Waste Management to Address the Climate Crisis

A CIRCULAR ECONOMY AND MITIGATION PATHWAY

Partenariat français pour les déchets
PFD
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French solid waste partnership

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ASTEE

the Scientific and Technical Water and Waste Organisation

Founded in 1905 and recognised of public interest, Astee is the French association of water and waste professionals. It is a network comprised of nearly 4,000 members, both public and private.

Astee wrote the guide presented in **Chapter 2** through its working group "Bilan des émissions GES du secteur des Déchets" (GHG emissions assessment for the waste sector), which brings together key experts of the French waste sector to carry out in-depth reflections on greenhouse gases, their assessment and the possible mitigation actions.

In addition, Astee is regularly called upon to consolidate opinions or recommendations for public authorities and commissioned to produce reference documents. The Astee guide was written in accordance with the guidelines issued by ADEME (The French Agency for Ecological Transition) and is part of ADEME's collection of sector-specific guides designed to promote the use of GHG assessment methods.

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ISWA

International Solid Waste Association

The International Solid Waste Association (ISWA) is an international network of waste professionals and experts from around the world whose mission is to promote and develop sustainable and professional waste management worldwide and the transition to a circular economy.

ISWA has been ensuring the presence of the Waste and Resources sector at the UNFCCC Climate COPs for the past decade and hosted a dedicated Waste and Resources pavilion since COP-28 in 2023, giving the industry a home and focal point in the wider climate change mitigation discussion. ISWA acknowledges and appreciates the contributions of its National Members to waste management & climate topics; both in representing their own national stakeholders on the global stage as well as interpreting and acting upon global messages within their local context. Through this, ISWA is able to bring together diverse regional perspectives into globally relevant messages while maintining an eye on more local contexts, challenges and solutions. The French Solid Waste Partnership is the National Member of ISWA for France jointly with Astee, and has contributed greatly to the work of the ISWA Working Group on Climate Change and Waste Management as well as generously supported the ISWA Waste & Resources pavilion with their time an resources.

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Bringing together the expertise of specialists from a variety of backgrounds, this publication argues that sound waste management provides mitigation outcomes that address the climate crisis. It invites the readers to reflect on pathways to improve waste management systems around the world, as illustrated by a number of pragmatic, practical case studies. Improving waste management enables to reduce global greenhouse gas (GHG) emissions, as well as to achieve the UN Sustainable Development Goals (SDGs).

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Executive summary

This international publication aims to inspire local and global stakeholders to **make sound household waste management systems accessible to all**, everywhere around the world. At global level it reduces **greenhouse gas (GHG) emissions**, as well as diffuse pollutions on land, waterways, and oceans. At local level, it improves human and ecosystems' health, liveability, and business opportunities. This publication illustrates the implementation of **Environmentally Sound Management (ESM) of waste** by various project examples, establishing a direct link with GHG emissions reduction. Mitigation pathways include enhanced prevention, improved recycling and energy recovery, as well as the safe management of the waste that could not be avoided or valorised. The publication is structured in 5 chapters, providing an overview of the global context and GHG emissions assessment approaches, before diving into 3 categories of levers for actions: technical measures, regulatory frameworks, and financing.

The global context is that waste management is increasingly recognised as a critical mitigation lever to address the climate crisis. Although the sector contributes 3 to 5% of global GHG emissions, it holds the potential to reduce up to 20% of these emissions through the transition to circularity. Achieving this potential requires establishing **local, functional, and holistic waste management systems**, which can be incrementally upgraded to meet higher ambitions. The international spotlight on waste management has recently increased, with the **Global Methane Pledge** signature at COP-26 and the **Waste and Resources Pavilion** at COP-28. Remarkable international initiatives such as GMI, CCAC, and Waste to Zero recognize the sector's critical role in achieving the **Sustainable Development Goals (SDGs)** of the **2030 Agenda** and the **Paris Agreement**, initiating a global mobilisation for improved waste management practices.

To maximise this impact, it is essential to conduct thorough **GHG emissions assessments**. Several approaches exist, stemming from the IPCC Guidelines, but **adapted to the reporting needs and the local context**, as for example the Astee methodology guide* in **the case of France**. Based on the waste management system boundaries, assessments include **direct (Scope 1) emissions, indirect energy-related (Scope 2) emissions**, and **other indirect (Scope 3) emissions**. Evaluating **avoided emissions** separately enables to select the mitigation solutions that reduce global emissions, rather than only those of the organisation itself. The three-tier International Panel on Climate Change (IPCC) assessment method is used for national reporting on Scope 1 emissions, whereas methods that include the other scopes are used for organisational level reporting and aim to drive global GHG reduction actions by organisations.

Waste management should not only be seen as a source of Scope 1 emissions but also as an opportunity to leverage GHG emissions reductions by other sectors, such as industrial production, energy, or agriculture. This includes waste generation prevention, recycling of materials, and recovery of energy. The prevention of waste generation is the most efficient mitigation measure through the reduction of emissions from the production of goods and from waste management. It is however the most complex to implement, as it requires a shift in citizens' behaviours as well as in production and economic models. It involves many sectors of activity, impacts employment, and modifies income sources for states, companies, and workers, particularly in the informal sector. This lever is therefore both an opportunity and a risk for a just transition, as it affects the whole of society.

Reducing direct GHG emissions of a waste management system focuses on **reducing black carbon (from open burning), methane emissions (from organic waste)**, and **fossil CO_2 (from incineration)**. Black

* Bara, C. *et al.* (2024). *Guide méthodologique pour l'évaluation des émissions de gaz à effet de serre du service de gestion des déchets ménagers et assimilés*. Guide sectoriel 1ère Version – Edition 2024. Astee. https://www.astee.org/publications/guide-methodologique-pour-levaluation-des-emissions-de-gaz-a-effet-de-serre-du-service-de-gestion-des-dechets-menagers-et-assimiles/ Last accessed on 13 November 2024. [Hereinafter Astee (2024). *Guide méthodologique*].

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carbon has a global warming potential 1,500 times higher than carbon dioxide, methane 34 times higher. Both are short lived pollutants. Reducing their emissions has therefore a crucial role to play to curb the global warming trend in the short term. To minimise these emissions, it is necessary to implement a **holistic ESM of waste approach tailored to the local context**. This system may incrementally provide alternatives to open burning and dumping, manage organic waste to produce soil amendments and energy, and recover energy from incineration or engineered landfills, before exploring innovative approaches such as carbon sequestration.

Public policy is crucial in driving incremental change in waste prevention and management: national and local policies translate regional or international frameworks objectives to drive local actions. In the case of France, the incorporation of European Union (EU) and international regulations into national law, especially since 2015, has triggered significant improvement in waste management practices, particularly in reducing landfill methane emissions, recycling, and prevention. National strategies and policies must set ambitious, yet realistic targets and standards, which implementation can be enforced. They provide strategic land planning and structure the organisational and fiscal systems that will support the implementation of ESM of waste, while encouraging low-carbon practices.

In many emerging economies, the existing fiscal systems do not allow to fund all the required investments in sound waste management infrastructure. International financial institutions, Non-Governmental Organisations (NGOs), and private companies play a pivotal financing role, supported by several **financial mechanisms**—including **carbon markets, green finance, grants and loans**, and **philanthropic funding**. Their terms of reference orient waste management projects to deliver sustainable development outcomes, including GHG emissions reductions. However, international funding remains insufficient mostly because of a lack of sound local governance, that could support the investors' confidence in the long-term sustainable operation of the projects.

In conclusion, waste management presents a significant opportunity to address the climate crisis, providing multiple pathways for reducing and avoiding GHG emissions by other sectors. Achieving this potential requires activating a range of levers, including technical solutions, policy reform, and financial support. For these levers to be implemented, all actors in the sector—public, private, and informal—must be actively involved, playing their respective roles. **This is a call for global cooperation leading to concrete action to ensure waste management becomes a central pillar of climate action**. Only about 20 countries have included the mitigation outcomes of waste management in their Nationally Determined Contributions (NDCs). These commitments, whether conditional or unconditional to foreign support, need to increase urgently.

Credit : Benjamin Sellier.

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Key Terms

Avoided emissions: Avoided emissions refer to GHG emissions that are reduced outside the scope of an organisation's activities. They result from the use of one of the organisation's products or services to replace a more 'carbon-intensive' solution providing an equivalent service. In practical terms, avoided emissions are the result of a comparative analysis of emissions between/from two scenarios: the new solution implemented is compared with a reference scenario representing the previous situation. They must not be subtracted from the organisation's GHG emissions. Avoided emissions must always be accounted for separately. Adapted from Astee, 2024[II].

Circular carbon economy: Circular carbon economy is defined as follows, "*Technologies that enable the production of carbon-based molecules and synthesis products that are useful in the energy, chemical and transport sectors, with favourable environmental and societal impacts*" (CEA, 2021[III]). It is about providing circularity by giving several subsequent usages to fossil carbon molecules extracted from the earth's resources prior to their release as carbon dioxide in the atmosphere. These usages include materials and energy production.

Circular economy: "*Economic system that uses a systemic approach to maintain* a circular flow of resources (systematic cycling of the provisions and use of resources within multiple technical or biological cycles)*, by recovering, retaining or adding to their value, while contributing to sustainable development*" (ISO/FDIS 59004, 2024[IV]). Circular economy can be approached by 7 angles: "*sustainable sourcing, eco-design, industrial symbiosis, functional economy, responsible consumption, extending the duration of use, efficient management of end-of-life materials and products*" (AFNOR, 2018, para. 2[V]).

CO_2 equivalent: "*Carbon dioxide equivalent (CO_2eq) is a unit of measurement used to compare the emissions of various greenhouse gases on the basis of their global warming potential (GWP), by converting the quantities of the various gases emitted into an equivalent quantity of carbon dioxide*" (Astee, 2024, p. 10).

Direct GHG emissions (Scope 1): "*GHG emissions from fixed or mobile sources located within the system owned or operated by the organisation, i.e. from sources owned or controlled by the organisation*" (Astee, 2024, p. 10).

Elimination, or final disposal: "*All operations that cannot be considered as recovery, even if they have the secondary consequence of substance, materials, products or energy recovery*" (ADEME, 2023, p. 8[VI]). These operations include incineration and engineered landfills.

Environmentally Sound Management (ESM) of waste: "*Taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes*" (Basel Convention, Article 2(8)[VII]). ESM also refers to a comprehensive waste management framework described in Chapter 1.

Extended Producer Responsibility (EPR): "*An environmental policy approach in which a producer's responsibility for a product is extended to the waste stage of that product's life cycle. In practice, EPR involves producers taking responsibility for the management of products after they become waste, including collection; pre-treatment, e.g. sorting, dismantling or de-pollution; (preparation for) reuse; recovery (including recycling and energy recovery) or final disposal. EPR systems can allow producers to exercise their responsibility by providing the financial resources required and/or by taking over the operational aspects of the process from municipalities. They assume the responsibility voluntarily or mandatorily; EPR systems can be implemented individually or collectively*" (UNEP, 2024, p. 5[VIII]).

Greenhouse Gas (GHG): "*A natural gaseous component of the atmosphere or of anthropogenic origin, which absorbs and re-emits radiation of a specific wavelength in the infrared spectrum emitted or re-emitted by the sun, the Earth's surface, the atmosphere and clouds. Among the main man-made greenhouse gases are carbon dioxide, methane and nitrous oxide*" (Astee, 2024, p. 11). Black carbon is also a powerful GHG resulting from open burning.

Key Terms

Household and similar waste: *"All waste, hazardous or non-hazardous, produced by households or waste collected by public services not produced by households. Waste from public green spaces, and market waste collected by the public waste management services are considered as household and similar waste"* (From ADEME, 2023, p. 7). It therefore includes part of the waste produced by economic activities. It is referred to as municipal solid waste is most international publications.

Indirect GHG emissions linked to energy (Scope 2): *"GHG emissions from the production of electricity, heat or steam imported and consumed by the organisation"* (Astee, 2024, p. 10).

Just transition: *"The greening of economies in the context of sustainable development and poverty eradication will require a country-specific mix of macroeconomic, industrial, sectoral and labour policies that create an enabling environment for sustainable enterprises to prosper and create decent work opportunities by mobilizing and directing public and private investment towards environmentally sustainable activities"* (ILO, 2015, Title V(14)(1)[IX]).

Material footprint or Raw Material Consumption (RMC): *"Corresponds to all the raw materials used to satisfy a country's final consumption, including indirect flows (raw materials used during production abroad, during transport, etc)"* (INSEE, 2019, p. 1[X]).

Mismanaged waste: *"Collected waste that has been released or deposited in a place from where it can move into the natural environment (intentionally or otherwise). This includes dumpsites and unmanaged landfills. Uncollected waste is categorised as unmanaged"* (UNEP, 2024, p. 4).

Municipal Solid Waste (MSW): *"Includes all residential and commercial waste but excludes industrial waste"* (UNEP, 2024, p. 5).

Other indirect GHG emissions (Scope 3): *"Other (GHG) emissions indirectly generated by the organisation's activities that are not included in indirect energy-related emissions but are linked to the complete value chain"* (Astee, 2024, p. 10). Indirect emissions are generated outside of the organisation's system boundary as a consequence of its activities.

Prevention: *"Any measure taken before a substance, material or product becomes waste, where such measures contribute to the reduction of at least one of the following items:*

- *The quantity of waste generated, including through re-use or the extension of the useful life of substances, materials or products;*
- *The harmful effects of the waste generated on the environment or human health;*
- *The content of substances harmful for the environment or human in the substances, materials or products."* (ADEME, 2023, p. 8).

Recyclable: *"For something to be deemed recyclable, the system must be in place for it to be collected, sorted, reprocessed, and manufactured back into a new product or packaging at scale and economically. Recyclable is used here as a short-hand for 'mechanically recyclable'"* (UNEP, 2024, p. 6) which can be defined as the *"processing of waste into secondary raw material or products without significantly changing the chemical structure of the material"* (UNEP, 2024, p. 5).

Recycling: *"Processing of waste materials for the original purpose or for other purposes, excluding energy recovery"* (UNEP, 2024, p. 5).

Reuse: *"All operations by which substances, materials or products which are not waste are used again for an identical use to that for which they were originally intended (art. L541-1-1* [of the Code de l'environnement])*"* (ADEME, 2023, p. 8).

Reparation: *"Control, cleaning or repair operations with a view to recovery, whereby products or components that have become waste are prepared for reuse without any further pre-treatment"* (ADEME, 2023, p. 8).

Repurpose: *"Any operation by which substances, materials or products which have become waste are used again (art. L541-1-1* [of the Code de l'environnement]) (ADEME, 2023, p. 8).

Sustainability: *"State of the global system, including environmental, social and economic aspects (which interact, are interdependent and are often referred to as the three dimensions of sustainability), in which the needs of the present are met without compromising the ability of future generations to meet their own needs. Sustainability is the goal of sustainable development"* (ISO Guide 82:2019[XI]).

Valorisation: *"Any operation whose main result is that waste is used for useful purposes as a substitute for other substances, materials or products that would have been used for a particular purpose, or that waste is prepared to be used for that purpose, including by the producer of the waste (art. L541-1-1* [of the Code de l'environnement])*"* (ADEME, 2023, p. 9). It can either be material or energy.

Introduction

Credit : Mostafa Meraji, *Pixabay*.

Solid Waste has environmental impacts at local, regional and global levels. Both its management and impacts are strongly connected to people's perception of their waste. Most humans would want waste not to exist. The consequence is a lack of actions to improve waste management, even though, the costs triggered by mismanaged waste on health, climate, and biodiversity are estimated to exceed those of sound waste management by a factor of 5 to 10[XII]. Actions to improve waste management are lagging. Too many of the existing negative impacts remain unmanaged, left to accumulate and for future generations to care for.

The international climate crisis has brought growing attention to the waste sector as a significant contributor. This publication argues that **sustainable waste management is an essential solution to mitigate the global climate crisis, both directly and indirectly**. The arguments are illustrated and made more tangible by observations on the **"case of France"**, as well as by a series of projects. This document aims to inspire all waste sector stakeholders to take sustainable waste management actions, each in their respective roles, whether technical, social, regulatory, or financial. The ultimate objective of reducing global GHG emissions can be achieved through a transition towards waste minimisation, waste collection, treatment and the recovery of materials and energy anchored in a viable circular economy. This transition may be achieved while walking a just transition pathway and contributing to all the UN 2030 Sustainable Development Goals (SDGs), even if waste is only mentioned in SDGs 11 and 12. SDG 11 indicators focus upon making cities inclusive and sustainable in urbanisation aspects; those of SDG 12 focus on recycling, to which the informal sector is largely contributing around the world. In this regard, particular attention should be given to workers from the informal sector when operating the transitions towards more circular and low-carbon economies. Furthermore, the implementation of sound waste management systems around the world will deliver significant progress on other SDGs, such as SDG 3- health, SDG 6 - water and sanitation, SDG 13 - climate, SDG 14 - life below water, SDG 15 - life on land, and SDG 16 -peace and justice.

ISWA's COP declaration[XIII] states the following: "*According to the Global Waste Management Outlook 2024 (GWMO 2024), the world generates approximately 2.1 billion tons of municipal solid waste (MSW) annually. Alarmingly, waste generation is projected to increase by over 77% by 2050. Only 62% of the MSW generated in the world is managed adequately and only half of it is effectively recov-*

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ered as a resource. On the other hand, in low-income countries around 90% of the waste generated is discarded in unregulated dumps or openly burned. This stark reality highlights the pressing need for sustainable and integrated waste and resource management worldwide. By improving waste management, we can prevent up to 20% of the total anthropogenic GHG emissions in the world—one of the most significant opportunities for climate mitigation available today. However, despite its potential, the waste and resource management sector remains a largely untapped source of mitigation in global climate strategies".

This present publication is prepared with an objective to show-case global efforts relating to MSW management for a sustainable and circular waste sector, providing insights on the **case of France**. It highlights the need for the design, adoption and implementation of sustainable waste management practices. The publication is structured in 5 chapters:

Chapter 1 provides an overview of the **global context** on waste management and its GHG emissions, what is meant by Environmentally Sound Management (ESM) of waste, as well as the global frameworks that drive change for waste management to address the climate crisis;

Chapter 2 sets out the key notions and methodologies to **define, assess and monitor GHG emissions**. These are key elements to guide appropriate decision and policy making, that support the implementation of context-based sustainable waste management systems that reduce GHG emissions;

Chapter 3 presents the **technical levers** to reduce direct and indirect emissions, as well as increase avoided emissions;

Chapter 4 focuses on **policies and regulations** that provide the framework needed to enable technical actions, including their financing;

Chapter 5 recognises the role of **international finance** in supporting the transition towards improved waste management everywhere and the delivery of the associated mitigation outcomes.

The guidance provided aims to support establishing waste management plans that include not only the assessment of Scopes 1 and 2 emissions, but also Scope 3 (emissions upstream and downstream of the waste management system) as well as avoided emissions. This is needed to fully account for the potential of improved waste management to contribute as a net GHG emissions reducer and as an indirect reducer through its key role in the transition to a circular economy.

Key messages relate to the following topics: the urge to **reduce GHG emissions** from the waste sector to address the climate crisis; the **co-benefits of adopting ESM of waste systems in terms of SDGs; the role of waste prevention and management in the circular economy**; the **relevance of legislation in driving change** and the necessity to identify **financing to implement actions**.

Professionals working on, or considering working on this topic, are invited to join the ISWA Climate Change working group to share know-hows and exchange on challenges.

Practically implementing an Environmentally Sound Management (ESM) of waste: illustrations

This Table provides an overview of the projects illustrating this publication. The projects are also presented in a separate document, to facilitate access to their description. The Table also highlights the type of climate mitigation lever implemented in the project: **T** for technical, **R** for regulatory, and **F** for financial.

TABLE 1 **List of projects illustrating the publication**

PROJECT	WHERE, WHO	TYPE OF LEVER			AIM
		T	R	F	
n°1 **Restaurant food waste recovery**	China, Shaoyang **AFD**	Methane	x	x	This project diverts restaurant food waste from animal farm use through a dedicated collection system. This system collects and pre-treats used food oil, produces biogas for heat and power co-generation thanks to an anaerobic digestion facility, as well as ensures the financial viability of these operations thanks to a waste collection tax, and the sales of oil, electricity and heat.
n°2 **Organic waste recovery**	France, Greater Paris **Syctom**	Methane Prevention	x		Following a new regulation making source separation of organic waste mandatory, this project aims at building an organic recovery system. This includes a multitude of collection schemes (on-site composting, door-to-door collection, voluntary deposit) - with the goal of collecting 100 kt/year of biowaste within the service area - and the construction of a methaniser on the river port of Gennevilliers to produce biomethane and organic fertilizer.
n°3 **CoMétha Pyrogazification Project**	France, Paris **Syctom, SIAAP**	Methan Fossil carbon			This research and development (R&D) project and innovative technology aims at treating a mix of organic waste to maximise the production of biogas from organic matter, to minimise the volume of solid residues and to recover nutrients made of nitrogen and phosphorous. This is possible thanks to high temperature and high pression, thus maximising the quantity produced/recovered of carbon molecules.
n°4 **Biochar to regenerate soil health**	Canada, Quebec **Suez**	Methane Fossil carbon		x	This project converts unused biomass into biochar[1] and bioenergy through pyrolysis conversion. This allows to sequester carbon (thus generating negative GHG emissions, which are used on the carbon market), reuse existing carbon molecules and to improve the health and productivity of soils.

Note: "T" stands for Technical lever; "R" stands for Regulatory lever; "F" stands for Financial lever.

