a pathway to longer term objectives. For example, near-term measures to use waste as a fuel should avoid locking in long-term infrastructure, contracts or business models that depend on continued growth in waste volumes without taking into account increased measures to prevent, reuse and recycle waste.

Next, policy makers may map key solutions – including technologies, infrastructure and behaviour – as well as possible barriers to their implementation. Understanding the range of available solutions, their costs and challenges to overcome for implementation would help scope and target policy support accordingly. Within this space, while costs may pose a barrier for many solutions, there is also a considerable behavioural and social component to many relevant measures. For example, this may include awareness of material efficiency solutions among architects and engineers, waste-sorting behaviours in households, and supply chain co-ordination among collectors and potential users of waste for energy.

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The waste management hierarchy can serve as a useful organising principle during this phase, with prevention, reduction, reuse and recycling preferred to energy recovery and disposal. Different countries will enter this hierarchy from different starting points, and priorities and sequencing should reflect existing infrastructure as well as enabling conditions such as governance arrangements, institutional capacity, financing, workforce capabilities and public participation. Where uncontrolled dumping remains significant, basic waste collection and sorting infrastructure may be an essential first step before more advanced treatment and recovery options can be effectively deployed. Where waste management systems are already well established, priority focus areas may include improved design to enhance material efficiency, recycling for less recycled materials like plastics, and expansion of using organic wastes for energy and/or nutrient recovery. Collaboration between national and local governments may be useful during this phase, given that local governments manage multiple aspects of waste management in many countries, as will collaboration among departments responsible for waste, energy and economic development.

Choose and design targeted and broader policies according to priorities

Once priority areas of intervention have been identified in the first phase, policy makers may choose the most suitable policy interventions from a menu of possible solutions. While the possible strategies are diverse, they all aim to make lower waste and lower emissions choices easier and more economically attractive for producers, consumers and waste managers. The framework shown in Figure 14 identifies a variety of available policy options, spanning across strategies and value chains, and including two complementary types of policy intervention.

Some measures are targeted to enable specific solutions or value chains or to overcome specific barriers. Examples include product design requirements that target long lifetimes, extended producer responsibility schemes, public financing of waste collection and sorting, or fiscal incentives for biogas and biomethane production. These measures can be particularly valuable where important infrastructure is missing, solutions have high upfront costs or substantial ongoing operational costs without readily available funding streams, or there are barriers related to behaviour and conventional business practices that are unlikely to be overcome by broader economic signals alone. Such measures may be more impactful in terms of increasing the likelihood of specific shifts, although they are narrower in reach.

Other measures send a broader signal for emissions reductions, which may incentivise various circular economy and waste reduction strategies across value chains, as well as other decarbonisation strategies. Carbon pricing, emissions

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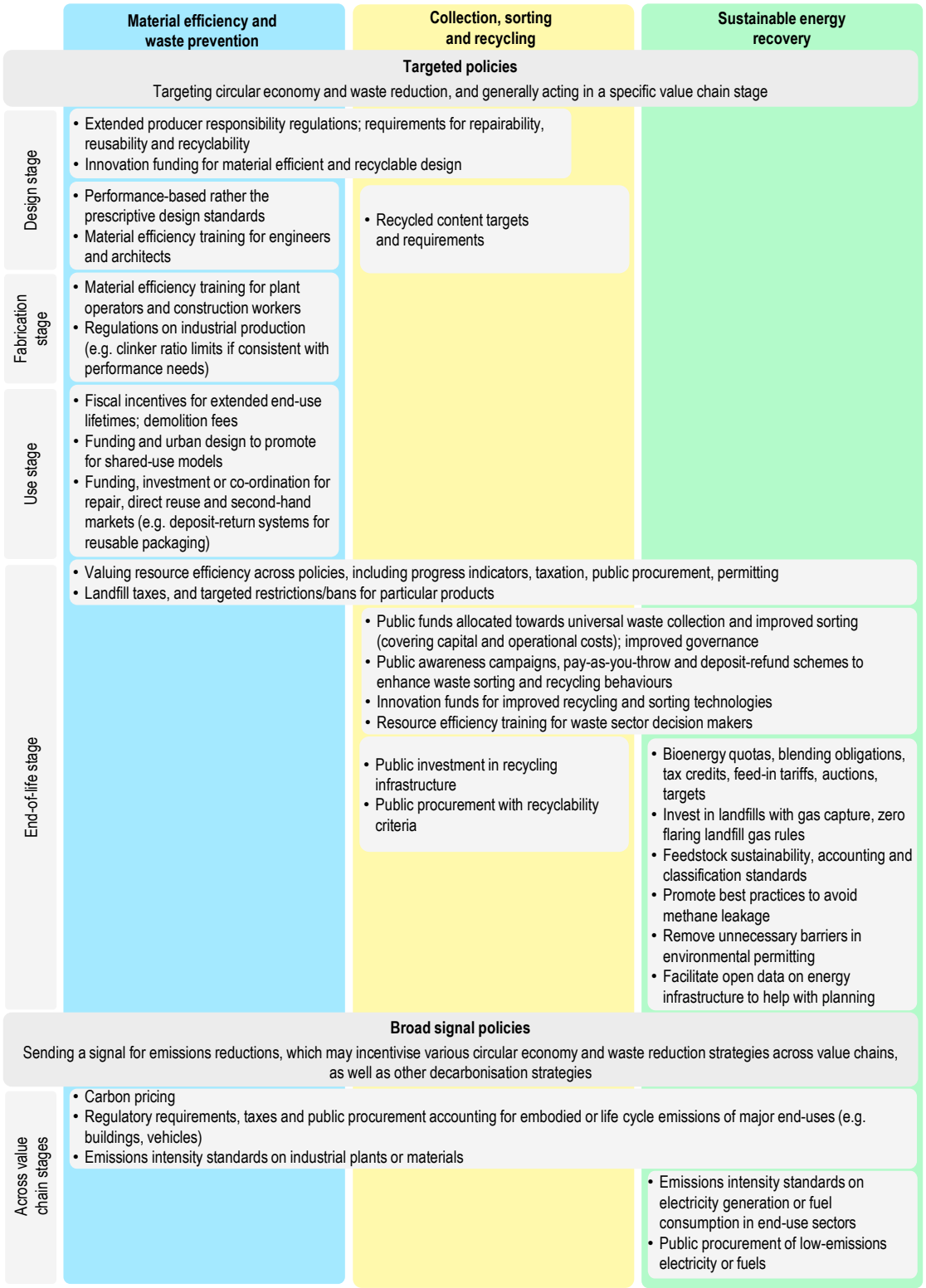
intensity standards, low-emissions public procurement and life cycle emissions requirements can all shift incentives by making the environmental and emissions impacts of material use and waste more visible in economic decisions. These broader signals can help make more efficient use of emissions-intensive materials, support the uptake of recycled materials where appropriate, and discourage disposal when higher value alternatives exist. While their reach is broader and they can play a crucial role in incentivising several different decarbonisation levers at once, they may be insufficient on their own to drive actions that face particular or higher barriers.