[1] *"Biochar is defined as charcoal and carbon-rich material produced by partial oxidation (pyrolysis at ≤700 °C in the absence or limited supply of oxygen) of carbonaceous organic sources such as wood and plants, excluding fossil fuel products"*. In. Battacharya, T. *et al.* (2024). Advances and prospects for biochar utilisation in food processing and packaging applications. *Sustainable Materials and Technologies*. Vol. 39. https://doi.org/10.1016/j.susmat.2024.e00831. Last accessed on 7 October 2024. p. 2.

PROJECT	WHERE, WHO	TYPE OF LEVER			AIM
		T	R	F	
n°5 **Recycled PET production**	France, Limay **Paprec**	Fossil carbon			This project treats 45 000 t/y of plastic bottles (PET) that come from a selective collection system, to produce 41 000 t/y of recycled plastic (rPET). This rPET can be a substitute for PET.
n°6 **WAGABOX technology**	Europe and North America **Waga Energy**	Methane			This innovative technology purifies landfill gas, thanks to both membrane filtration and cryogenic distillation, to recover grid compliant biomethane. This recovered energy is then used as green fuel for transport and industry, and for households.
n°7 **Barka Landfill**	Oman, Muscat **Veolia**	Methane Fossil carbon		x	This project aimed at setting up a 100% controlled solid waste treatment system, thus moving away from open dumpsites. The new landfill receives 2 500t/day of highly compacted waste, promptly covered. This infrastructure treats leachate and permeate is reused to cover the needed landfill operations. It also has gas flaring installed. Biogas recovery is under evaluation and tyres are processed in chips to fuel a nearby cement plant.
n°8 **Non-recyclable waste into green energy**	France, Sète **Paprec**	Fossil carbon			This Waste-to-Energy (WtE) plant produces heat and power for the local industrial sites from non-recyclable waste as an alternative to landfilling, in an 18.1MW oscillating furnace. This project thus increases energy autonomy while energetically valorising waste.
n°9 **MassBio2 the CO_2 Dashboard**	France **Groupe Merlin**	Fossil carbon Prevention			This project assesses the share of biogenic and fossil carbon in incineration flue gas, waste and energy. This dashboard allows to collect data on the waste streams treated, thus providing knowledge on the evolution of waste generation and consumption habits. It enables to identify prevention and recycling actions to reduce GHG emissions.
n°10 **Istanbul Waste-to-Energy Plant**	Turkey, Istanbul ISTAC **Veolia**	Fossil carbon Methane			This WtE plant produces green energy, especially electricity thanks to an 85MW turbine. It has an objective of reaching carbon neutrality by 2053.
n°11 **Geothermal CO_2 capture**	Greater Paris **Syctom, BRGM, SLB**	Fossil carbon	x		This R&D project aims at capturing and stocking CO_2 from incineration flue gases into a deep geothermal plant. This plant then recovers heat from the geothermal aquifer to supply district heating.
n°12 **A waste to resources industrial system**	France, Tarn **Urbaser, Trifyl**	Methane Prevention			This project adopted an industrial systemic approach to transition from landfills to a resource recovery oriented treatment, including recycling materials and producing energy. This MSW plant valorises 80% of waste, producing biomethane, new raw materials, fertilizer and Refused Derived Fuel (RDF).

Note: "T" stands for Technical lever; "R" stands for Regulatory lever; "F" stands for Financial lever.

PROJECT	WHERE, WHO	TYPE OF LEVER			AIM
		T	R	F	
n°13 **Improving household waste management**	Togo, Lomé **AFD, EU, Boad**	Methane		x	This project allowed the improvement of household waste management for a sustainable transition in Lomé. The holistic SWM system includes the implementation of engineered landfills managing leachate and biogas, encouraging recycling and recovery initiatives, and improving financial resources.
n°14 **A women-led informal waste collection system in Hà Nôi**	Viêt Nam, Hà Nôi **IRD**	Black carbon Methane	x		This study aimed at collecting data on Hà Nôi's waste collection and recycling system, to upgrade in an appropriate manner its waste management system, especially to guide policy-makers in improving working conditions and to support the informal sector. Thus, 20% of urban waste is collected by an informal system (mostly by women), with street collectors, waste deposit managers and recyclers.
n°15 **Open burning & Air quality**	Bolivia, El Alto & La Paz **IRD, IGE**	Black carbon	x		This study aimed at evaluating airborne pollution in El Alto and La Paz and to identify its sources (mainly road traffic but impacted by waste burning too) as a baseline for future policies.
n°16 **Promoting integrated solid waste management in Senegal**	Dakar and northern regions **AFD, World Bank, AECID**	Black carbon Methane Fossil carbon	x	x	This project, which aims at establishing a holisitic and integrated solid waste management in Senegal, strives for the improvement of the regulatory, financial and fiscal framework of the sector, but also at developing private/public partnerships. The project also aims at the rehabilitation of the Mbeubeuss Dakar dumpsite, while integrating the informal sector in the process.
n°17 **Green landfill to energy**	International Meknès **Suez**	Methane		x	This project, of green controlled landfills as implemented in Meknès, Morocco for instance, not only aims at improving waste management by moving away from open dumpsites, but it also recovers energy to produce biomethane and renewable electricity. Furthermore, it maximises its energy production by exploiting the land value and infrastructures, via photovoltaic installations for instance. It is an innovative financing model for waste treatment in developing countries.
n°18 **Strengthening national policies**	South Pacific **AFD, SPREP PROE**		x	x	This regional initiative encourages cooperation between insular countries to prevent marine debris (plastic), used oil, post-disaster waste from degrading the environment. To do so, local authorities are supported to make policies for the establishment of holistic waste management systems especially by improving existing infrastructures and promoting sustainable financing.

Note: "T" stands for Technical lever; "R" stands for Regulatory lever; "F" stands for Financial lever.

PROJECT	WHERE, WHO	TYPE OF LEVER			AIM
		T	R	F	
n°19 **Capture and valorisation of incineration fumes**	France, Paris **SYCTOM**	Fossil carbon			This ongoing research project aims at capturing CO_2 from incineration fumes via algae and to valorise it through a photobioreactor which would produce bioplastics.
n°20 **Clean School Operation by Gbobètô**	Benin, Wémé region **Engineering X, MSP, CCT**	Black carbon		x	By focusing on the 3Rs (reducing, reusing and recycling), this project aims at reducing open burning through the implementation of a clean school operation. Thus, the 10 concerned schools will reduce single-used plastics, build recycling units to which children will bring their homes' recyclables, and develop composting systems for vegetable gardens.
n°21 **Reducing open burning of MSW**	Uganda, Mbarara City **Engineering X, MSP, CCT**	Black carbon	x	x	This project aims at reducing open burning and its negative impacts on health and safety by involving all the stakeholders, especially citizens, policy-makers and implementer, informal workers and companies.
n°22 **Néolithe, carbon sequestration and material recovery**	France **Néolithe**	Fossil carbon			This innovation aims at sequestering carbon and at producing aggregates to be used in construction. This project recovers material from non-recyclable, non-inert and non-hazardous waste via accelerated fossilisation.
n°23 **A French example of Pay-As-You-Throw (PAYT)**	France **Local authority**		x		This economic tool aims at implementing a fair and locally adapted polluter pays principle. It consists in the introduction of a fee dependent on the amount of waste generated by users and households. This fiscal lever allows to raise users' awareness, to reduce the volumes of waste, to improve waste management operations and to finance the system.
n°24 **Indore biomethane plant**	India **India Municipal Corporation**	Methane		x	This plant processes source separated organic waste into compost and biomethane. This project allowed to create jobs and to secure revenues, especially through carbon markets.
n°25 **Carbon markets supporting a compost facility in Touba**	Senegal, Touba **Sonaged, MUCTAT, Allcot**	Methane		x	This compost and methanisation facility aims at diverting organic solid waste from mismanaged landfills to reduce methane emissions. This project contributes to the country's unconditional NDC and uses the carbon market for funding.

Note: "T" stands for Technical lever; "R" stands for Regulatory lever; "F" stands for Financial lever.

1. The Global Context

Waste management is a local issue, but GHG emissions are a global one. The actions taken or not taken in a given place contribute to mitigating or aggravating the current climate crisis. This chapter provides an overview of the emissions associated to waste management, how international frameworks define Environmentally Sound Management of waste, the latest climate COPs, and the context on global initiatives associated to waste management.

1.1. THE CONTRIBUTION OF THE SOLID WASTE SECTOR TO GLOBAL GHG EMISSIONS

In 2020, the waste sector, as defined by the IPCC, generated **1.65 billion tons (Bt) CO_2 equivalent (CO_2eq), or 3.5%[2] of the 56 giga tons of total GHG emissions in the world**[XIV]. When considering indirect emissions, and avoided emissions, following a Life Cycle Assessment (LCA) approach, **the waste sector can contribute to reducing up to 20% of global emissions**[XV].

FIGURE 1 presents the "waste sector's" GHG emissions depending on what is included or not in the assessment (refer to **ZOOM 1**).

The major sources of direct GHG emissions from the solid waste sector are mismanaged organic waste producing methane (CH_4) and nitrous oxide (N_2O), the incineration of waste producing fossil carbon dioxide (CO_2), and the open burning of waste producing both fossil carbon dioxide and black carbon. Reducing methane and black carbon emissions is an efficient way to curb the global warming trend, given the high short-term global warming potential of these molecules (see **ZOOM 2**).

ZOOM 1 — System boundaries of national reporting versus organisational reporting

National reporting is structured to enable the assessment of global emissions, as well as drive national commitments to reduce GHG emissions. The IPCC framework divides the activities within "sectors", which are the same for all countries. It also provides a methodology to assess the direct GHG emissions associated to these activities within each sector to enable the reporting required under Article 6 of the Paris Agreement, even for countries with limited data availability. Solid waste management is included in the "Waste Sector," along with wastewater management. Waste-to-Energy activities are excluded from the "Waste Sector" and reported under the "Energy Sector".

Organisational reporting is structured to meet the requirements either of mandatory commitments driven by national regulations or sectoral commitments, as well as voluntary commitments. All the activities related to solid waste management and on which the organisation has control will be included in the system boundary.

Therefore, the system boundary of the "Waste Sector" at international level is different from the system boundary of an organisation managing waste.

[2] For this data, the waste sector is only comprised of wastewater, landfills, and incineration without energy recovery.

FIGURE 1

GHG emissions from the waste sector depending on the chosen system boundary[3]

[3] Information compiled from ISWA's Climate Change Working Group web page. See Wilson, D. C., Ramola, A. & Paul, J. (2024). Unlocking the significant worldwide potential of better waste and resource management for climate mitigation: with particular focus on the Global South. *Waste Management and Research*. Vol 42(10), pp. 1-13. https://journals.sagepub.com/doi/10.1177/0734242X241262717?icid=int.sj-abstract.citing-articles.2 Last accessed on 14 October 2024.

2

ZOOM

Waste that generates GHG emissions

The main GHG molecules generated from solid waste management activities are fossil carbon dioxide (CO_2), methane and black carbon. The emissions of each molecule are translated into carbon dioxide equivalents (CO_2eq) by multiplying their quantity by their Global Warming Potential (GWP). Specific waste management practices contribute most to the generation of GHG emissions, in particular open burning, dumped or landfilled organic matter, and the life cycle of plastics:

- **Open burning of MSW in urban areas and on legacy[4] waste dumpsites** contribute to 11% of total global particulate matter <2.5 µm emissions, and **to the generation of 6 to 7% of total global black carbon emissions**. Black carbon, produced as the result of incomplete combustion, **has a 20-year GWP of 4,470**, and a 100-year GWP of 1,055–2,240[XVI]. Black carbon from open burning accounts for 2 to 10% of global CO_2eq emissions[XVII]. Reducing black carbon emissions contributes significantly to curb the global warming trend in the short term, due to the short lifespan of this molecule.
- **Mismanaged organic matter emits GHG in the form of methane** and nitrous oxide. On open dumps, landfills, or poorly managed composting facilities, **stockpiled organic matter undergoes an anaerobic fermentation that produces methane, which has a GWP of 84 when calculated over 20 years**[XVIII], because it is a short-lived molecule. The GWP of methane is 34 when calculated over 100 years. Therefore, reducing methane emissions also contributes to urgently curbing the global warming trend. Nitrous oxide (N_2O) emissions are less well understood and difficult to assess precisely. They are a research topic, given their GWP of 273 over 100-years.
- In 2019, it was estimated that throughout their life cycle, **fossil-based plastics emitted 1.8 GtCO_2eq, or 3.4% of the total GHG emissions**. 90% of these emissions are generated during the production and transformation into plastic products[XIX]. Incineration of plastic waste with or without energy recovery generates about 2.3 tCO_2eq per ton of plastic[XX]. The most effective means to reduce GHG emissions is **to reduce the production of plastics from virgin materials**, increase the proportion of recycled plastics and reduce the amount incinerated, therefore giving **several lives to each fossil carbon molecule** that had been extracted to produce plastics.

Credit : Corinne Trommsdorff.

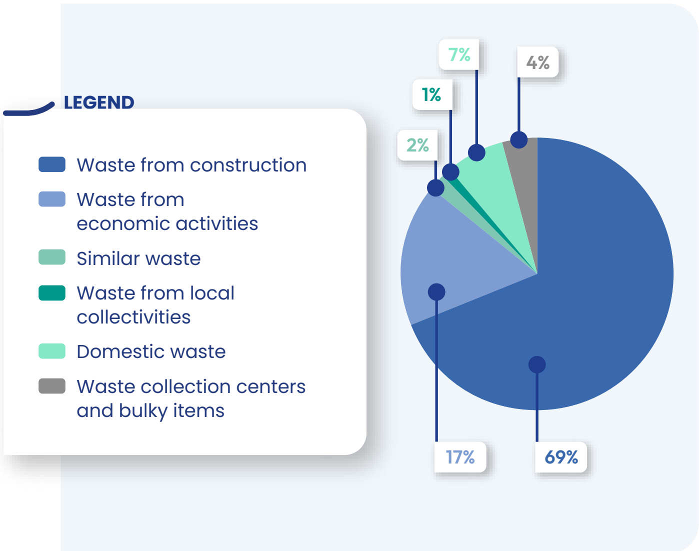
[4] Legacy dumpsites are the existing dumpsites that remain in place even though they are no longer used to dump more waste.

The GHG emissions of the waste sector, already significant today, are bound to increase, if we stick to business as usual (BaU) and its associated drastic increase of waste volumes. In the last decades, the intensified industrialisation, urbanisation and associated global economic development, coupled with rapid population growth, has triggered massive generation of Municipal Solid Waste (MSW).

An estimated 3.8 BtCO_2eq per year of MSW will be generated by 2050, against 2.1 Bt in 2020[XXI], or **an estimated 80% increase over this period** according to the available data. These projected increasing amounts of waste are directly associated with **doubling of the sector's direct GHG emissions by 2050 compared to 2015**, showing an increase from 1.3 BtCO_2eq to 2.3 BtCO_2eq[XXII].

In 2020, France generated 97.5 million tonnes (Mt) of MSW and waste from economic activities excluding construction, representing 31 % of the country's total 310 Mt of waste generated (see **FIGURE 2**). **From 2006 to 2010, the French total waste generation increased by about 10 %** (largely above the population and GDP growth of 3% over the same period). **Between 2011 and 2020, the total waste generation decreased by about 12%,** from 355 Mt to 310 Mt[XXIII]. The 2017 MODECOM[5] characterisation campaigns had allowed to identify that 80% of the residual household waste (which was estimated at 7% of total waste in 2020) could be recycled or recovered[XXIV].

FIGURE 2 **Share of waste production in France by sector (in 2020)**



Source : ADEME. (2023). *Déchets chiffres-clés*. Edition Juin 2023. ADEME La Librairie. Réf. ADEME : 011982. https://librairie.ademe.fr/economie-circulaire-et-dechets/6108-dechets-chiffres-cles-edition-2023.html

Note: The Kyoto Protocol excludes sorting and incineration with energy recovery from the waste sector. It includes landfills, wastewater treatment, incineration without energy recovery, open green waste and vehicle fires, and biological treatment of solid waste. In France, there are only two incineration installations without energy recovery (53kt), against 118 with energy recovery (14,520kt) of which only 80 are linked to heating networks[XXVI].

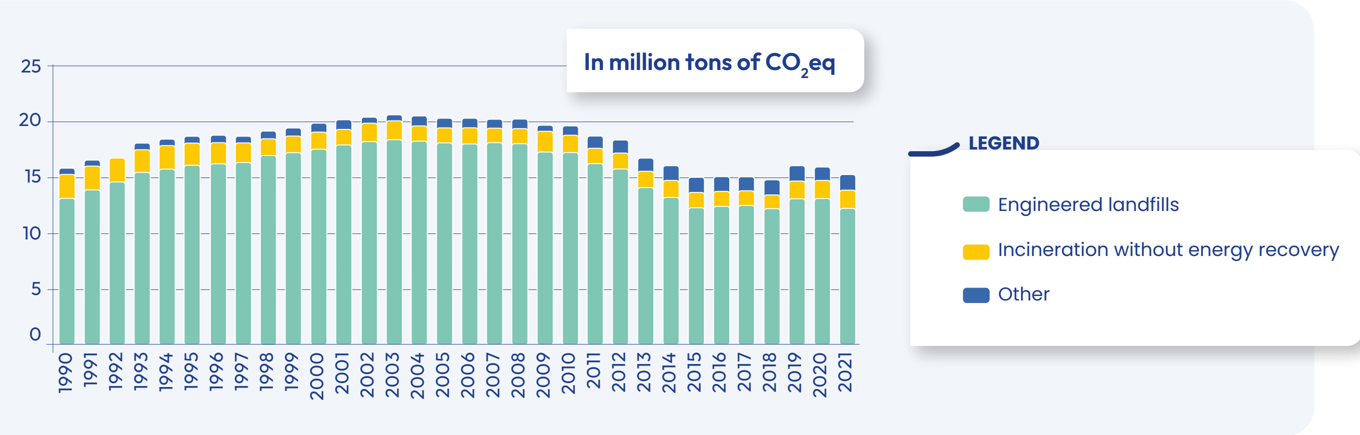
As per the 2006 IPCC Guidelines, the French waste sector excludes WtE plants. When also excluding wastewater management, the French waste sector (as per **FIGURE 2**) emitted about 18 MtCO_2eq in 2021, or approximately 4.5% of the country's total GHG emissions this same year (415 MtCO_2eq)[XXV]. Engineered landfills are responsible for the largest emissions, or about 13 MtCO_2eq in 2019 (See **FIGURE 3**). WtE plants, reported under the energy sector, are responsible for approximately 7 MtCO_2eq in 2019 (See **FIGURE 4**). The emissions from engineered landfills are mostly methane leaking to the atmosphere, which have significantly reduced since 2002 as a result of improved onsite operational practices and enhanced organic waste diversion from landfills, in line with the objectives set by the 1999 EU Landfill Directive[6] and by the 2008 Waste Framework Directive[7]. Fossil CO_2 emissions from incineration with energy recovery have significantly been growing over the last decades.

Though total GHG emissions of the French waste sector were about 25 MtCO_2eq in 2021 (including WtE), about 14.6 MtCO_2eq were avoided that same year. Avoided emissions are GHG emissions reduced by third parties using products or services resulting from the waste management activities, in **replacement of a more 'carbon-intensive'** solution (refer to **section 2.2.**). The 14.6 MtCO_2eq avoided result of sustainable waste management practices adopted in France, including recycling and energy recovery[XXVII]. These avoided emissions are estimated based on the avoided production of virgin raw materials, and the avoided consumption of fossil energy sources.

[5] National characterisation campaign for household waste, MODECOM. In. Astee (2024). *Guide méthodologique*.
[6] Council Directive 1999/31/EC of 29 April 1999 on the landfill of waste, called Landfill Directive.
[7] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, called Waste Framework Directive.

FIGURE 3

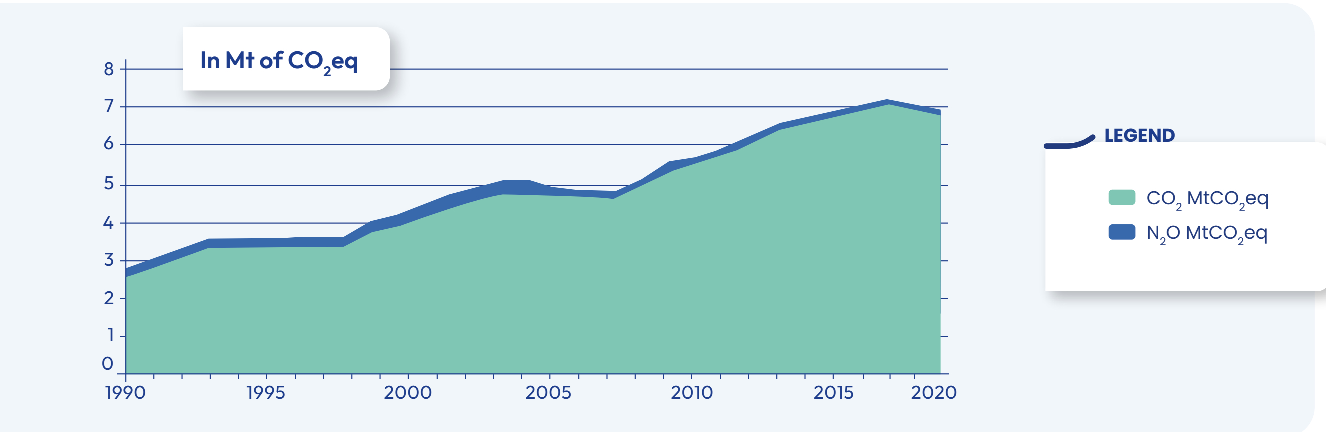
Breakdown of CO_2eq emissions from the centralised waste treatment in France (metropolitan France and overseas territories)



Source: CITEPA, « Rapport Secten édition 2022 », 2023. In. Astee (2024). *Guide méthodologique*. p. 44.