In practice, most policy packages will require a variety of measures from both categories and across a variety of actions, tailored to national and local circumstances. For countries with weaker formal waste management, priorities may surround setting up robust infrastructure and institutions, including developing collection, sorting, and recycling process and facilities; setting clear responsibilities across levels of government; and finding ways to raise and allocate sufficient finance for ongoing operational costs. Investments should be chosen and sequenced taking into account the financial, technical and institutional capacity to operate and maintain them over the long term. Meanwhile, countries with established waste management systems may prioritise more advanced solutions, such as examining design standards, public procurement policies and fiscal incentives to enhance their support for more resource-efficient outcomes.

Designing an appropriate policy package also requires considering trade-offs and balancing multiple priorities. As in the previous phase, considering the waste management hierarchy, coherence of near-term strategies with longer term objectives and an awareness of practical barriers are important. For example, pursuit of waste to energy should not be a substitute for efforts on waste prevention and recycling, and long-term contracts for waste material supply should take into consideration future likely improvements in these areas. Deciding whether to implement landfill taxes, bans or other restrictions should weigh possible unintended consequences, such as open dumping, if viable alternative treatment or recycling options are not yet in place, and, where appropriate, could also consider other options such as requirements for suitable treatment before landfilling to directly address emissions and other environmental impacts. Meanwhile, recycled content mandates need to consider realistic scenarios of global material availability. Policy design should then include guardrails and ensure adequate stakeholder consultation.

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Figure 14 Policy options to increase circularity and waste reduction in synergy with energy systems decarbonisation



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Collaborate internationally to accelerate progress

Finally, international collaboration and knowledge sharing can help accelerate progress. Countries are at varying stages of developing their circularity and waste management strategies. Exchanging experiences, capacity building and technology collaboration can help countries advance more quickly, particularly for EMDEs. Existing platforms such as the PREVENT Waste Alliance and UNEP's One Planet Network can facilitate such knowledge sharing on waste management and circular economy approaches. Furthermore, access to international finance – including loans, concessional finance and guarantees – can, in some cases, help bridge gaps in domestic public and private finance, including for large upfront infrastructure investments and strengthening institutional capacities. Technical assistance can also support the development and implementation of policies and measures to prevent waste, improve resource efficiency and strengthen waste management systems.

Achieving the overall COP31 targets will require efforts from a multitude of actors at the local, national and international levels. While the challenge is great, so too are the opportunities if governments take leadership on reducing waste, improving resource efficiency and reducing the associated emissions.

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Annex

Abbreviations and acronyms

COP	Conference of the Parties
EDGAR	Emissions Database for Global Atmospheric Research
EMDE	Emerging market and developing economies
EU	European Union
GHG	Greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
MSW	Municipal solid waste
N_2O	nitrous oxide
NH_4	methane
NZE	Net Zero Emissions by 2050 Scenario
SDG	Sustainable Development Goal

Units of measure

bcme	billion cubic metres equivalent of natural gas
CO_2	carbon dioxide
EJ	exajoule
Gt CO_2-eq	gigatonne of carbon dioxide equivalent
Mt	million tonnes
Mt CO_2-eq	million tonnes of carbon dioxide equivalent

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