FIGURE 4

The evolution of GHG emissions from waste incineration with energy recovery in metropolitan France, from 1990 to 2020



Source: CITEPA. Adapted from Astee (2024). *Guide méthodologique*. p. 44.

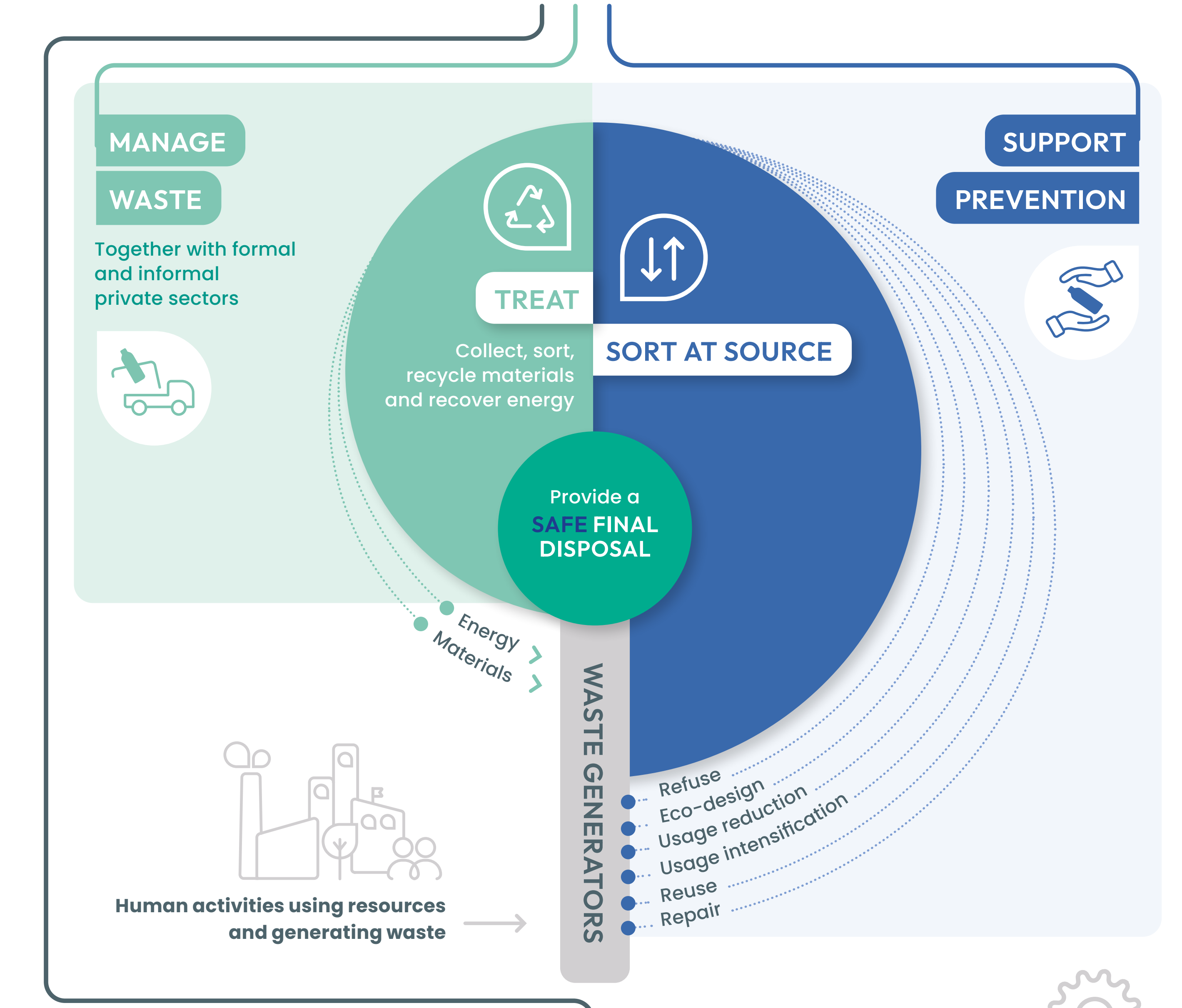
1.2. ESM OF WASTE TO ADDRESS THE CLIMATE CRISIS

A massive reduction of GHG emissions related to the waste sector is only possible with a thoroughly organised waste management system, from prevention and collection to safe final disposal. ESM of waste is defined by the Basel Convention[XXVIII] (See **ZOOM 3**) and illustrated in **FIGURE 5**. ESM of waste is based on the internationally recognised waste management hierarchy: 1/ prevention which is about reducing waste generation, 2/ valorisation which is about recycling materials and recovering energy, and 3/ safe final disposal of the waste that could not be prevented or safely recovered in the local context. The implementation of **ESM of waste** locally relies on the **development of capacities and infrastructures**, the complex planning of **circular and integrated strategies**[XXIX] to implement the waste management hierarchy, and well-defined roles and responsibilities, to orchestrate the involvement of the different stakeholders (See **TABLE 2**). **ESM of waste can play a key role in the achievement of most SDGs, beyond providing mitigation opportunities.**

FIGURE 5 illustrates the establishment of ESM of waste by local authorities and highlights five support mechanisms needed to implement this complex task. Indeed, as described in **TABLE 2**, many actors must take part in implementing these mechanisms beyond local authorities, including governments, NGOs, research and training institutes, financial institutes, the private sector and users.

FIGURE 5

ENVIRONMENTALLY SOUND MANAGEMENT OF WASTE IMPLEMENTED BY LOCAL AUTHORITIES



Local governments are supported by many stakeholders on 5 mechanisms

Public Policies and enforcement

- Strategies
- Clear roles and responsibilities
- Organisational and regulatory frameworks
- Standards

Funding mechanisms

- Cost recovery
- Taxation and incentives
- International investments
- Solidarity

Integrated spatial strategic planning

- Current situation
- Cross-sector planning
- Mutualisation between territories

Training and research

- Knowledge and skills
- Just transition
- Innovation

Prevention

- Education and awareness
- Transitioning production systems
- Transitioning economic models

TABLE 2

Stakeholders' roles in the implementation and operation of waste management systems

MECHANISMS/ LEVELS OF ACTION	Public Policies and enforcement	Funding mechanisms	Integrated spatial strategic planning	Training and research	Prevention-specific actions		
					Education, communication, awareness	Evolution in the modes of production	Evolution of the economic models
International institutions (UN, ISO,...)	Set legally-binding obligations, common standards and requirements; Set agreements and enforce them; Promote international cooperation; Assign roles and responsibilities.	Set financial mechanisms, frameworks, and obligations for international cooperation; Support the development of solidarity funds.		Establish training, technical assistance, technology transfer and knowledge exchange centres (e.g. Basel and Stockholm Conventions) for a just transition.	Introduce a "Zero Waste" Day; Introduce and implement the SDG framework.	Set standards.	Set agreements and enforce them.
International Financial Institutions (IFIs)		Fund projects.	Incentivise through their Terms of Reference.	Incentivise through their Terms of Reference.	Incentivise through their Terms of Reference.		
International NGOs	Advocacy.	Channel solidarity; Fund projects.		Develop training programmes.	Develop public awareness programmes.	Advocacy.	Advocacy.
National or supra-national governments and legislative bodies (incl. EU)						Advocacy; Encourage and enable social entrepreneurship.	Advocacy; Encourage and enable social entrepreneurship.
National NGOs	Define national strategies, legislation and enforcement; Set minimum standards; Enforce compliance; Assign roles and responsibilities.	Set the fiscal system to support cost recovery; Implement appropriate taxation systems and incentives; Assign budgets; Assign solidarity funds.	Regulate baseline data acquisition to support national strategic planning; Frame and regulate cross-sector planning.	Identify needs; Define a strategy for a just transition; Fund training and research; Support innovation.	Organise national communication campaigns.	Set standards.	Set agreements and enforce them.
Companies (producers, retailers)		Implement EPR schemes.		Develop eco-design knowledge and skills.		Advocacy; Implement innovations.	Advocacy; Implement innovations.
Local authorities	Establish the political vision, local strategy and goals; Make organisational choices; Set the terms of the public-private partnerships.	Define service fees and investment budget allocations.	Collect baseline and monitoring data; Coordinate across sectors and between adjacent jurisdictions; Enable mutualisation between territories.	Coordinate with local research institutes to adapt innovations to the local context; Develop knowledge and skills of the workforce.	Implement local communication campaigns.	Support local innovations.	Support local innovations.
Private operators		Implement sustainable business models.	Facilitate mutualisation between territories.	Innovate.	Develop programmes and amplify.		
Users	Vote.	Pay taxes.	Participate.	Learn and embrace improved behaviours.	Amplify the reach of the campaigns to raise awareness.	Choose lower waste generation options.	Choose to pay for the environmental and social impacts of products.

Note: All the actors listed above are interdependent in fulfilling their respective roles and functions to implement a fully operating waste management system. They influence and interact with each other within and between the different levels of action (international, national and local) and within each of the 5 mechanisms supporting local waste management systems (public policies and enforcement, funding mechanisms, integrated spatial strategic planning, training and research, prevention-specific actions).

3

The Basel Convention[8] and the ESM of waste[9]

The issue of waste management, particularly the cross-border transport of hazardous wastes, has driven the creation of the 1992 Basel Convention. Ratified by 191 Member States[10], the **legally-binding Convention**[XXX] defines and sets **obligations for signatory States** to take all appropriate measures around the following 3 main pillars:

- Prevent and minimise the generation of hazardous wastes and other wastes;
- Promote the ESM of hazardous wastes and other wastes;
- Control transboundary movements of hazardous wastes and other wastes; and apply a regulatory system through a written "Prior Informed Consent" procedure[XXXI], where transboundary movements are permissible.

More specifically, as mentioned in Article 4(2)[XXXII], Parties have the following **obligations**: reduce waste to a minimum, ensure the availability of adequate disposal facilities, prevent pollution due to waste management, and reduce to a minimum transboundary movement of waste, limiting waste exportation to countries who can manage it in an environmentally sound manner.

Highlighting the importance of the sustainable management of waste for human health and the environment, the Convention considers illegal traffic of waste as a crime in Article 4(3). It aims to protect developing countries from unwanted wastes that they cannot safely manage. According to the Convention's Article 9, Parties to the Convention shall both introduce **appropriate legislation and regulations, as well as co-operate** to fight against illegal waste traffic.

Over the years, Parties to the Convention have put a stronger emphasis on the **application of the waste management hierarchy** and committed to actively promote and implement more efficient waste prevention and minimisation strategies. In the context of a circular economy, the Basel Convention's waste hierarchy plays a crucial role in promoting the reuse, repair, recycling and recovery of waste.

To apply this waste treatment hierarchy, the Basel Convention puts a strong emphasis on the need to **adopt a systemic and holistic approach to waste management** and to consistently combine information, public policy and enforcement.

The ESM Framework[XXXIII], which implementation by the Parties remains voluntary, recommends in part V(A)(14) to have **data on the quantities and types of waste streams** to be managed in the most appropriate manner possible, to have sufficient and appropriate capacities to manage these streams, and to clearly distribute the roles and responsibilities of those who have a role in the generation and management of waste.

Recognising that countries are facing challenges to implement ESM of waste in a systematic and comprehensive manner, the ESM Framework intends to provide practical guidance for all stakeholders by establishing a common understanding of what ESM encompasses, identifying tools to support and promote its implementation, and identifying strategies to do so.

The permanent and sustainable establishment of an ESM of waste is only possible if fiscal and public policies establish a functional and long-lasting waste management system. It is also **dependent on context-adapted institutional structures that can support, organise and regulate this waste management system**. International regulations, like multilateral environmental agreements and multilateral institutions, especially the UN, play a crucial role in establishing standardised frameworks to do so.

A number of interlinkages between climate change, hazardous chemical and wastes have been identified. A report exploring the technical aspects of these interlinkages, based on existing literature, towards ultimately supporting the identification of opportunities for taking action on both climate change and hazardous chemicals and waste, in a cost-effective, integrated manner has been developed[XXXIV].

ZOOM

[8] Full name: Basel Convention on the control of transboundary movements of hazardous wastes and their disposal. https://www.basel.int/Portals/4/Basel%20Convention/docs/text/BaselConventionText-e.pdf Last accessed on 11 October 2024.

[9] In the context of the Basel Convention, waste refers to hazardous and other wastes, as formulated in the Convention.

[10] The United States of America and Haiti have signed but not ratified this legally-binding Convention.

1.3. RISING ATTENTION ON THE WASTE SECTOR AT THE LATEST CLIMATE COPs

The **COP-21 2015 Paris Agreement**[XXXV] materialised the recently grown attention of the international community for the issues of climate change and crisis. Each of the 196 countries which have signed the 2015 Paris Agreement have an obligation to declare their Nationally Determined Contributions (NDCs), as per Article 6, in line with the Agreement's goal to reduce emissions, whether they are high or low GHG emitting countries. All countries **commit to a certain level of GHG reduction** by setting deadlines and can specify whether these commitments are "**unconditional**" (the case for all developed countries) or "conditional" to foreign investments. **83% of NDCs consider making use of international market mechanisms** to reduce their GHG emissions[XXXVI].

The 2021 Glasgow COP-26 took place in the context of the first 5-year deadline for countries' NDCs (as determined by the Paris Agreement). These were deemed insufficient by the 2021 United Nations Framework Convention on Climate Change (UNFCCC) NDC Synthesis Report. This report emphasised the urgent need to overachieve the latest NDCs or/and to increase ambitions to keep warming well below 2°C, or to limit it to 1.5°C[XXXVII]. In line with the need to broaden climate mitigation ambitions, the signature of the **Global Methane Pledge**[XXXVIII] was an additional step towards achieving the Paris Agreement goals. Methane emissions account for 17% of global GHG emissions, 20% of which come from waste management. This sectoral agreement has 111 signatory States, which are responsible for 45% of global human-caused methane emissions. This pledge establishes the goal to **reduce methane emissions by 30% by 2030**. Annual ministerial meetings are held to ensure the achievement of this objective with an emphasis on the need for transparency, coherence and completeness of national GHG data. Thus, signatory States should progressively move from using the Tier 1[11] approach of the IPCC Guidelines for national inventories, to a more accurate quantification of methane emissions relating the specificities of the assessed operations, consistently with the UNFCCC, Paris Agreement and IPCC guidance. **The reduction of methane emissions from waste is now recognised as a promising pathway to addressing climate change in a short time span** and through comparatively low investments that deliver significant co-benefits.

The **2022 COP-27 in Sharm El Sheikh** had paved the way to giving waste some attention, with the Marrakech Partnership for Global Climate Action highlighting the importance of reducing and valorising waste, especially focusing on open burning, open dumping, and organic waste management. The organic fraction of waste accounts for 50 to 70% in Africa[XXXIX].

At the **2023 COP-28 in Dubai** the Waste to Zero Initiative was launched by the United Arab Emirates, as the first effort to propose a global coalition composed of private/public sector entities with the ambition to decarbonise the waste management sector.

COP-28 also hosted for the first time ever, a Waste and Resources Pavilion, which put a focus on the need to generate less waste, improve organic waste management, promote ESM and control illegal waste trafficking, as means to achieve both the Paris Agreement and the UN SDGs.

As of 2024, only about[12] **20 countries have included waste in their NDCs**, whether as conditional or unconditional commitments.

However, waste management was not mentioned in the final agreement text. The upcoming **COP-29** in Baku, Azerbaijan identifies methane reduction from food waste as a critical action for mitigating climate change.

Therefore, efforts by the sector are ongoing to bring waste management higher on the political agendas, to drive the recognition of the sector's potential to be included in the NDCs' revision planned for 2025.

[11] Tier 1 is based on a single global emission factor; Tier 2 on a country-level emission factor; Tier 3 on site-specific measurements.

[12] The data on the exact number of countries is unclear based on the available sources. See UNDP. (2021). *UNDP Climate Promise Progress Report*. UNDP *et al.* https://www.undp.org/sites/g/files/zskgke326/files/2021-05/undp-climate-promise-progress-report-april-2021.pdf and Climate Watch's website: https://www.climatewatchdata.org/ Last accessed on 11 October 2024.

1.4. INTERNATIONAL INITIATIVES DRIVING THE REDUCTION OF GHG EMISSIONS ASSOCIATED TO SOLID WASTE

International initiatives such as city-networks, coalitions, or partnerships have emerged worldwide, to drive multi-sectoral action beyond what governments were initiating on their own.

One of the longest standing initiatives is the **Global Methane Initiative (GMI)** which was first launched by 14 countries as Methane to Markets in 2004. With 49 Partner Countries and more than 1,000 Project Network members as of 2024, GMI highlights the challenges, opportunities, successes and best practices related to reducing methane emissions. Reducing methane emissions in the short term **can curb the global warming trend** over the next 20-30 years, buying time for other systemic changes to reduce fossil CO_2 emissions. The initiative provides technical implementation assistance in 3 sectors which account for an estimated 50% of total methane emissions by 2030: oil and gas operations, the biogas sector (including MSW, wastewater, and agriculture), and coal mining. GMI provides technical support, best practices information, training on methane mitigation and recovery, and capacity building support for the implementation of methane reduction policies and projects. Since 2004, **GMI Partners have reduced approximately** 670 million metric tons CO_2eq[XL], equivalent to **~1% of annual global emissions or of removing nearly 160 million gasoline-powered cars from the road for a year**. GMI actively engages global stakeholders and enriches the discussion amongst policymakers, industries, technical experts and researchers, for instance by organising the Global Methane Forum every other year.

Another international initiative pushing for the effective implementation of climate mitigation solutions is the **Climate and Clean Air Coalition (CCAC)**. It was created following the finding by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation in 2011[13] that reducing **short-lived climate pollutants (SLCPs) has a big potential in reducing GHG emissions**[XLI]. The CCAC Waste Hub works for the coordination and facilitation of exchange of information and knowledge between stakeholders working on waste management to reduce SLCPs, for instance with the **ISWA Task Force for Closing Dumpsites** partnership[14]. It actively pushes for the achievement of the Paris Agreement by partner countries, via their NDCs and other planning documents. It advocates for the elimination of open burning of waste[XLII], while providing financial support thanks to their Trust Fund.

The African Ministers Conference on Environment (AMCEN) with support from the UNEP Africa Regional Office in 2022 passed a resolution to reduce open waste burning in the African continent. **Targets set are 40% by 2030 and 60% by 2040**. Engineering-X, a UK based non-profit trust, together with the UN High Level Climate Champions team has formed a **Multi Stakeholder Partnership (MSP)**, composed of 12 International organisations towards implementation of this resolution. Since open burning of waste also includes methane emissions, this partnership has been playing a critical role in methane emission reduction from the African Continent.

The Waste to Zero Initiative, launched during the 2023 COP-28 and signed by more than 40 entities, has several objectives, the main one being the decarbonisation of the waste management value chain and therefore the definition of a credible net zero target for the sector. It argues this can be done by **acting on Scopes 1, 2 and 3 emissions**, and by directing investments in **waste management decarbonisation activities**[15].

Chapter transition

The urgency to address the climate crisis is well recognised globally, and though global action is lagging to reduce emissions, the waste management sector is starting to be recognised for its potential contribution to the mitigation agenda. The confusing differences in system boundaries associated with waste management activities have hindered global advocacy in the past. Now, as global interest for the waste sector grows, the ability for local stakeholders to take action will rely on their capacity to assess their GHG emissions, identify the levers to reduce these, and take action within an enabling environment that provides policies and strategic frameworks, as well as funding mechanisms. The following chapters provide insights on these topics.

[13] In 2012, UNEP, Bangladesh, Canada, Ghana, Mexico, Sweden and the United States got together to form the CCAC.

[14] This international partnership aims at closing dumpsites around the world. Closing the World's biggest Dumpsites Task Force | ISWA Last accessed on 11 October 2024.

[15] One of the key milestones of this initiative is the publication of a report (still under development) with the baseline of the GHG emissions from waste globally based on LCA methodology. Waste to Zero. (n.d.) Introduction. *Globalwastetozero.com* https://globalwastetozero.com/index.html#introduction. Last accessed on 11 October 2024.

2. GHG Assessments for Solid Waste Management Activities

GHG emissions assessments are **needed at two levels**: 1/ the level of international reporting, which aggregates the direct emissions of all activities by sector within each country, and 2/ the level of an organisation or project, which focuses on the direct, indirect emissions, as well as avoided emissions to drive mitigation actions within the organisation and its whole value chain. Assessment results are key at global level to bring attention to the sector's global potential, and at organisational level to **drive local mitigation action** by all stakeholders. Refer to ZOOM 1 for more details on national versus organisational reporting.

This chapter focuses on assessments by public or private organisations. It presents the notions of system boundaries and scopes of emissions, an overview of the GHG emissions associated with waste management activities, and a few models used internationally. The intent is to support local stakeholders in charge of waste management to identify their most significant emissions and be able to monitor the impact of their mitigation actions.

2.1. DEFINITION OF SYSTEM BOUNDARIES

Any organisation planning to assess its GHG emissions must define its system boundary to clearly identify the activities it is responsible for, either because it **manages them directly**, or because it **owns assets** associated with these activities.

GHG reporting on waste management then differs depending on whether the activities are within or outside of the system boundary. According to the International Standard Organisation (ISO) 14046-1 norm established by the 1990 GHG Protocol, there are 2 types of organisational system boundaries: capital share[16] and control.

The **"control" approach**, is based either on the activities **performed directly (operational)**, or those **financed up to at least 50%** by the organisation (**financial**)[17]. As mentioned by the GHG Protocol[XLIII], double counting of emissions must be avoided in trading schemes and for mandatory government reporting[18]. Governments usually require that GHG organisational reporting is done on the basis of **operational control** since the responsibility for compliance generally falls on the operator. The financial control approach may be used by large companies.

[16] For clarity purposes, this publication will not be expanding on this approach, which is most relevant to multinational firms but is not allowed for national reporting.

[17] The economic nature of the relationship between the company and the operation takes the upper hand on the property legal status. A company can have the financial control of an operation even if it owns less than 50% of its assets.

[18] Double counting emissions from a joint operation in the case of voluntary corporate public reporting may not matter. The company however must provide adequate disclosure on its consolidation approach.

In the case of France, the system boundary for GHG reporting by local authorities in charge of waste management is based on the operational control approach and includes both the activities over which they have legal responsibilities and the activities related to assets they own. These activities are part of their system boundary whether they perform these activities themselves or outsource them[XLIV], as detailed in the methodology guide by Astee (the French Scientific and Technical Water and Waste Organisation)[XLV]. In case a legal responsibility is transferred to another organisation through a legal agreement[19], the GHG emissions associated with the facilities and activities corresponding to the transferred competency are included in the system boundary of the recipient of this transfer.

2.2. THE DIFFERENT SCOPES OF EMISSIONS (SCOPES 1, 2, 3 AND AVOIDED EMISSIONS)

GHG emissions are categorised into **3 scopes** of emissions as defined by the IPCC GHG Protocol.

The first scope (**Scope 1**) refers to the direct GHG emissions generated by activities or installations within the organisation's system boundary.

The second scope (**Scope 2**) accounts for the organisation's indirect emissions linked to the consumption of energy from an energy provider operating a national grid (electricity, heat, natural gas network).

The third scope (**Scope 3**) represents all the other indirect GHG emissions. These emissions are generated outside the system boundary as a result from the organisation's activities. They include the purchase of supplies, the use of its goods and services, upstream and downstream of its activities. Even if emissions from this scope aren't mandatorily reported under the ISO 14069-2013 norm, they offer a complete overview of the emissions associated with the organisation's activities.

Depending on the system boundary, the way GHG emissions are classified under Scope 1 or 3 will change (see **FIGURE 6**).

In France, decree n° 2022-982[20] broadened the scope of GHG reporting to include Scope 3 in the mandatory GHG assessment. It is the first country to **make Scope 3 reporting mandatory**[XLVI]. Assessing these emissions allows to **better identify the levers** appropriate for an organisation to reduce global emissions: the ones they own (Scope 1), and the ones they can influence through their operations (Scope 3). It also allows to account for avoided emissions linked to specific activities and based on well-established reference scenarios. Avoided emissions can never be subtracted from Scope 3 emissions and need to be reported separately.

Avoided emissions are not recognised as a separate scope. However, they **provide interesting information to assess the potential of the local waste management activities to reduce global GHG emissions**. They refer to GHG emissions that are reduced by third parties using products or services resulting from the waste management activities, in replacement of a more 'carbon-intensive' solution providing an equivalent service. In practical terms, avoided emissions are the result of a comparative analysis of emissions between two scenarios: the **solution implemented is compared with a reference scenario** representing the realistic alternative situation. They cannot be subtracted from the organisation's GHG emissions. Avoided emissions must always be **accounted for and reported separately**.

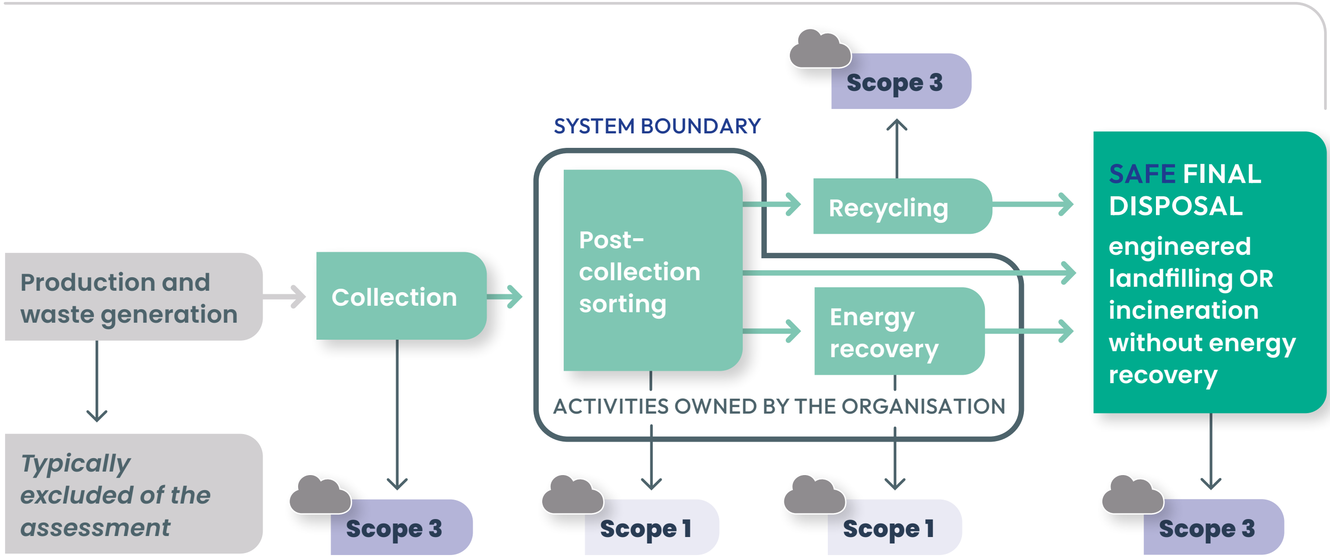
For example, in Limay, France (**Project 5**), a recycling plant receives 45,000 t/year of discarded plastic PET bottles from the selective collection process and sorting facilities. From this feedstock it produces about 41,000 t/year of recycled plastic (rPET)[XLVII]. This project reduces the organisation's GHG

[19] The waste management competency transfer often occurs from a single municipality to a metropolitan area regrouping several municipalities, for instance.
[20] Decree no. 2022-982 of 1 July 2022 on greenhouse gas emission assessments (*relatif aux bilans d'émissions de gaz à effet de serre*).

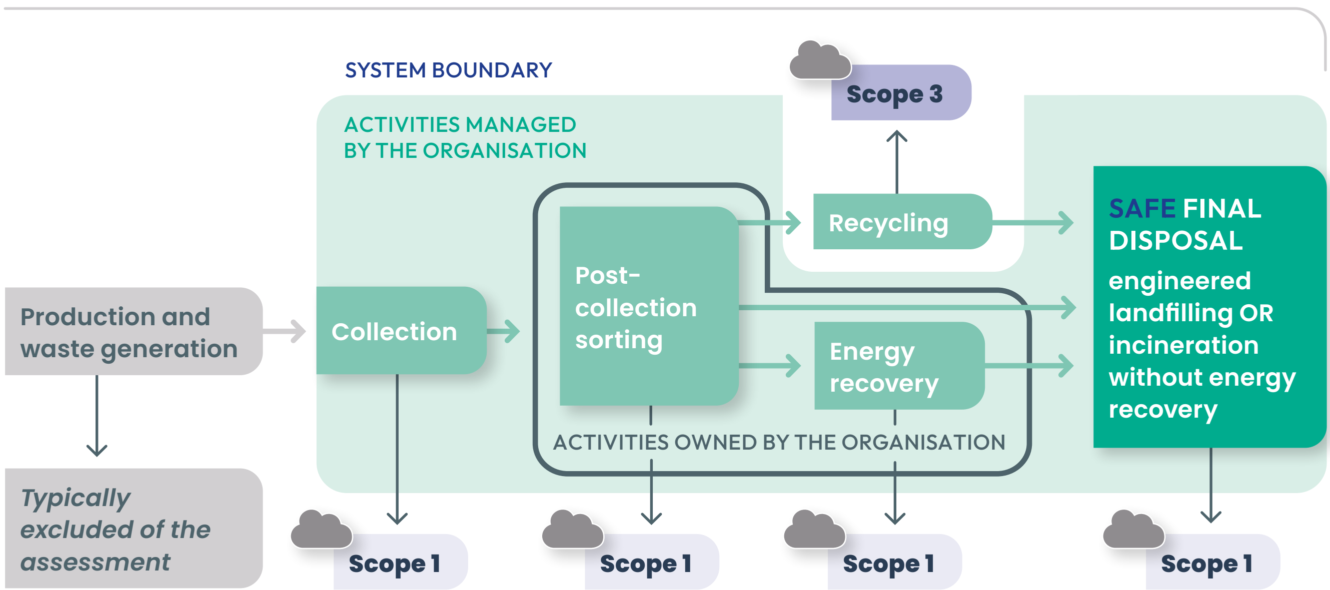
emissions by optimising the efficiency of the process itself (e.g. energy optimisation), and enables avoided emissions by providing the packaging industry with rPET as a substitute for virgin PET. In this project, the produced recycled PET emits 70% less GHGs than virgin PET production. In this case, avoided emissions are calculated based on the use of virgin PET as the reference scenario, resulting in 50 kt CO_2eq avoided emissions in 2022. The plant makes available a low-carbon product to third parties. It can therefore report the difference between the emissions associated to their production process and the emissions of virgin PET production as avoided emissions through a separate line in their annual report.

FIGURE 6 **GHG emissions scopes of each activity depend on the choice of the system's boundaries**

a. GHG emissions using a system boundary based on the financial control by the organisation



b. GHG emissions using a system boundary based on the operational control by the organisation



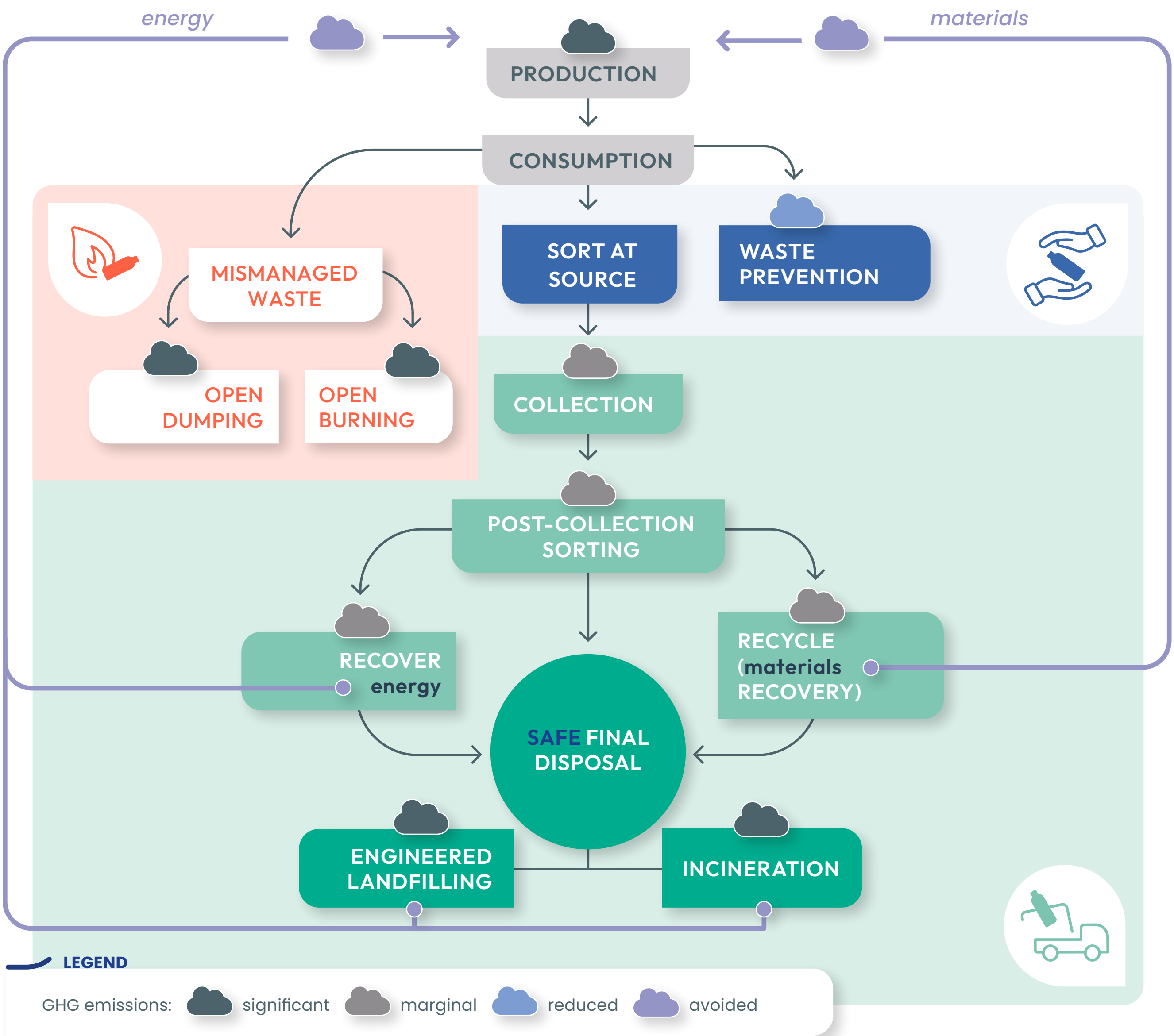
2.3. ASSESSING GHG EMISSIONS OF WASTE MANAGEMENT ACTIVITIES

The waste sector contributes to the climate crisis through its direct and indirect GHG emissions (Scopes 1, 2 and 3). It also has a large potential in reducing global GHG emissions through its contribution to a circular carbon economy[21], and its associated avoided emissions, mentioned in the previous section and illustrated in **FIGURE 7**. However, this section focuses only on the assessment of GHG emissions under Scopes 1, 2 and 3.

The most significant sources of emissions associated to waste management are the following, as represented in **FIGURE 7**:

- Mismanaged waste producing methane, nitrous oxide and black carbon;
- Incineration with or without energy recovery;
- Engineered landfills methane leakage over the lifetime of the landfill;
- Production processes upstream of waste generation. These are usually not accounted for by organisations managing waste, not even under Scope 3 emissions, given both the difficulty to assess and the lack of control over these emissions.

FIGURE 7 GHG emissions throughout the waste life cycle



[21] The circular carbon economy corresponds to the approach of re-using the carbon molecules contained in fuels or products several times before its release to the atmosphere as carbon dioxide, developing ways to capture it after its first life to become a feedstock for different usages, may it be plastics, carbon fibers, or fuels.

TABLE 3 presents a summary of the waste management activities that can lead to GHG emissions, sorted by Scopes 1, 2 and 3 and the ISO emissions categories, which are commonly used for GHG reporting at organisational level. Under each emission source, the assessment consists of a time-bound calculation, usually over 1 year, and based on a method adapted to the available data, following the IPCC three-tier approach (refer to **section 2.4**). The **TABLE 5** in the **ANNEX 1** presents the assessment methods used in France, which are based either on IPCC emission factors, country specific emission factors, or a guidance for a site-specific assessment of emissions.

TABLE 3 **GHG emissions categories, associated waste management activities and possible reduction levers**

SOURCE OF EMISSIONS	MAIN SOURCES	EXAMPLES OF LEVERS FOR ACTION
Direct emissions (Scope 1) occurring during the assessment period		
1.1 **Direct emissions from stationary combustion sources**	Heating of premises using fossil fuels (oil or gas). Fuel consumption by equipment (engines, start-up burners, generators). **Combustion of waste** • CO_2 (biogenic and fossil); • N_2O (negligible when high temperature incineration); • Black carbon (open burning). Combustion of biogas in flare (biogenic CO_2).	• Reduce usage times; • Improve engine energy efficiency and change in motorisation or heating mode; • **Reduce tonnage of fossil-based waste (plastics);** • Store CO_2 from flue gases and exploring its usage for Carbon Capture and Storage (CCUS) projects.
1.2 **Direct emissions from mobile combustion sources**	Movement of vehicles and equipment belonging to the organisation on site and between sites (machinery and light vehicles). Mobile thermal equipment (shredders, bucket loaders, grapples, etc.).	• Optimise travel routes; • Intensify the use of vehicles by approaching their maximum capacity; • Optimise distances between sites; • Choice of engines for mobile equipment.
1.3 **Direct emissions from non-energy processes**	Incineration flue gas treatment (N_2O). Degradation of organic matter during composting. • Biogenic CO_2; • N_2O, CH_4 (if fermentation of the material is not well controlled).	• Furnace management to ensure the most complete combustion possible (temperature, mixing of inputs); • Good knowledge of the waste flows and proficiency of processes.
1.4 **Direct fugitive emissions**	Air conditioning equipment. Unintentional anaerobic fermentation of the organic fraction of waste (CH_4, N_2O) during temporary storage of waste prior to treatment. **Biogas leaks** from methanisation and **landfill facilities** (CH_4).	• **Eliminate open dumping and open burning;** • **Knowledge of the waste processed;** • **Maintenance of biogas production equipment;** • **Monitor leaks from landfill sites;** • **Quality of landfill operation practices, including the final covers.**

Notes : the optional assessment categories for waste management are shown in grey font. The activities and levers presenting the highest GHG potential are shown in red font.

SOURCE OF EMISSIONS	MAIN SOURCES	EXAMPLES OF LEVERS FOR ACTION
Indirect energy-related emissions (Scope 2) occurring during the assessment period		
2.1 **Indirect emissions from electricity consumption**	Energy consumption for the operation of buildings, plants, sorting sites, vehicles and electrical equipment.	• Reduce electricity consumption; • Switch to green energy consumption.
2.2 **Indirect emissions from energy consumption other than electricity**	Heating network supplying the buildings and the process.	• Switch to green energy consumption.
Other indirect emissions (Scope 3) occurring during the assessment period		
3.1 **Upstream freight**	Transport of waste-to-waste collection centres and voluntary drop-off points using vehicles not belonging to the organisation (contracted out).	• Reduce volumes, modify motorisation and transport mode, and reduce distances through strategic land planning and of the location of infrastructures (waste collection centres, recycling industries, etc.).
3.2 **Downstream freight transport**	Transport of subcontracted products (slag, rejects, sorted materials, etc.) using vehicles that do not belong to the organisation.	
3.3 **Commuting to and from work**	Transport of the entity's employees to and from work.	• Reduce the distance and frequency of journeys; • Promote soft mobility through financial levers and necessary development (bike parking...) among others.
3.4 **Transporting users and customers**	Emissions generated by visitor travel (customers, suppliers, school visits, etc.).	• Reduce distances and mutualise transport.
3.5 **Business travel**	Business travel using vehicles not belonging to the organisation (plane, train).	• Reduce the distance and frequency of journeys.

Notes : the optional assessment categories for waste management are shown in grey font. The activities and levers presenting the highest GHG potential are shown in red font.

SOURCE OF EMISSIONS	MAIN SOURCES	EXAMPLES OF LEVERS FOR ACTION
4.1 4.5 **Purchases of goods or services**	Emissions associated with the manufacture of equipment or products required for the activity during the assessed period: • Reagents: flue gas treatment (incineration, co-incineration) or deodorisation; • Pre-collection equipment: bags, bins, voluntary drop-off points, skips, etc.; • Subcontracting (maintenance, works, billing of fees, payroll, project management, studies, etc.); • Consumables: water, office equipment, security, etc. Materials for the works (asphalt, backfill using recycled aggregates, etc.).	• Consume as little as possible (while respecting standards and regulations); • Consume as responsibly as possible (maximise and intensify the use of goods, reuse, recycle, etc.).
4.2 **Fixed assets**	Emissions generated by the construction of assets capitalised by the organisation and required for operations over several years.	• **Encourage the use of recyclable and low-carbon construction materials;** • **Intensify the use of facilities** (for example 24/7 vs 16/5).
4.3 **Waste management**	Treatment of operating waste not accounted for elsewhere and not treated internally: refuse, slag and bottom ash.	• Choice of treatment processes for this waste (energy and materials recovery if possible (RDF, residual sodium chemicals, etc.)); • Reduce waste volumes: furnace management, sorting performance, etc.
4.4 **Leased assets**	Leased assets such as vehicles, machinery and computers.	• Intensify the use of assets by approaching their maximum capacity.
5.1 **Use of products sold**	Emissions that occur during the use of products sold or distributed. These products mainly include recycled plastics, compost and digestates, and RDF.	• Establish contracts with companies committed to reducing their GHG emissions.
5.3 **End of life of products sold**	**End-of-life of recycled plastic products.**	• **Apply the 10Rs principle (refuse, rethink, reduce, etc.).**

Notes : the optional assessment categories for waste management are shown in grey font. The activities and levers presenting the highest GHG potential are shown in red font.

In the case of France, the Astee produced a methodological guide[XLVIII] for the French waste management sector to support the assessment of GHG emissions associated with each activity relating to waste management: pre-collection, collection, sorting, and treatment. For each of the potential emissions under each activity, the guide provides possible methodologies that can be used by the organisation to assess its Scope 1, 2 and 3 emissions. The full guide is available online in French and a summary table is presented in **ANNEX 1** (**TABLE 5**).

2.4. METHODS USED TO ASSESS GHG EMISSIONS

This section presents four main approaches to assess GHG emissions: the internationally recognised IPCC Guidelines, organisational reporting **methods defined at national or international level, Life Cycle Assessments (LCA), and carbon trading.** The methods are all anchored in the same science but differ in the way they deal with limited data availability and the related assumptions made to assess emissions. They also differ on the system boundaries from the narrowest with the IPCC Guidelines to the widest with the LCA approach.

The Paris Agreement made GHG assessment and reporting a legal obligation for all State Parties, which have to prepare national inventories based on **the IPCC method**. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories provide an assessment methodology based on a **three-tier approach** to enable increasingly accurate GHG emissions assessments depending on data availability. In general, a single global emission factor is proposed for Tier 1, a country-level emission factor is proposed at the Tier 2 level, and Tier 3 is most accurate because it is based on site-specific measurements. Volume 5 of the IPCC Guidelines is dedicated to Waste Management and was refined in 2019[XLIX].

Other methods, anchored in the IPCC guidance and science, have been developed to support **organisational annual reporting** used by municipalities, facilities and companies. For example, France has developed the BEGES methodology[L], and the waste sector guidance presented in **TABLE 5**.

The LCA modelling approach is also widely used. It considers all the scopes of emissions, throughout the life of a product, from extraction of raw materials to the avoided emissions from the second life given to these materials. It enables the evaluation of waste management systems and technologies in more depth to orient strategic decisions in investments or operational actions such as identifying alternatives to prevent plastic waste. It is recognised as a standardised method, which assesses the environmental impacts, beyond the only indicator related to global warming, associated with waste management. The **US EPA WARM** and the **Canadian IWM** are examples of LCA models. However, LCA modelling requires a lot of data and assumptions made when data is unavailable have to be carefully considered.

Finally, **carbon trading** certified companies have developed methods to assess and certify emissions reductions or sequestration. The certificates received may be traded in carbon markets (refer to **Chapter 5** for more details on this mechanism).

The quality of the assessment depends on the quality of the input data. Current reporting on waste management activities suffers from a lack of data availability, accuracy, transparency, and standardisation[22]. This weakens the sector's global advocacy and may result in misleading conclusions on the best GHG reduction levers. Ongoing work aims to develop new methodologies[23], **harmonising data** and collecting **more local and context-based data**. Data drives sound decision making on mitigation actions and creates a safer investment environment.

Chapter transition

GHG assessment methodologies are in place and able to guide decision makers at identifying the largest emission sources. These methods are designed to allow for an assessment using assumptions based on the local context when actual measurements are not available. However, the more accurate the data, the finer the conclusions may be to adjust mitigation actions and enable the monitoring of the impact of these actions. The next chapter presents the most relevant GHG reduction actions that may be considered in any waste management system GHG reduction plan.

[22] As identified by Maalouf and El-Fadel, aggregated emissions (Tier 1 approach) have a variability ranging from 3 to 65% without standardisation, against 2 to 17% when its parameters are standardised. In. Maalouf, A. & El-Fadel, M. (2019). Towards improving emissions accounting methods in waste management: A proposed framework. *Journal of Clean Production*. Vol. 206, pp. 197-210. https://www.sciencedirect.com/science/article/abs/pii/S0959652618327264?via%3Dihub Last accessed on 11 October 2024.

[23] For example, the SSW management software which is adaptable to specific national contexts. In. Maalouf, A. & El-Fadel, M. (2020). A novel software for optimising emissions and carbon credit from solid waste and wastewater management). *Science of The Total Environment*. Vol. 714. https://www.sciencedirect.com/science/article/abs/pii/S0048969720302461?via%3Dihub Last accessed on 11 October 2024.

3. Technical Actions to Reduce GHG Emissions

The waste sector climate mitigation actions consist of 1/ reducing GHG emissions under each of the three scopes discussed previously, and 2/ providing low-carbon services or products (assessed under avoided emissions), which enable third parties to reduce their own emissions.

As mentioned earlier, waste generation prevention is typically not included in the GHG assessment of waste management services, because it is only partially influenced by waste management services. However, given the significance of the GHG emissions associated to waste generation, this chapter starts with the prevention lever, followed by measures that fall within the waste management services' full responsibility.

3.1. ACTIONS BEYOND WASTE MANAGEMENT: PREVENTION AND IMPROVED RECYCLABILITY

Prevention depends on the actions of a multitude of players. It is a very complex but powerful lever to reduce emissions in two ways: 1/ through the reduction of the amount of total waste, and in particular the amount of mismanaged waste, and 2/ through the reduction of goods production along with their associated transport and virgin resources extraction.

Like waste prevention, increased recyclability is also out of the hands of waste managers. It is however key to enhance materials recovery and reduce GHG emissions in industrial processes through reduced raw materials extraction. It enables carbon circularity (see **ZOOM 4**).

> Both the prevention and increased recyclability levers require systemic changes in production and economic models but, up and foremost, they require to on-board citizens into major behaviour changes.

These changes take time.

It is urgent to rethink the production-consumption couple to undertake, in line with SDG 12, a "Do more and better with less" approach based on the 10Rs principle[24]. The associated transformation of the production-consumption system, would not only address the climate crisis, but the triple planetary crisis:

- **Refuse**: avoid producing and buying unnecessary products;
- **Rethink**: questioning the potential environmental impacts of a product throughout its life cycle before producing or consuming;
- **Reduce**: minimising resource use and developing more efficient consumption patterns;
- **Reuse**: reusing products for a second purpose - moving away from an industry based on resource extraction, and from an economy based on planned obsolescence;
- **Repair**: working against the culture of throwing away, both for consumers, and for producers, especially by designing the products that can easily be repaired;

[24] The 10 Rs are: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover.

- **Refurbish**: restoring and modernising an old object to make it as new as possible again, by changing some parts and pieces;
- **Remanufacture**: completely rebuilding an object for refurbishing;
- **Repurpose**: redefine a new destination for the object - creatively finding new uses for items that might otherwise be discarded, thus turning potential waste into a resource.

These first 8Rs are meant to generate less waste upstream, via **decreased consumption**, **extended product life cycle**, and by giving a **new use or life to old products**. The private sector is key in making this transition happen to reduce waste volumes that need to be managed and to reduce emissions associated with the production of goods. **The last two Rs**, "**Recycle**" and "**Recover**" energy, are part of the waste management system and further emphasise the importance of valorising all existing products to **decrease the amount of resource extraction**.

On this last point, **France** has made important efforts to increase its material productivity[25] defined as the ratio between the Gross Domestic Product (GDP) and the domestic material consumption. Between 2010 and 2018, the French material productivity experienced a 12% progression, moving from 2.63€/kg to 2.96€/kg[LI]. Thus, in 2018, generating one euro of additional wealth required 338g of material, against 380g in 2010[LII]. In 2021, the index reached 3.2€/kg[LIII]. This index, though it reflects the decoupling between economic growth and resource extraction, needs to be put in perspective because it depends highly on the variations in construction materials, it does not include imported materials, and it only partially reflects the changes in behaviours of consumers.

Credit : Corinne Trommsdorff.

Integrating these 10Rs allows to define a strategy to move towards a circular economy. **Project 20** has been working on the implementation of a waste management system in the Wémé region, Benin, based on the 3Rs: reducing, reusing, and recycling, to prevent as much waste as possible from entering the waste management system. **Project 5** or **Project 12**, in France focus on the last 2Rs, working on continuous improvements to increase the proportion of recycled materials which can be extracted from a waste stream.

To internalise and apply these principles, **awareness campaigns and general public mobilisation** play an important role. **Education** from the smallest age also contributes to improve consumers behaviours. **Evidence-based information and transparency** develops trust with the general public or economic players. Projects such as **Project 9**, in France or **Project 15**, in Bolivia working on data collection support these awareness campaigns.

[25] Article 74 of Law n°2015-992 of 17 August 2015 *relative à la transition énergétique pour la croissance verte* (on the energy transition for green growth) sets a goal of a 30% material productivity increase between 2010 and 2030, to reach 3.42€/kg.

Beyond the transformation of production systems, and the education of users, **prevention also requires transitioning economic models**. To support the transition to a true circular economy, several governments explore the transition to a collaborative economy[26] and an economy of functionality[LIV], in which individuals share goods, no longer buy or own an object, but buy the service provided by the object or good, thus intensifying and mutualising its usage. These new economic models favour cooperation between territorial actors and may be developed in alignment with a just transition. Changes to economic models require the involvement of all stakeholders, from public and private sectors, but also from formal and informal sectors.

The informal sector in many places around the world plays a crucial role in recycling. The informal waste workers are structured in a multitude of ways and mostly involve women playing a key role as street collectors and recyclers. For instance, as illustrated by **Project 14**, in Hà Nôi, Viêt Nam, the informal waste sector collects 20% of urban waste, which they then recycle. **The informal waste sector worldwide is often involved in waste collection, sorting, recycling and reuse. Improving working conditions is crucial to reduce pollution, health risks and gender inequalities for workers and inhabitants, as well as to contribute to reducing GHG emissions through improved operations.**

ZOOM

4

Plastics and the transition towards a circular carbon economy

Carbon circularity, or circular carbon economy, aims at technically recovering the carbon molecules, reusing them as an input in the production of new products, recycling them into bioenergy through the natural carbon cycle, and removing any remaining excess from the atmosphere by storing it[LV]. Carbon circularity is based on the idea of reusing carbon molecules as many times and as long as possible, but also needs to be tied to a circular economy. Indeed, carbon circularity requires having markets, prices and economic actors running their business. An example of carbon circularity is French **Project 5**, where recycled PET is produced, preventing the extraction of fossil carbon, and retaining already extracted carbon molecules in the economy. Another example is the R&D **Project 19** in France, where the carbon molecules from fossil and biogenic origin, have been used once to produce goods, a second time to produce energy in the incinerator, and a third time to produce algae that can serve as a base to produce plastics. Other projects use algae to produce biofuels.

3.2. ESTABLISHING A SOUND WASTE MANAGEMENT SYSTEM

Beyond waste generation prevention and reduction, the main GHG mitigation levers within a waste management operation are 1/ **reducing open burning** and uncontrolled combustion that produce black carbon[27]; 2/ **improving organic waste management** to reduce methane emissions, and 3/ **reducing the proportion of plastic waste** fed to Waste-to-Energy (WtE) projects **to reduce fossil CO_2 emissions**. Solutions and project examples are presented in this section. However, not all solutions are appropriate for a given local context. Each approach should be carefully analysed by local policy makers and project designers, considering context-dependent factors such as social, demographic, economic, infrastructural institutional and geopolitical. Only solutions adapted to the specificities of the local context will be viable and sustainable on the long term.

[26] Collaborative economy is defined as "*a practice that increases the use of a good or service, by sharing, exchanging, bartering, selling or renting it, with and between private individuals*." In. Gouvernement. (2019). L'économie collaborative. *Ecologie.gouv.fr*. https://www.ecologie.gouv.fr/politiques-publiques/leconomie-collaborative Last accessed on 11 October 2024.

[27] Open burning of waste not only generates black carbon emissions, but also fossil CO_2 emissions when plastic is burnt.

3.2.1. Reducing black carbon emissions through improved waste management services made accessible to all

Credit : Ludovic Piron.

As mentioned in **ZOOM 2**, black carbon results from open burning of waste which commonly takes place when waste management systems are lacking. When there is an absence of adequate collection services, open burning happens on the side of roads, in people's backyard, or on the edges of villages and neighbourhoods. In case of insufficient treatment capacity, open burning also happens regularly on open dumps and poorly managed landfills, to which waste is brought by collection services. **Preventing black carbon emissions requires providing all human settlements with an alternative to open burning and dumping, whether in low density population areas or cities**. For example, **Project 20** introduced a Clean School Operation in Benin to reduce open burning of waste. Mbarara City's **Project 21**, Uganda, inferred an estimated diversion of 26% of the generated waste from open burning.

Moreover, preventing open burning not only reduces black carbon emissions, but also delivers significant health benefits by decreasing the release of hazardous chemicals, such as dioxins and furans, persistent organic pollutants (POPs) targeted for control under the Stockholm Convention[LVI].

Providing an alternative to open dumping and open burning requires establishing a sustainable waste management system in line with the concept of waste treatment hierarchy[28]. This is a complex task, which relies on five "support mechanisms" each involving stakeholders at different levels, as illustrated by **FIGURE 5** and **TABLE 2**. In places where waste management systems are under-developed, it is necessary to first prioritise the development of infrastructures for the collection and safe final disposal of all waste. The more the collection services become established, the easiest it will be to enhance the source-separation and recycling activities. For this to work, well-functioning waste collection services must be in place, the collected waste transported to these final disposal facilities, and land needs to be reserved for the transfer stations and disposal sites to be in adequate locations. A safe final disposal may be an engineered landfill or an incinerator, operated and maintained to protect human health and the environment. All this is a major challenge in most emerging economies. Frequent hindrances are land availability and the complexity of the collaboration between governance layers, ranging from community leaders to regional or national institutions. However, setting up this safe final disposal system is a crucial step to eliminate open burning and the associated GHG emissions. **Project 13** in Togo or **Project 16** in Senegal are examples of a holistic planning approach to provide a sustainable alternative to open dumping and open burning. **Project 21** successfully managed to reduce the amount of openly burned waste and to holistically improve waste management by adopting a multi-stakeholder approach. The project not only worked on raising awareness among citizens, policymakers and other stakeholders, but it also advocated for public policies preventing open burning and improving collection services, and it provided training to company leaders as well as informal workers to improve waste management as a whole.

> Once a waste management system is functional, **GHG emissions can be assessed and further mitigation actions,** beyond the elimination of open burning and open dumping, **can be planned**.

The implementation of technical levers to reduce methane and fossil carbon emissions from the waste sector, are discussed in the next sections.

[28] The waste treatment hierarchy: prevention (Priority 1), waste valorisation (Priority 2) and elimination (Priority 3)

3.2.2. Methane emissions


Credit : Corinne Trommsdorff.

The most pernicious GHG emissions from the waste sector are methane emissions, as they occur when waste is not managed, or not managed properly. When the **organic fraction of waste is piled up unaerated, it ferments** and generates methane emissions. The first step is therefore closing open dumps as mentioned in the previous section, first by implementing waste diverting measures, then through a gradual phasing-out of existing dump sites in favour of properly managed disposal sites, with adequate planification including technical, environmental, economic and social considerations[LVII]. These engineered landfills must include a prompt installation of the final cover. Indeed, even when organic waste is diverted from landfills, there remains an organic fraction in the landfilled waste that will generate biogas containing methane. Designing landfills for this gas to be captured is key to preventing methane emissions. It also opens a business opportunity to valorise the recovered biomethane, should the local infrastructure allow it.

For the organic waste diverted from dumping or landfilling, two main approaches are available for low-GHG emissions: 1/ **Collecting a sorted-at-source organic fraction of waste to transform it into a soil amendment or animal feed**, or 2/ **transforming organic waste into energy**. These approaches are complimentary for optimal valorisation.

This section presents in more depth how organic waste can be managed both to reduce methane emissions and enable avoided emissions. The previous section already covered the need to put an end to open dumping, resulting in methane emissions.

Therefore, this section reviews three other levers of action: 1/ the recovery of carbon and nutrients, 2/green energy production, and 3/improving landfilling practices. Each of these require **careful territorial planning and governance to establish the necessary infrastructures and enable to** make use of the recovered organic matter, biomethane, heat or electricity, working in collaboration with **the agriculture or industrial sector.**

Recovery of carbon and nutrients: conversion, valorisation and circularity

Carbon and nutrients may be recovered through the transformation of organic waste into **organic matter, fertiliser or protein feed**. This is aligned with the waste treatment hierarchy and can be **combined with energy recovery**. For a safe nutrient recovery, **separation of organic waste at home or in restaurants** is key to avoid having a polluted organic matter feedstock. This requires communication efforts to create a culture among users to properly separate and sort their waste.

Project 1 in China presents an example where restaurant food waste is collected and brought to an anaerobic digestion facility producing biogas for heat and power co-generation. This project enables green energy production, contributes to local job creation, and significant GHG emissions reduction of -70 ktCO_2eq per year compared to the pre-project situation.

In the case of **Project 2**, in France, on-site composting, door-to-door collection and voluntary deposit sites, aim to divert the organic fraction of waste from incineration with energy recovery to produce biogas and fertilisers in a methaniser facility under construction. This project doesn't reduce methane emissions but enables avoided emissions through the recovered soil amendment and biomethane. Another example of nutrient recovery is **Project 4** in Canada which produces biochar, used to regenerate the soils' organic content. Biogenic carbon is sequestered into soils and bioenergy is produced via pyrolysis of the unused biomass.

R&D projects are exploring the potential of Black Soldier Flies (BSF) to produce animal feed for pets or livestock. When at a larval stage, BSF eat an amount of organic waste equivalent to their weight. These flies are then killed at the larval stage and converted into protein feed.

Green energy production

Organic waste can be used to **produce green energy**. The fermentation of organic waste happening naturally in open dumps can be controlled in an industrial facility to intentionally produce biogas that is captured to be used as a source of energy. This biogas may be purified into biomethane to be injected in a natural gas distribution grid or compressed into liquid fuel. When not purified, it may be burnt on site to produce heat and electricity through a combined heat and power engine, as in **Project 1**, China. Other, more technically advanced processes such as Pyrogazification (see **Project 3**) will produce a **combination of syngas, heat and electricity**. **Project 24**, in India, processes and converts source separated organic waste into compost and biomethane. The green energy produced could fuel the equivalent of 450 buses.

The lower grade organics or polluted feedstocks can either be treated in incinerators or combined into Refused Derived Fuel (RDF)[29] bricks if dry enough. This polluted feedstock will then produce heat that can directly be used by industries and in district heating. **Project 12** in France has diverted most of its organic waste from landfills to a dual methaniser system: one line dedicated to a clean source-separated feedstock, and another one dedicated to the organic fraction of Municipal Solid Waste (MSW) from biomechanical sorting. The clean feedstock produces biomethane and a fertiliser that is land applied. The polluted feedstock is transformed into biomethane, and dry organic residual is incorporated into the RDF production.

Landfill operation and management improvement: reducing methane leakage and recovering biomethane as green energy

This third lever of action relates fully to methane emissions reduction, while opening the possibility of leveraging avoided emissions through the recovered biogas. Improved **operation and management** of engineered **landfills reduce methane leakage** and enable the **recovery of biogas** as a green energy. The organic waste that could not be diverted towards options 1 or 2 listed above is taken to landfills, which may range from a poorly managed stockpiling of waste to an engineered landfill[LVIII]. Good operating practices such as in **Project 7** in Muscat, Oman significantly reduce methane leakage. Increasingly advanced operating practices allow for energy production, such as in **Project 12** in France, and **Project 17** in Meknes, Morocco. Innovative technologies such as **Project 6** enable to clean the biogas to a high grade biomethane to enhance the energy recovery potential. This technology couples membrane filtration and cryogenic distillation to recover landfill gas, turning it into grid compliant biomethane. Since 2017, the biomethane produced by this technology has avoided 142 ktCO_2eq emissions, compared to the use of natural gas. The biomethane can be used as **green fuel for transport and industry**, when not injected in the **national gas grid**.

To recover the biogas, engineered landfills have to be designed and operated with state-of-the-art practices, which allow to capture approximately **80% of the biogas** produced over a 50-year period (slow decomposition). The remaining 20% leaks to the atmosphere[LIX]. These state-of-the-art practices are as follows:

- **a.** An anticipated capture system during the operating phase;
- **b.** Prompt installation of the final cover and capture system, with use of an impermeable cover;
- **c.** Operated as bioreactor, keeping optimal humidity to accelerate methane production once the biogas capture system is in place;
- **d.** Adequate maintenance and reporting;
- **e.** Enhanced recovery of captured gas, and;
- **f.** Treatment of residual methane emissions throughout the waste decomposition process[LX].

Measures "**a**" and "**b**" are the most relevant mitigation measures. Measure "**a**" is relevant because a large fraction of the biogas is produced in the first few months on the landfill[LXI], while the cells are in operation. Measure "**b**" prevents the methane from slowly leaking to the atmosphere over the following 50 years. The other measures are more about harnessing energy capture, which is a way to make the project economically viable. At the minimum, all landfills should be equipped with **a biogas capture and flaring system to prevent methane emissions. Leveraging energy production can be done at a later stage**.

[29] According to ISO/TR 21916:2021, RDF are solid wastes used as a fuel that do not meet the criteria of ISO 21640 to be classified as "solid recovered fuel". RDF contains high calorific fractions but has not been processed as extensively as required under ISO 21640. For clarity purposes, and according to the commonly used language, this publication only and indiscriminately refers to RDF.

3.2.3. Fossil CO_2 emissions

Credit : Marcin Jozwiak, *Unsplash*.

Fossil CO_2 is emitted through two main sources in the waste sector: 1/ the **use of fossil-based energy** to implement waste management activities (relatively low GHG emissions), and 2/ the **combustion**[30] **of waste**, which generate high GHG emissions, even if these are not accounted for under the waste sector emissions of national reporting when energy is recovered (refer to **Chapter 1**).

Given that the topic of putting an end to open-burning of waste is covered in **section 3.2.1**, this section presents three main action levers to reduce fossil CO_2 emissions: 1/ reducing fossil-based energy use, 2/ reducing fossil CO_2 emissions from incineration, and 3/ sequestering carbon.

Reducing fossil-based energy use for all waste management activities

Waste management activities include energy intensive tasks. These encompass long collection routes, the transport of recyclables (both feedstock and products), and the energy requirements for all facilities (sorting, recycling and elimination). **Optimising the energy use** of all these activities reduces fossil CO_2 emissions associated with fossil-based energy sources. The other lever is to **switch to renewable energy sources**, which might be produced on site (biogas) or purchased (green electricity, biofuels). The intensification of the use[31] of equipment allows to reduce the purchase of equipment and their associated Scope 3 emissions.

Reducing fossil CO_2 emissions from incineration

The most significant lever to reduce fossil CO_2 emissions from incineration is to **reduce the quantity of fossil-based products feeding them**. This requires rethinking the design, production, and consumption of goods which will then become waste, as covered in **section 3.1**. Beyond prevention measures, technical innovations such as **Project 9** in France can be used to **monitor the composition of waste**, by assessing the fractions of both biogenic and fossil carbon in incineration flue gas, waste and energy. This monitoring allows identifying possible actions upstream of the waste management system (prevention) and on the post-collection sorting to increase the fraction of recycled plastics versus that which is incinerated.

Another approach is **to capture CO_2 from the flue stack** from incinerators, boilers or co-generation engines. The captured CO_2 can be **used as a carbon base** in the chemistry industry, or algae production as a feedstock to **produce bioplastics**, as in the case of the R&D **Project 19** in France. Still at the innovation stage, this technology may in the future contribute to the circular carbon economy, where the already extracted fossil carbon molecules are given a second life.

In addition, **avoided emissions can be leveraged from the energy recovered from incineration** facilities (or from boilers fuelled with RDF). It can provide steam to public heating networks or industries, as well as electricity. Some industries, such as the cement industry, may directly use RDF as a fuel source. This energy replaces virgin fossil-based energy, therefore contributing to the global decarbonisation. Examples of projects producing energy that would replace previously fossil-based energy supplies include **Project 1** in China, **Project 2** in France, **Project 3** in France, **Project 4** in Canada, **Project 8** in France, **Project 10** in Turkey, **Project 12** in France, and **Project 17** in Meknes.

[30] Waste combustion at high temperature produces only CO_2, whereas low temperature combustion generates black carbon (for example under open burning conditions).
[31] The intensification of use of an equipment means maximising its use, by increasing the number of hours it is used until its end of life. It is part of the strategies to implement a circular economy.

Sequestering carbon

Carbon sequestration occurs when captured fossil or biogenic CO_2 is stored for thousands of years, therefore **removed from the atmosphere**. These are expensive, very innovative projects. The captured CO_2 (from flue stacks) may be **stored in deep-underground or aquifers**. The storage of CO_2 can be done geothermally, as in **Project 11** in Greater Paris, France, with the CO_2 dissolution capacity being higher in cold water, versus hot water. This project will store 300,000 tons of CO_2 in a deep aquifer, 40% of which is fossil. Heat from the geothermal aquifer will be recovered to supply district heating prior to the CO_2 injection in the cooled water. Another approach is to store carbon molecules from waste in materials, as in **Project 22**, in France, which transforms non-recyclable, non-inert and non-hazardous waste into aggregates, for use as construction materials. Its process of accelerated fossilisation generates negative emissions by sequestering more carbon than it emits. **Project 4** in Canada produces biochar which stores in the soils carbon molecules from wood waste.

Chapter transition

Mitigation actions rely on the implementation of Environmentally Sound Management (ESM) of waste, as well as the transition to economic models that fully support waste prevention, materials recycling, and energy recovery. The introduction of such mitigation actions throughout the waste life cycle (from production to treatment) requires strong political will and a commonly harmonised vision. Harnessing waste management as part of the solution to addressing the climate crisis can only be done with clear national and international goals, strategies and standards. In addition, the implementation of an ESM of waste requires sound funding mechanisms, as waste management remains a cost when considering all waste streams together, even when resources are recovered on some of those waste streams.

In the case of France, a decarbonisation roadmap[LXII] was developed in 2022 by the Strategic Committee for the Waste Processing and Recovery sector[32]. It aimed at developing a 3-point roadmap for this sector's decarbonisation: 1/ defining a trajectory for the waste flows[33], 2/ diminution of industrial emissions from the waste sector, and 3/ contribution of the waste sector to the decarbonisation of the economy via efforts to reduce Scope 3 emissions. This roadmap argues that decarbonisation will only be possible with support to infrastructure investments, prevention, improved collection and recycling services, economic and regulatory incentives, as well as more regulated organic recovery, but also through collective effort of all of the stakeholders.

The next chapter presents the importance of investing in policies and regulatory levers to support the implementation of mitigation actions. It starts with a review of international frameworks, continues with the example of France national level policies, before focusing on the economic and fiscal policies needed to support GHG reduction actions in waste management.

[32] *Comité Stratégique de la filière transformation et valorisation des déchets*, CSF TVD.

[33] Trajectory defined in line with current French regulations and, over 2030 - 2050 period, based on some target hypothesis (not defined in regulation yet, or cautious hypothesis given the observed trends). In. FNADE. (2023). *Orientation des flux de déchets à l'horizon 2050. Analyse prospective de la FNADE*. Fnade.org. https://www.fnade.org/ressources/documents/source/1/4866-ANALYSE-PROSPECTIVE-FNADE-D-ORIENTATION-DES-FLUX-DE-DECHETS-A-HORIZON-2050-VDEF.pdf Last accessed on 7 October 2024.

4. The Policy and Regulatory Levers

Public policies set the strategy and the associated regulatory frameworks enabling the implementation of a waste management system that contributes to a low-carbon and more circular economy. A **functioning and sustainable waste management system** can be progressively improved to support higher sustainable development ambitions. There are three key elements to policy and regulatory frameworks supporting waste management systems:

- **Assigning roles and responsibilities** for the prevention, collection, treatment, recycling, and elimination of waste, including providing a frame to public/private partnerships, such as to avoid a collectivisation of costs and the privatisation of profits;
- **Defining the administrative, financial, and fiscal resources** associated with the assigned responsibilities, as well as providing the financial incentive frameworks to drive the change defined in the strategy;
- Establishing **minimum environmental and health protection standards** along with technical guidelines for implementation, rigorous monitoring and reporting, as well as an independent regulator to enforce the set standards.

On the latter point, enforcement requires a robust legal framework and effective mechanisms to address the cause of potential violations. For example, sanctions for illegal dumping or open burning should differ if the violations result from a lack of infrastructure to properly dispose of waste, or a lack of acceptance of the service fee.

The development of waste sector public policies relies on national and local politicians with a strong vision and political will, supported by a handful of citizens, scientists, or operators championing the change needed. International frameworks reinforce or inspire these politicians and champions. Successful national or local policies are anchored in the reality of the local context, recognising the maturity level of the local administration, staff capacities, and citizens involvement. They propose a **stepwise approach** to achieve the **long-term vision from this starting point**.

This chapter presents the impact of the Paris Agreement as an international framework, the European regulatory frameworks regarding waste management, followed by the case of the French regulatory framework highlighting its incremental changes. It ends with an overview of economic and fiscal policies that support waste management.

4.1. INTERNATIONAL FRAMEWORK: THE PARIS AGREEMENT

International frameworks shape the global vision which is then translated into national level strategies and local action.

The main international framework shaping mitigation actions, not specific to waste management, is the 2015 **Paris Agreement**. It's a landmark **legally-binding** international agreement, introduced during the COP-21[LXIII], which marked a decisive turning point in climate change action worldwide. It drives global action to reduce GHG emissions in all sectors, based on the national commitments made under the Nationally Determined Contributions (NDCs), which have also triggered private sector commitments at company or sector level.

The Paris Agreement is considered as the **first universal agreement** on climate change which has fostered international awareness and some political actions. The Agreement defines core principles and frameworks, such as **common but differentiated responsibilities**[LXIV], or the **transparent communication of NDCs** by each State Party[LXV] to collectively work towards a maximum temperature increase of *"1.5°C above the pre-industrial levels"*[LXVI].

NDCs, whether committed as unconditional, which is the case of all developed countries, or "conditional" to foreign support and investment, may **drive the development of national Waste Management Plans**, and the implementation of local actions.

4.2. EUROPEAN UNION FRAMEWORKS

In the EU, member States have a **legal obligation to adapt** the EU Directives into their national legislation. There are three main recent European directives on waste management and GHG emissions[LXVII]. The first one is the directive (EU) 2018-851[34] which defines the **waste treatment hierarchy, confirms the polluter pays principle**[35]**, and introduces the Extended Producer Responsibility (EPR)** concept. The second directive is the 2018 RED II Directive[36] which **imposes GHG emissions reduction criteria**, and aims at ensuring the renewable character of produced energy, especially from the waste sector. It encourages the production of biofuels from waste residues and non-food feedstocks. The EU directive of 10 May 2023[37] opens the discussion on **the inclusion of municipal waste incineration plants** into the EU Emissions Trading System (EU ETS) as of 2028 (and 2031 at the latest). This would significantly increase the cost of incineration and consequently the total cost of waste management for cities which have invested in such infrastructure.

When it comes to GHG emissions, about 20 legislative texts and measures exist to achieve the "Fit for 55" package goal of a **net 55% reduction of GHG emissions by 2030** compared to 1990, to eventually reach European **carbon neutrality by 2050**[LXVIII].

[34] Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. This directive was adapted to the French context by order n°2010-1579 of 17 December 2010 and by decree n°2011-828 in July 2011.

[35] First recommended by the OECD in 1972 (In. Recommendation of the Council on Guiding Principles concerning International Economic Aspects of Policies, OECD/LEGAL/0102, of 26 May 1972, abrogated on 08 November 2023), and enshrined since 1987 in the EU Treaty.

[36] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable resources, called RED II. Revised version of the 2009 RED. Adapted into French law by order no. 2021-235 of 3 March 2021.

[37] Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC establishing a scheme for greenhouse gas emission allowance trading within the Union and Decision (EU) 2015/1814 on the establishment and operation of a market stability reserve for the greenhouse gas emission allowance trading scheme of the Union.

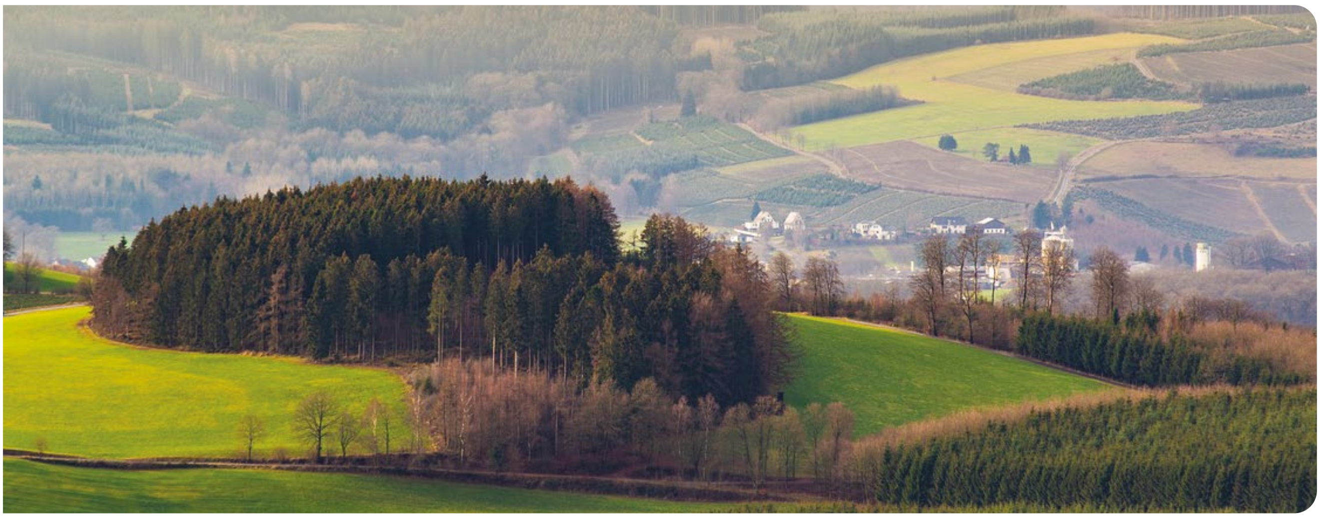
4.3. THE CASE OF FRANCE: WASTE MANAGEMENT REGULATORY FRAMEWORKS AND PUBLIC POLICIES DRIVING GHG REDUCTIONS

This section provides an example of how a **national framework evolves over time, in line with the global vision and goals**, through the case of France. The national framework sets strategies to achieve climate change mitigation goals, fiscal frameworks allowing for these strategies to be viably implemented, as well as assign the roles and responsibilities of each stakeholder for a coherent and functional system.

The French waste management system, as it currently exists, started coming about in 1975, with the **15 July 1975 Law no. 75-633**[38], and has since then been guided by a dynamic of **decentralisation**, transferring the **financial and operational competencies** to local authorities for the implementation and operation of local waste management systems. This enables local authorities to implement a cost recovery approach for waste management activities. **In France**, the total cost of waste management was estimated at about 19.6 billion euros in 2021, or 0.8% of the French GDP[LXIX]. Law no. 75-633 was abrogated in 2000, as the ***Code de l'Environnement*** (Environment Code) took over the waste sector regulation, establishing the **waste management hierarchy** in line with the European and global vision: prevention of waste, reuse, recycling, energy valorisation, and finally, elimination[39]. The Environment Code has evolved overtime to include any new environmental regulation introduced in France to drive GHG reductions in general, and in the waste sector, as summarised in **FIGURE 8** and **ANNEX 2**.

French public policies drive GHG emissions reduction in the waste sector by setting targets and strategies that require innovative and systemic changes in the management of MSW. International regulations have been crucial to make these changes possible, by setting ambitious climate goals and developing a joint vision between countries. These ambitions are the result both of bottom-up national diplomatic advocacy, and of top-down harmonisation of international goals and commitments.

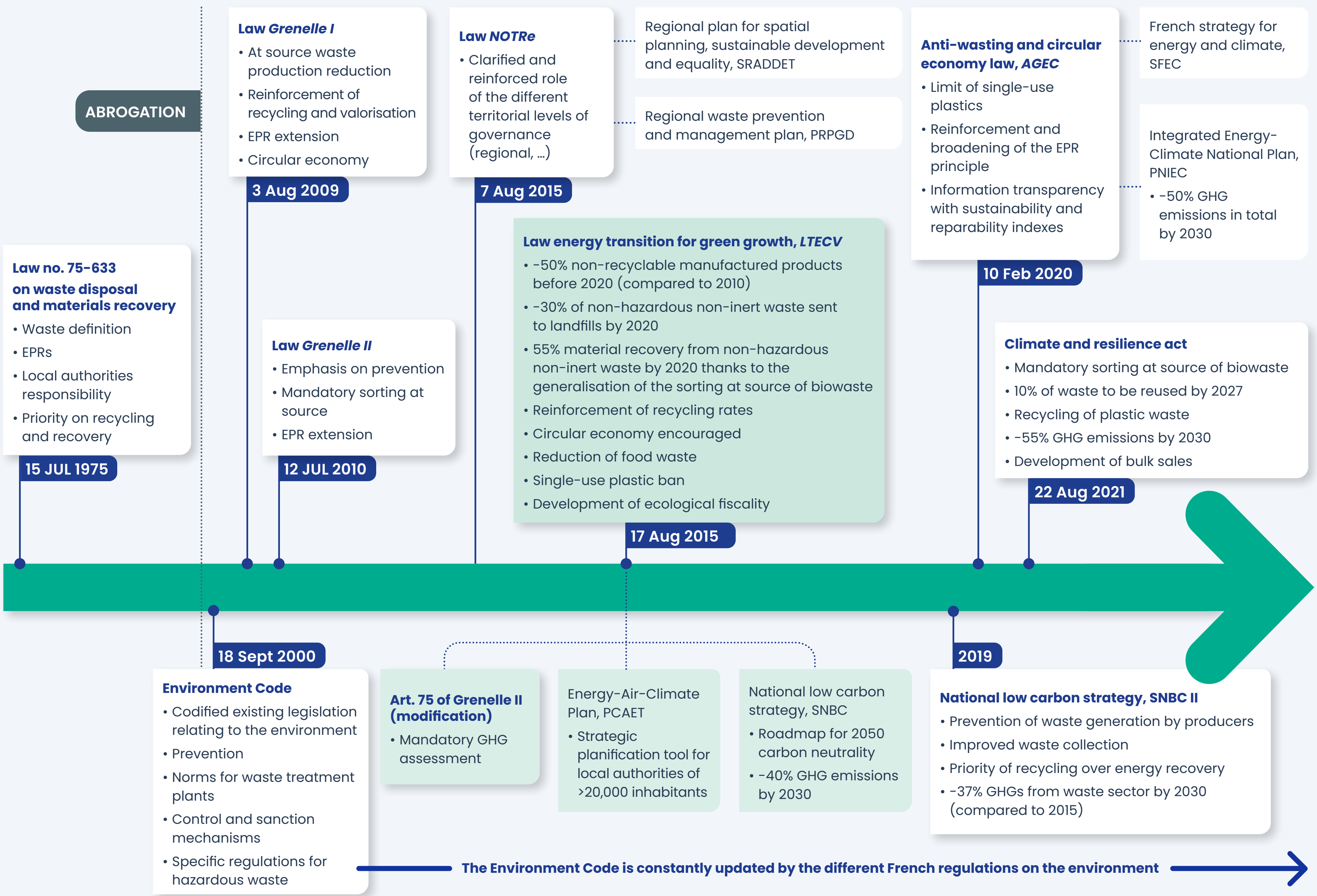
A well-functioning waste management system requires a cost recovery approach. Therefore, the national regulations have to include mechanisms for local authorities to recover their operating costs. Appropriate taxation and fiscal policies support a sustainable waste management system and the implementation of the environmental transition ambitions.



Credit : EvgeniT, *Pixabay*.

[38] Law no. 75-633 of 15 July 1975 on waste disposal and materials recovery (*relative à l'élimination des déchets et à la récupération des matériaux*).
[39] Article L. 541-1, Environment Code.

FIGURE 8 The French regulatory framework driving the transformation of waste management to prevention and resource recovery



4.4. THE KEY ROLE OF ECONOMIC AND FISCAL POLICIES TO FUND WASTE MANAGEMENT SERVICES

A waste management system requires funding schemes to cover its operation and investments costs.

These include building human capacity, infrastructure requirements, operations, and the organisational system needed for stakeholders to play their respective roles, including enforcement and compliance. Economic and fiscal policies define the funding sources and instruments that may be used within a country, as well as the conditions under which international funding sources may be accessed.

The **cost recovery approach** can be based on a combination of 1/ sustainable business models around materials or energy recovery, which can motivate private investment, 2/ service fees or a tax system to cover the operational costs that cannot be profitable, and 3/ bonus-and-penalties approaches to incentivise eco-design and waste prevention while covering treatment costs. These approaches all have to be adapted to the local context. For example, a service fee should only be implemented if the local context prevents a massive shift towards uncontrolled waste dumping or open burning, by those not willing to pay the fee. It needs to be supported by community leaders who can support the users' mindset shift towards paying for waste disposal.

In the case of France, the household waste service fees can be levied in two ways: 1/ the household waste collection tax (TEOM) which is paid annually by the property owner, 2/ the household waste collection fee (REOM) for the household's tenant, fully or partially based on their actual usage of the collection services, which is determined by the local authorities[LXXI].

Beyond providing funding sources for the waste management system, some economic instruments can be used as **incentives to trigger changes** along the whole industry chain or consumers towards enhanced prevention, reduction, collection, recycling, recovery and safe final disposal. Examples of such instruments are as follows:

- Incentive-based service fees that incentivise consumers to reduce waste volumes. An example of such a fiscal measure for highly sensitised communities is the pay-as-you-throw instrument (PAYT), which consists of applying a tax based on the weight or volume of the waste generated by households or companies[LXXII]. **Project 23** provides an example of PAYT model.
- EPR schemes, as described in **ZOOM 5**.
- Landfill and incineration taxes may be applied to waste landfilled or incinerated without energy recovery. This type of tax is an incentive to transition to circularity, but it needs to be carefully implemented to prevent the transfer towards open dumping.

Funding mechanisms for waste management that are based on the polluter pays principle (e.g. EPR) are a means to **make the environmental impacts economically visible to producers and to consumers**. This mechanism can only be set at state, national or supra-national level, and should earmark collected funds towards actions that reduce environmental impacts of waste management. **In the EU, much effort still needs to be done for polluters to really bear the induced costs on health and the environment**[40](also referred to as externalities). These costs are most often not included in the price of the produced goods and services. In the EU, in average over all sectors, only 44% of the €720 billion per year of these induced costs are internalised (i.e.: paid for, via taxation or other economic instruments to manage these impacts). When zooming in on waste treatment only[41], less than 1% of these induced costs are covered by existing economic instruments across the EU[LXXIII]. In other words, the remaining **99% of the induced health and environmental costs induced by waste management activities are not paid for**, and the impacts are therefore carried by the whole of society or remain to be addressed in the future.

[40] Here, air pollution and GHG emissions, water pollution, waste management, water scarcity, and biodiversity lost are included in the term external environmental costs. In. Mottershead, D. *et al.* (2021). *Green taxation and other economic instruments*.

[41] This data excludes revenues related to the waste collected by other actors than national governments. It should also be noted that the biggest contribution to these external costs relate to industry (with a total external cost of €186,056m/year), while households are those who internalise the most these costs.

ZOOM

EPR

In the 1980s the Organisation for Economic Cooperation and Development (OECD) introduced[LXXIV] the concept of EPR to extend the polluter pays principle. Since then, EPR has evolved to aim at **incentivising eco-conception** of goods via a contribution by the producer depending on the quality (recyclability, reduction of toxicity…) and on the quantity (reduction of the weight or volume) produced. It also aims to support consumer awareness raising and the establishment of a circular economy. It provides a shift in the financial and juridic responsibility from the waste operator to the producer.

Credit : recyclind, *Pixabay*.

In the case of France, **producers** have a **legal obligation to contribute or ensure the management of end-life products**. This can either be done collectively via the mutualised funding of certified eco-organisms, or individually. EPRs can either be financial, operational or mixed[LXXV]. The principle of EPR exists since 1975[42]. By 2025, about 25 EPR schemes will be functioning, resulting from both French and European law, in addition to voluntary schemes[43]. However, the goal to reduce volumes or weight of waste has faced some challenges[44]. The development of EPRs has led to an increase in recycling. However, there is an important potential to improve, with 40% of the wastes included in the many EPR schemes still not being collected through source separation or post-collect sorting, and 50% still not being recycled[LXXVI].

EPR schemes have to be designed and evaluated to prevent waste production, increase the recyclability of products, and finance the collection, sorting, recycling and final elimination of remaining waste[LXXVII].

Fiscal and economic measures are a powerful tool to make waste management projects and systems viable, and to prevent waste generation. However, it is challenging to design these instruments to ensure that **those who pollute the most are those who pay the most**[45], as well as to account for the principles of a **just transition and social justice**. In the last few years these instruments have been evolving to move away from labour taxation, by favouring environment or pollution taxation instead[46]. Green taxation is a crucial lever in promoting an Environmentally Sound Management (ESM) of waste, sustainable growth, and circularity, but the need to broaden and develop such fiscal tools remains. Indeed, existing **economic and fiscal policies in place in many countries only partially support** the development and operation of waste management services. In these countries, the implementation of an integrated waste management system, as well as specific projects aiming at reducing GHG emissions, relies on complementary international financing systems and institutions, as explained in the next chapter.

Chapter transition

Public policies and regulations at international and national levels set goals of climate mitigation and allow the establishment of a common vision amongst all stakeholders. These goals, frameworks, standards and requirements as well as their associated laws, guidelines and roadmaps need to be accompanied by enforcement mechanisms and fiscal policies that allow the effective implementation of sound waste management systems. In order to globally address the climate crisis and reduce GHG emissions, international financing is a lever to support the establishment of waste management locally. The great diversity of types of financial levers, as portrayed in the next chapter, enables the funding of waste management projects.

[42] Codified in Article L. 541-10 of the Environment Code.

[43] There are 2 voluntary EPR schemes: agri-supply products and mobil-homes.

[44] Part of the costs caused by the management of packaging waste are carried by the local authorities rather than the producers, or by the consumers when the producer decides to reflect these costs in the good's price.

[45] This is part of the polluter pays principle, as enshrined in Principle 16 of the 1992 Rio Declaration on Environment and Development.

[46] See Decision no. 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet'.

5. International Financing

National and local governments are the ones best positioned to define sources of funding and assign budgets to waste management investments and operation. However, given the limited funds in many countries, as well as lagging fiscal policies to support waste management operation, the support of **international financing is critical to accelerate the needed transition to Environmentally Sound Management (ESM) of waste everywhere and drive the delivery of significant mitigation outcomes**. International financing relies on numerous mechanisms which we will not explore in detail in this publication. This chapter presents carbon markets in detail followed by an overview of other mechanisms in place with a brief insight on their potential to contribute to mitigation outcomes amongst other outcomes.

5.1. CARBON MARKETS AND THEIR ROLE IN REDUCING EMISSIONS FROM THE WASTE SECTOR

Carbon markets are financial mechanisms that assign a monetary value to reduced or sequestered GHG emissions.

> These mechanisms can direct critical **funds to waste management projects, helping to reduce GHG emissions from the waste sector**, such as methane emissions from landfills.

Projects such as **recycling initiatives, landfill gas capture and recovery, composting and anaerobic digestion**, and **biochar production** can benefit from a range of carbon pricing instruments. Their eligibility depends on the project's size, location, the specific regulatory framework in place, and how they are referred to in a country's Nationally Determined Contributions (NDCs) under the Paris Agreement.

5.1.1. NDCs and access to carbon markets

In their NDCs, countries outline their climate action plans and GHG reduction targets, which can be either "unconditional" or "conditional," as explained in **Chapter 1**. Conditional commitments are to be achieved with external financial or technical support, such as international climate finance.

Waste management projects can leverage carbon market mechanisms in three potential scenarios, based on the country's NDC commitments:

- **Scenario 1: Waste management targets in unconditional NDCs**. If waste sector GHG reductions are part of the unconditional NDC targets, the country is committed to achieving these reductions using its own funding. Carbon market participation in this case is limited to projects that exceed the national targets. Projects that fall short may face financial penalties or carbon taxes, as mandated by national regulations.

- **Scenario 2: Waste management targets in conditional NDCs.** When waste management GHG reductions are part of its conditional NDC, the country acknowledges the sector's potential but lacks sufficient national funding to achieve these goals. In this case, waste management projects can seek carbon market financing for the entire GHG reduction they generate, with external funds helping them meet their targets.
- **Scenario 3: Waste management not mentioned in NDCs**. If the waste sector is not explicitly covered in a country's NDCs, projects in this sector can still access carbon finance for the total GHG reductions they achieve. These projects can be attractive candidates for carbon markets as they represent additional mitigation potential.

5.1.2. Carbon pricing instruments for waste management projects

Several carbon pricing mechanisms can enable waste management projects to generate funding through the sale of emission reduction credits. These mechanisms vary based on how carbon pricing is applied and regulated in different regions.

1. **Emissions Trading Systems (ETS).** ETS is a cap-and-trade system where **companies trade emission allowances**. Many sectors are covered by ETS systems, which account for **18% of global GHG emissions**. The European Union ETS (EU ETS) covers major sectors like power and manufacturing, but municipal waste and waste-to-energy (WtE) facilities have historically been excluded.
2. **Carbon tax.** A carbon tax directly **sets a price on carbon** by defining an explicit tax rate on GHG emissions or - more commonly - on the carbon content of fossil fuels, i.e., a price per tonne of CO_2eq. Unlike an ETS, the emission reduction outcome of a carbon tax is not predefined, but the carbon price is. This means that the tax provides certainty about the price of emissions but **leaves the quantity of reductions to market responses**. South Africa's **Carbon Tax**, introduced in 2019, is **€8 per tonne** in 2023, rising to **€9 by 2026**. It targets **large emitters** and funds **climate projects** like renewable energy. Companies can cut their tax by 10% using approved **carbon offsets**. This encourages investment in local projects and contributes to reduce **emissions**.
3. **Crediting mechanisms.** Three types of crediting mechanisms are available:

Type 1: Regulated global multilateral cooperation mechanisms, such as the Clean Development Mechanism (CDM) of the Kyoto Protocol or the future Article 6.4 mechanism under the Paris Agreement, allow waste sector projects to generate and sell carbon credits. These credits are often purchased by entities looking to meet their emissions reduction obligations or voluntary climate goals. Waste projects, such as landfill gas capture and methane avoidance, are commonly eligible under these systems.

Type 2: Regulated bilateral cooperation enabled by the Article 6.2 mechanism under the Paris Agreement allows countries to transfer carbon credits internationally through cooperative agreements. One country may fund emission reductions in another while counting the reductions toward its NDC targets. This is particularly relevant for waste management projects in countries with conditional NDCs, where external financing can be essential to meeting GHG reduction goals. The KliK Foundation—through bilateral agreements with countries like Morocco and Senegal—supports waste management projects that reduce methane emissions and generate Internationally Transferred Mitigation Outcomes (ITMOs), contributing to the global effort to meet climate goals. For example, in the case of Senegal, which has waste management as part of its NDCs conditional commitments, **Project 25**, as a methane avoidance project, was eligible to receive funding through the carbon market.

Type 3: Global mechanisms outside of the international frameworks, based on the trustworthiness of the carbon standards (such as "Gold Standard" or Verified Carbon Standard, VCS) certify the GHG reduction of a project into a "credit" that can be sold on a Voluntary Carbon Market (VCM). Companies or individuals that voluntarily seek to reduce or offset their emissions can purchase carbon credits from waste management projects. The VCM provides a financial incentive for organisations to go beyond mandatory reductions. It allows waste sector projects, such as methane avoidance projects, that may not qualify under the aforementioned mechanisms to secure funding by generating carbon credits.

TABLE 4[47] summarises the broad types of carbon markets corresponding to the above-mentioned carbon pricing instruments, that can contribute to fund waste management projects reducing GHG emissions.

TABLE 4 **Summary of carbon pricing instruments and their associated carbon markets**

CARBON PRICING INSTRUMENTS	ETS AND CARBON TAX	CREDITING MECHANISMS	
Type of market	**Domestic Compliance Market**	**International Cooperation & Article 6(2) and 6(4) Market**	**Voluntary Carbon Market (international)**
Purpose	Achieving NDCs domestically	Achieving NDCs cooperatively	Making additional contributions to mitigation action
Motivation	Compliance with regulations (ETS, carbon tax)	Increase NDC ambition and flexibility	Going beyond own emissions reductions targets
Buyers	Corporates/entities bound by regulation	Parties (countries)	Corporates/individuals
Units	Emission allowances and offset credits	Internationally Transferred Mitigation Outcomes (ITMOs)	Voluntary credits
Governance	National or sectoral regulations	International oversight and rules	Self-regulation with internationally recognised standards (e.g. IC-VCM, carbon standards)

Carbon markets are an interesting source of funding, both as a way for emerging economies to access international funds and for developed economies aiming to incentivise change in waste management practices through carbon allowances or taxes. However, the funding available through carbon markets remains fairly small compared to the full cost of the waste management projects. Carbon markets apply in the same way to the production sector and to waste management, even though waste management is very different in essence. Prospective international discussions are emerging to develop new mechanisms that could better recognise the mitigation outcomes of an ESM of waste service, considering that the service deals with the output of the production and consumption processes.

5.2. BEYOND CARBON MARKETS: OTHER KEY INTERNATIONAL FINANCIAL MECHANISMS

Significant investments are still required to support the implementation of holistic ESM of waste systems throughout the world. Under a "Waste Management as Usual" scenario, it is estimated that by 2050 MSW will globally cost US$640.3 billion (or about 30% more than in 2020), including US$443 billion in externalities. However, under a circular economy scenario, a full net gain of US$108.5 billion has been estimated by 2050, thanks to the avoided environmental and health costs associated to the extraction of raw resources[LXXVIII]. The key idea is that the important financial gaps to fund both waste management systems and the transition to the circular scenario will actually provide a return of investment, thanks to avoided costs. These investments would allow leveraging the waste sector's full potential mitigation outcomes. However, the current economic models do not allow to account for these indirect forms of return on investments.

[47] Inspired by: Jones, D. *et al.* (n.d.) Introductory Webinar. Article 6 of the Paris Agreement & carbon markets. *United Nations development Coordination Office, United Nations Climate Change, IGES, RCC MENA and South Asia.* Accessed on 7 October 2024. https://unfccc.int/sites/default/files/resource/UN%20DCO%20Webinar%20on%20Art%206%20and%20Carbon%20Markets%2018th%20April%202024%20Final.pdf

A diversity of financial institutions and mechanisms, beyond carbon markets, provide essential resources to fund the necessary **green and just transition, delivering co-benefits beyond mitigation outcomes**.

A few are summarised below:

- **ESG (for Environment, Social and Governance) investments.** ESG finance incorporates environmental, social, and governance factors into investment decisions to promote sustainability and ethical practices. These private investments contribute to mitigate climate change by supporting responsible companies and projects.
- **Green finance**. Green finance focuses on investments in projects that promote environmental sustainability, such as renewable energy and climate change mitigation. It aligns financial systems with global efforts to lower emissions and supports the transition to a low-carbon economy. As a key part of EU green finance, the European taxonomy provides a standardised system to identify sustainable economic activities[48]. It guides investors with criteria aligned to EU climate goals, particularly in areas like waste management, though it controversially excludes incineration with energy recovery.
- **Grants and loans by development banks or philanthropies**. Grants and loans are key financial tools for reducing GHG emissions in waste management, as they support projects aligned with the SDGs and Paris Agreement. Grants provide non-repayable funds for innovative waste reduction initiatives, while loans offer essential support for large-scale infrastructure projects like treatment facilities. For example, the French Development Agency (AFD) supports systemic change in Lomé, Togo (**Project 13**) or in Senegal (**Project 16**) through its investments on a comprehensive waste management system. Philanthropic funding provides flexible resources for research and community-based programs that raise awareness and reduce waste generation. However, challenges remain in accessing these funds, and platforms like the IFC Circularity Plus[LXXIX] can help local stakeholders better navigate funding opportunities to implement more effective waste management systems.
- **Solidarity and cooperation mechanisms involving countries, local authorities or companies**. They provide critical support to local authorities to develop projects or systems that are not always considered as viable enough to obtain grants or loans. They also support projects that are not sustainable enough to be considered as a green bond. Examples of such mechanisms are the Global Environment Facility, the CCAC Trust Fund, the Green Climate Fund, or the AFD. For example, AFD supports the cooperation between local authorities in the South Pacific to prevent the degradation of the environment (**Project 18**). It also supports solidarity projects between local authorities in France and those in emerging economies through the FICOL program. These solidarity and cooperation mechanisms not only facilitate resource sharing and knowledge exchange but also drive systemic changes necessary for achieving sustainable waste management on a broader scale.

The above-listed international financing mechanisms support local authorities' investments in ESM of waste, with GHG emissions reduction being one of the required outcomes. However, they remain insufficient and complex for local project owners to access. In addition, existing mechanisms do not usually support operating costs, which remain a major barrier to the implementation of ESM of waste in many emerging economies. New solidarity mechanisms could emerge in the future, given that the impacts of mismanaged waste are global.

[48] Objectives and criterias for projects to be considered sustainable can be found in Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088.

Conclusion

Solid waste management may only **contribute up to 5% to global GHG emissions** but holds the potential to contribute much higher mitigation outcomes through the transition to a circular economy. GHG emissions can be reduced, sequestered and avoided 1/ through the implementation of local ESM waste systems that prevent open burning and dumping, and that controls methane emissions from biowaste, 2/ through the improvement of existing waste management systems that recover materials and energy, and 3/ through transitioning to a circular economy in which much less waste is produced and goods are produced in a way that allows repairs, reuse, and the incorporation of recycled materials. Such management of waste has the remarkable potential of **reducing global GHG emissions by 20%**[LXXX]. Numerous international frameworks and initiatives have recently emerged to enable the implementation of an ESM of waste.

Defining mitigation actions in the waste sector requires to be able to assess and monitor GHG emissions, in order to set reduction targets. Common efforts are being made to encourage and enable thorough data collection, availability and transparency, to continuously improve GHG emissions assessments. As observed in the case of France, **standardised and adaptable GHG assessment methodologies, accounting for Scopes 1, 2, and 3 emissions, as well as avoided emissions** are crucial to implement the most appropriate waste management GHG reduction levers. These levers include not only practical waste management actions (**Chapter 3**), but also public policies and regulations which enable these actions (**Chapter 4**), as well as international funding that support these actions in emerging economies (**Chapter 5**).

The most impactful mitigation lever is waste generation prevention, but these measures are complex, tied to worldwide economic models, and involve many stakeholders outside the waste sector. As far as practical actions are concerned within the waste management system, **the first level of action** is to establish a **locally tailored ESM of Waste systems**. Having a functioning waste management system in place is **crucial to end open burning and dumping of waste**, which generate black carbon and methane, in addition to the important negative impacts both on health and the environment. **The second level of action is to reduce methane emissions**. Levers to do so encompass recovering carbon and nutrients via the transformation of organic waste into fertilisers, producing green energy, and improving landfill operations and management. **The third level of action is to reduce fossil CO_2 emissions** from incinerated plastic waste by capturing the CO_2 in the flue stacks to sequester it or using it as a base for the chemical industry. The climate impact of incineration plants can also be significantly reduced through the sale of recovered energy, which leads to avoided emissions (see **section 2.2.**), i.e. enabling a third party to reduce its emissions by consuming this recovered energy in place of fossil energy.

Conclusion

Public policies and regulations strongly determine the implementation of such mitigation levers. Indeed, regulations in line with international, national and local political visions and goals **drive and guide change**. International frameworks such as the Paris agreement define **global objectives** and translate them **into national commitments**. National and supranational regulations **legislatively enshrine these commitments** and develop **national and local guidelines or roadmaps** to drive change. **Fiscal policies and economic instruments** derived from regulations are key to locally implement these changes.

The policy framework being still under development in many emerging economies, **international financing**, aligned with international frameworks such as the Paris Agreement and the SDGs provide the necessary incentives for local action. International financing **complements national fiscal policies** through a variety of mechanisms. These mechanisms, if well regulated, can fund local projects to deliver global mitigation outcomes. These include carbon markets, green finance and taxonomies, grants, loans and philanthropic funding, and international cooperation and solidarity.

Holistic sustainable waste management systems implemented worldwide will contribute to addressing both the climate crisis and the SDGs. Establishing these systems everywhere and improving those in place relies on developing waste management plans that include not only the assessment of scopes 1 and 2 emissions, but also Scope 3 (upstream and downstream emissions) as well as avoided emissions, in order to drive the circular economy transition. Including such plans in all of the NDCs at the next round of commitments would be an amazing lever to drive the necessary national policy frameworks and local actions, supported by international financing where necessary.

Waste management can only be efficient in reducing global GHG emissions if all stakeholders are involved, each in their respective roles. This report calls its readers to take action and become champions of the implementation of an ESM of waste locally, as a contribution to global climate and sustainable development outcomes.

Credit : Ria, *Unsplash.*

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[LXXIII] *Op. cit.* Mottershead, D. *et al.* (2021). *Green taxation and other economic instruments.* p. 62.

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[LXXVI] Paugam, A. *et al.* (2024). *Rapport. Performances et gouvernance des filières à responsabilité élargie du producteur.* Inspection générale des finances [N°2024-M-007-04]. https://www.igf.finances.gouv.fr/files/live/sites/igf/files/contributed/Rapports%20de%20mission/2024/2024-M-007-04%20Rapport%20public%20REP_Pour%20internet.pdf Last accessed on 11 October 2024.

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[LXXVIII] *Op. cit.* UNEP. GWMO 2024. p. 41.

[LXXIX] IFC. (n.d.) *Circularity Plus: Accelerating Waste-to-Value Solutions.* World Bank Group. https://www.ifc.org/content/dam/ifc/doclink/2023/ifc-circularityplusprogram-final-sept2023-ifc-2023.pdf Last accessed on 11 October 2024.

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ANNEX 1 Summary of the Astee GHG assessment guidelines

TABLE 5 French guidelines for GHG assessment

N° (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France**, emission factors are updated on ADEME's Base Empreinte[49] or CITEPA's OMINEA database[50].	EXAMPLES OF LEVERS FOR ACTION
			Direct emissions (Scope 1, category 1)	
1.1	**Direct emissions from stationary combustion sources**	Heating of premises using fossil fuels (oil or gas). Fuel consumption by equipment (engines, start-up burners, generators). **Combustion of waste** • CO_2 (biogenic and fossil); • N_20 (negligible when high temperature incineration); • *Black carbon (open burning)** Combustion of biogas in flare (biogenic CO_2). * *not covered in the Astee guide.*	Fuel consumption multiplied by the Emission Factor (EF)[51] associated with this fuel (see ADEME's Bilan Carbone® methodology (2004)). For the combustion of waste in an incinerator, there are several methods for assessing fossil CO_2 emissions, from the least accurate to the most accurate: • National emission factor CO_2eq/tonne of waste incinerated; • Estimation of the proportion of fossil carbon in waste and the proportion of unburnt; • Modelling based on measurements of tonnage processed, PCI, emission factor, carbon oxidation factor, O_2 consumption and CO_2 emissions (for the BIOMA method, ISO Standard 18466 or OBAMA method); • Regular measurements of ^{14}C in flue gas samples to determine the quantity of CO_2 of fossil origin resulting from the combustion of waste specific to the collection basin.	• Reduce usage times; • Improve engine energy efficiency and change in motorisation or heating mode; • **Reduce tonnage of fossil-based waste (plastics);** • Store CO_2 from flue gases and exploring its usage for Carbon Capture and Storage (CCUS) projects.

EXAMPLE:

Collection from waste collection centres: Purchase of fuel oil or gas if the tank is on site (not connected to the network);
Sorting centre: Generator set, production of heat, electricity or **cooling**;
Heat treatment: Oxidation of fossil fuels (burner to start or maintain the combustion of waste, emergency generator, heating, etc.).

In **grey font**, items for which assessment is optional.
In **red font**, the most significant sources of emissions and reduction levers.

[49] See Accueil | Base Empreinte® (ademe.fr).
[50] See Ominea - Citepa
[51] When the quantities of fuel consumed are not available, it is possible to make estimates based on accounting method, particularly for transport, energy, products, works, etc. This accounting method consists of "*using the chart of accounts to list all the assets [concerned] and selecting the most relevant. The emission factors are then applied [...]. The emissions calculated must then be divided by the number of years corresponding to the legal entity's accounting depreciation period*". In. ADEME (2020). *Méthode pour la réalisation des bilans d'émissions de gaz à effet de serre conformément à l'article L.229-25 du code de l'environnement*. Version 5 de juillet 2022. Ministère de la transition écologique. https://www.ecologie.gouv.fr/sites/default/files/documents/metho-do_BEGES_decli_07.pdf p. 83. This method is not very precise, but it is satisfying to assess small GHG sources, and for approximate estimations.

N° (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France,** emission factors are updated on ADEME's Base Empreinte or CITEPA's OMINEA database.	EXAMPLES OF LEVERS FOR ACTION
1.2	**Direct emissions from mobile combustion sources**	Use of vehicles and equipment belonging to the organisation on site and between sites (HGVs, machinery and light vehicles). Mobile thermal equipment (shredders, bucket loaders, grapples, etc.).	Two methods for estimating road transport emissions based on available data: 1. Fuel consumption x Emission Factor (EF); 2. Kilometres travelled and tonnages moved (by fuel type). Example: transport between sites managed by the same entity. See Method on page 78 of the Astee guide. For river transport, the distance travelled can be calculated using the VNF river calculator[52].	• Optimise travel; • Intensify the use of vehicles by approaching their maximum capacity; • Optimise distances between sites; • Choice of engines for mobile equipment.
EXAMPLE:	**Collection from waste collection centres**: Mobile thermal equipment (plant shredder, bucket loader, grapple, etc.); Vehicles for transporting outgoing waste, if these are owned by the organisation; Oxidation of waste in the furnace. **Sorting centre**: Transport of waste between sites (from other sites); **Thermal treatment**: Fuel for vehicles controlled by the organisation; Transport of waste between sites; **Composting**: Wheel loader, windrower, DV shredder, screening machine, etc; **Landfill**: Lorry bringing waste to the landfill and compactor.			
1.3	**Direct emissions from non-energy processes**	Incineration flue gas treatment (N_2O). Degradation of organic matter during composting • Biogenic CO_2; • N_2O, CH_4 (if fermentation of the material is not well controlled).	• **Flue gas heat treatment**: less than 3% of emissions. See Astee Guide for calculation. • **Composting**: Quantity of organic waste composted or quantity of carbon and nitrogen contained in inputs. Methodological recommendation: Either specific EF (when the agronomic value is known) or generic EF (depending on the type of input), data to be specified depending on the quantity, type of input and type of composting platform.	• Furnace management to ensure the most complete combustion possible (temperature, mixing of inputs); • Good knowledge of the flows handled and mastery of processes.
EXAMPLE:	**Thermal treatment:** NOx treatment with **SNCR**; **Composting**: Lack of control over parameters such as C/N, temperature, humidity and oxygen during the fermentation and maturation phases.			

In grey font, items for which assessment is optional.
In red font, the most significant sources of emissions and reduction levers.

[52] See the French website VNF - Calcul d'itinéraire fluvial. Once the places of departure and arrival have been entered into the calculator, it gives the number of kilometres to be covered. Note: in addition to calculating the emissions linked to river transport, we often have to add those corresponding to pre- and post-carriage by road.

Nº (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France,** emission factors are updated on ADEME's Base Empreinte or CITEPA's OMINEA database.	EXAMPLES OF LEVERS FOR ACTION
1.4	**Direct fugitive emissions**	Air conditioning equipment. Unintentional anaerobic fermentation of the organic fraction of waste (CH_4, N_2O) during temporary storage of waste prior to treatment. **Biogas leaks from** methanisation and **landfill facilities** (CH_4).	**Temporary waste storage**: quantity of waste, type of facility (open/closed hall). **Landfill** : Quantity of biogas captured; quantity and types of waste stored during the year. 3 approaches for estimating CH_4 emissions : • theoretical models based on the quantity of biogas captured (IPCC, ADEME method, see page 110 of the Astee Guide); • theoretical models based solely on stored waste flows (RECORD recommendation). ECH_4 = quantity of waste x emission factor integrating future CH_4 emissions x (1-methane capture rate) x (1-oxidation rate set at 10% by default); • methods for actual measurement of CH_4 emissions (by drone and/or on foot).	• **Eliminate open dumping and open burning;** • **Good knowledge of the flows processed;** • **Good maintenance of equipment linked to biogas production;** • **Regular monitoring of leaks from landfill sites;** • **Quality of landfill coverage.**

EXAMPLE:

Methanisation: Poorly maintained digester and leaks from safety valves; leaks during biogas purification or cogeneration; storage of digestate which releases methane;
Landfill: Leaks when landfills are in operation and leaks due to cover failures on closed landfills.

In **grey font**, items for which assessment is optional.
In **red font**, the most significant sources of emissions and reduction levers.

N° (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France**, emission factors are updated on ADEME's Base Empreinte or CITEPA's OMINEA database.	EXAMPLES OF LEVERS FOR ACTION
Indirect emissions linked to energy (Scope 2, category 2)				
2.1	**Indirect emissions from electricity consumption**	Energy consumption for the operation of buildings, plants, sorting sites, vehicles and electrical equipment.	EF x electricity consumption (see Methodological insert no. 2). 2 approaches: • the location-based approach: average EF of the network used; • the supplier approach («market based»): EF made available by the electricity supplier. If details of consumption by equipment or by process are available, retain these details in the calculation of emissions so that you can identify the main areas where reduction measures can be taken. **Heat treatment**: Electrical purchase of the site.	• Reduce electricity consumption; • Switch to green energy consumption.
EXAMPLE:	**Collection at waste collection centres**: Lighting, IT and electrical equipment (compactors, etc.); **Sorting centres**: Emissions linked to the operation of the centres, such as the conveyor belts on which the waste passes.			
2.2	**Indirect emissions from energy consumption other than electricity**	Heating network supplying the buildings and the process.	EF x heat consumption.	• Switch to green energy consumption.
EXAMPLE:	**Collection from waste collection centres**: Heating or air conditioning of premises by a local heating/cooling network.			

In grey font, items for which assessment is optional.
In red font, the most significant sources of emissions and reduction levers.

N° (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France**, emission factors are updated on ADEME's Base Empreinte or CITEPA's OMINEA database.	EXAMPLES OF LEVERS FOR ACTION
Other indirect emissions (Scope 3, categories 3 to 6)				
3.1	**Upstream freight transport**	Transport of waste-to-waste collection centres and voluntary drop-off points using vehicles not belonging to the organisation (contracted out).	Kilometres travelled and tonnages moved (by fuel type). Example: transport between sites managed by the same entity. See Method on page 78 of the Astee guide.	• Reduce tonnages; • Changes in motorisation and transport mode, and distances through strategic planning of the territory and the location of infrastructures (waste collection centres, recycling industries, etc.).
3.2	**Downstream freight transport**	Transport of subcontracted products (slag, rejects, sorted materials, etc.) with vehicles not belonging to the organisation.		
3.3	Commuting to and from work	Transport of the entity's employees to and from work.	ADEME Empreinte database.	• Reduce the distance and frequency of journeys; • Promote soft mobility through financial levers and necessary development (bike, parking...) among others.
3.4	Transporting users and customers	Emissions generated by visitor (customer) travel (customers, suppliers, school visits...).	Base Carbone®. EF for modes of transport x distance travelled[53].	• Reduce distances and mutualise transport.
3.5	**Business travel**	Business travel using vehicles not belonging to the organisation (plane, train).	Reduce the distance and frequency of journeys.	• Reduce the distance and frequency of journeys.

In grey font, items for which assessment is optional.
In red font, the most significant sources of emissions and reduction levers.

[53] See pages 52 and 92-95 of the ADEME guide : Réalisation d'un bilan des émissions de gaz à effet de serre : distribution et commerce de détail - La librairie ADEME

Nº (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France**, emission factors are updated on ADEME's Base Empreinte or CITEPA's OMINEA database.	EXAMPLES OF LEVERS FOR ACTION
4.1 4.5	**Purchase of products or services**	Emissions associated with the manufacture of equipment or products required for the activity during the reporting year : • Reagents: flue gas treatment (incineration, co-incinera-tion) or deodorisation; • Pre-collection equipment: bags, bins, voluntary drop-off points, skips, etc.; • Subcontracting (mainte-nance, works, billing of fees, payroll, project management, studies, etc.); • Consumables: water, office equipment, security, etc. Materials for the work (asphalt mix, backfill with recycled aggregates...).	Tonnage of reagents required to operate the process in question x EF specific to each product or service (see Base Carbone or ask the supplier). Note: this refers to the manufacture of reagents; transport should be included under item 3.1. Accounting method for works-type services or consumables.	• Consume as little as possible (while respecting standards and egulations), as well as possible, and responsibly (maximise and intensify the use of goods, reuse, recycle, etc.).
4.2	**Fixed assets**	Emissions generated by the construction of assets capitalised by the organisation and required for operations over several years.	Takes into account the lifespan of assets. Emissions depend on surface area (buildings and roads), quantities (equipment), the nature of vehicles or expenditure (monetary emissions).	• **Encourage the use of recyclable and low-carbon materials in production;** • **Intensify the use of facilities** (for example 24/7 vs 16/5).
4.3	**Waste management**	Treatment of operating waste not accounted for elsewhere and not treated internally: refuse, slag and bottom ash.	Volumes and data specific to each treatment process for each type of waste.	• Choice of treatment processes for this waste (energy recovery if possible (RDF, residual sodium chemicals, etc.)); • Reduce waste volumes: furnace management, sorting performance, etc.

In **grey font**, items for which assessment is optional.
In **red font**, the most significant sources of emissions and reduction levers.

N° (According to ISO)	SOURCE OF EMISSIONS	MAIN SOURCES	DATA TO BE USED BY EMISSION SOURCE **In the case of France**, emission factors are updated on ADEME's Base Empreinte or CITEPA's OMINEA database.	EXAMPLES OF LEVERS FOR ACTION
4.4	**Leased assets**	Leased assets such as vehicles, machinery and computers.	Not specific to the sector. Refer to ADEME recommendations.	• Intensify the use of assets by approaching their maximum capacity.
5.1	**Use of products sold**	What happens to products sold during their use: materials and energy. This mainly concerns the faith of recycled plastics, compost and digestates, and RDF.	All products sold during the reporting year should be considered, even if all the emissions will only occur in the future. Emissions must be calculated over the entire lifespan of these products.	• Establish contracts with companies committed to reducing their GHG emissions.
5.3	**End of life of sold products**	End-of-life of recycled plastic products.	As the operator has no influence on the end-of-life of the products sold (materials), we have not developed a methodology for assessing this item.	• Apply the 10Rs principle (reject, rethink, reduce, etc.).

In grey font, items for which assessment is optional.
In red font, the most significant sources of emissions and reduction levers.

ANNEX 2 List of French regulations presented in FIGURE 8

Law no. 75-633 of 15 July 1975 on waste disposal and materials recovery (*relative à l'élimination des déchets et à la récupération des matériaux*);

Environment Code of 18 September 2000 (*Code de l'environnement*) constantly updated since 2000 as shown on the bottom part of **FIGURE 8**;

Law no. 2009-967 of 3 August 2009 on the implementation of the Grenelle Environment Round Table (*de programmation relative à la mise en œuvre du Grenelle de l'environnement*), called Grenelle I;

Law no. 2010-788 of 12 July 2010 on national commitment to the environment (*portant engagement national pour l'environnement*), called Grenelle II;

Law no. 2015-991 of 7 August 2015 on the new territorial organisation of the Republic (*portant nouvelle organisation territoriale de la République*), called NOTRe;

Articles L4251-1 to L4251-11 of the General code of local authorities (*Code général des collectivités territoriales*) modified by the law NOTRe. Introduction of the regional plan for the spatial planning, sustainable development and territorial equality (*Schéma Régional d'Aménagement, de Développement Durable et d'Egalité des Territoires*), called SRADDET;

Articles R541-13 to R541-27 of the Environment Code (*Code de l'environnement*) modified by the law NOTRe. Introduction of the regional waste prevention and management plan (*Plan régional de prévention et de gestion des déchets*), called PRPGD;

Law no. 2015-992 of 17 August 2015 on energy transition for green growth (*relative à la transition énergétique pour la croissance verte*), called LTECV;

Articles R229-51 to R229-56 of the Environment Code (*Code de l'environnement*). Modified by the LTECV to introduce a climate-air-energy territorial plan (*Plan climat-air-énergie territorial*), called PCAET;

Decree no. 2015-1491 of 18 November 2015 on national carbon budgets and the national low-carbon strategy (*relatif aux budgets carbone nationaux et à la stratégie nationale bas-carbone*), called SNBC I;

Decree no. 2020-457 of 21 April 2020 on national carbon budgets and the national low-carbon strategy (*relatif aux budgets carbone nationaux et à la stratégie nationale bas-carbone*), called SNBC II. SNBC II is in line with the Regulation (EU) no. 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision n°280/2004/EC;

Law no. 2020-105 of 10 February 2020 on the fight against waste and on the circular economy (*relative à la lutte contre le gaspillage et à l'économie circulaire*), called AGEC;

The French strategy for energy and climate (*Stratégie française sur l'énergie et le climat*) is currently being designed[LXX], and should be comprised of the programmation law on the energy and climate (*Loi de programmation sur l'énergie et le climat*), called LPEC; of the SNBC III; of the 3rd edition of the national plan of adaptation to climate change (Plan national d'adaptation au changement climatique), called PNACC3; and of the 3rd edition of the plurianual energy programmation (*Programmation pluriannuelle de l'énergie*), called PPE3;

The 2024 French integrated energy-climate national plan (*Plan national intégré énergie-climat*) , called PNIEC;

Law no. 2021-1104 of 22 August 2021 on combating climate change and building resilience to its effects (*portant lutte contre le dérèglement climatique et renforcement de la résilience face à ses effets*), called Climate and Resilience Act (*Loi Climat et Résilience*).

Waste Management to Address the Climate Crisis

PROJECT EXAMPLES

Partenariat français pour les déchets
PFD
FSWP
French solid waste partnership

HOLISTIC WASTE MANAGEMENT / METHANE REDUCTION

CHINA - Shaoyang

AFD GROUPE

RESTAURANT FOOD WASTE RECOVERY

n°1

Reducing sanitary health risks, promoting waste to energy

Prevent restaurant food waste use as direct animal feed, through dedicated collection and treatment systems:

- Introduction of a dedicated collection system for restaurant food waste.
- Collection and pre-treatment of used food oils.
- Anaerobic digestion facility producing biogas for heat and power co-generation.
- Financial viability of the operations through:
  - Waste collection tax
  - Sales of oil, electricity and heat.

CLIMATE BENEFIT

- 70 ktCO_2eq/y avoided compared to former situation (methane emissions from biowaste)
- Green energy production

CO- BENEFIT

- Reducing major public health risks associated to biowaste direct use in animal feed
- 174 jobs created

→ **FOCUS** La gestion des déchets solides | AFD - Agence Française de Développement

WASTE TO RESOURCES

FRANCE – Greater Paris

syctom

ORGANIC WASTE RECOVERY

n°2

Supporting local authorities to sort, collect and treat domestic food waste

Mandatory source separation of organic waste as of January 2024:

- Collection schemes : on-site composting, door-to-door collection, voluntary deposit.
- Targeting 100 kt/year of biowaste collected in the service area.
- Construction of a methanizer on the river port of Gennevilliers by 2026 to produce biomethane and organic fertilizers.

CLIMATE BENEFIT

- Biogas production
- Organic fertilizer use, to avoid GHG emissions from chemical fertilizer production

CO- BENEFIT

- Citizens' awareness on reducing food waste and recovering the value of waste

→ Plan Biodéchets : améliorer le tri et la valorisation des déchets alimentaires - Syctom (syctom-paris.fr)

WASTE TO RESOURCES

COMÉTHA PYROGAZIFICATION PROJECT

n°3

FRANCE – Paris

syctom

A disruptive technology opposing incineration and complementary with methanization

From R&D to a full-scale pilot:

- Treat a mix of organic waste, including food waste and sewage sludge.
- Maximize the transformation of organic matter into syngas.
- Minimize the volume of solid residues (ashes).
- Recover nutrients (nitrogen and phosphorus).

CLIMATE BENEFIT

- Renewable energy production
- Phosphorus recovery, to avoid GHG emissions from phosphorus mining

CO- BENEFIT

- Synergies between organic waste producers
- New type of contracting models to support innovation
- Nutrient recovery

→ Cométha (cometha.fr)

CARBON SINK

BIOCHAR TO REGENERATE SOIL HEALTH

n°4

CANADA - Quebec

suez

Pyrolysis conversion of unused biomass into biochar and bioenergy

Biochar application in soil stores carbon while improving soil health and productivity. The first of its kind plant is set up in Quebec:

- Phase 1: 10 kt biochar/y by end 2024.
- Phase 2: ramp-up capacity up to 30 kt biochar/y.

SUEZ has the ambition to sequester 800 ktCO_2eq/y by 2035.

CLIMATE BENEFIT

- 1 ton of biochar produced ~ 2.7 ton of net CO_2 sequestered
- Green energy production ~ 50 GWh/y of bioenergy surplus for a 20kt/y biochar plant

CO- BENEFIT

- Regenerate soil biodiversity and productivity
- Improve and sustain soil health

→ Carbonity Project - Airex Energy (airex-energy.com)

WASTE TO RESOURCES

FRANCE - Limay

PAPREC

RECYCLED PET PRODUCTION

n°5

France Plastiques Recyclage

Production of recycled plastic (rPET) as a substitute for primary PET:

- 45,000 t/year of PET bottles from selective collection processed.
- 41,000 t/year rPET produced.

CLIMATE BENEFIT

- rPET generates 70% less CO_2 than primary PET
- 50 kTon CO_2eq avoided by 2022 by using rPET in place of primary PET

CO- BENEFIT

- Increases the sustainability of the bottled water industry.

→ France Plastiques Recyclage : dernière ligne droite pour les travaux d'extrusion (paprec.com)

WASTE TO RESOURCES

EUROPE
AND NORTH AMERICA

waga energy

WAGABOX® TECHNOLOGY

n°6

A benchmark solution for landfill gas purification for recovery

Coupling membrane filtration and cryogenic distillation to upgrade landfill gasinto grid compliant biomethane:

- Improvement in energy yield compared with cogeneration.
- Optimized methane capture as there is no limitation in air concentration in landfill gas.
- Example: WAGABOX® in Claye-Souilly, France
  - Capacity: 130 GWh/y
  - 21,000 kg CO_2eq avoided/y
  - 20,000 households supplied with biomethane.

CLIMATE BENEFIT

- 142 ktCO_2eq avoided (since 2017) compared to former landfill operation scenario
- Green fuel for transport and industry
- Methane emissions reduction

CO- BENEFIT

- Improving landfill operation

→ Technologie - Waga Energy (waga-energy.com)

HOLISTIC WASTE MANAGEMENT

OMAN - Muscat

be'ah بيئة

VEOLIA

BARKA LANDFILL

n°7

A landmark of the Omani journey from open dumpsites to 100% controlled solid waste treatment

2,500 t/day of waste are highly compacted and readily covered with soil to reduce emissions:

- Biogas is recovered; the installation of a gas engine is in planning; the capture of biogas from open cells is evaluated.
- Leachate is treated; the permeate reused to cover the landfill operation needs; no discharge.
- Tyres are processed in chips to fuel a nearby cement plant.

CLIMATE BENEFIT

- Methane emissions are significantly reduced
- Green energy from biogas about to be harnessed

CO- BENEFIT

- More than 1M people benefit of an improved environment
- Water and soil pollution from open dumps is avoided
- Multiple use of fossil carbon: from tyres to energy

WASTE TO ENERGY

FRANCE - Sète

PAPREC

NON-RECYCLABLE WASTE INTO GREEN ENERGY

n°8

Heat and power production as an alternative to landfilling

The Sète waste-to-energy plant:

- 55,000 t/y of non-recyclable waste processed in an 18.1 MW oscillating furnace to produce:
  - 15.7 GWh of electricity
  - 23 GW of steam

CLIMATE BENEFIT

- Energy production

CO- BENEFIT

Energy autonomy :

- Produces electricity for 4,000 to 6,000 households
- Produces steam for an oil seed industry

→ L'éco-centre Ikos Fresnoy-Folny, pionnier de la méthanisation (paprec.com)

WASTE TO ENERGY

FRANCE - Limay

MASSBIO₂ THE CO_2 DASHBOARD

n°9

Assessing biogenic and fossil carbon fractions in incineration waste and energy from waste

From flue gas to waste composition… by measuring the origin of CO_2 (^{14}C analysis):

An algorithm assesses biogenic and fossil CO_2, the waste composition, and the renewable energy fraction.

CLIMATE BENEFIT

- Measure CO_2 emissions to understand waste composition and identify levers driving mitigation actions

CO- BENEFIT

- Citizens and decision-makers awareness to reduce waste production
- Metrics on waste composition to drive action

Groupe MERLIN

→ Nos innovations -R&D | Groupe Merlin (cabinet-merlin.fr)

WASTE TO ENERGY

TÜRKIYE- Istanbul

ISTANBUL WASTE-TO-ENERGY PLANT

n°10

Istanbul Metropolitan Municipality - İSTAÇ A.Ş

Treatment capacity of 1.1 M/t waste per year:

- Europe's largest waste to energy facility.
- Electricity production by an 85 MW turbine = meets the needs of 1.4 million inhabitants.
- Objective of carbon neutrality by 2053.

CLIMATE BENEFIT

- 1,4 $MtCO_2eq$/y of carbon emissions are reduced (through reduced landfilling and transportation)
- Green electricity production

CO- BENEFIT

- Improve the environment for inhabitants
- Improved energy autonomy

İSTANBUL BÜYÜKŞEHİR BELEDİYESİ

istaç

VEOLIA

→ Décarbonation: Veolia devient l'opérateur du 1er site de production d'énergies à partir de déchets de Turquie

CARBON SINK

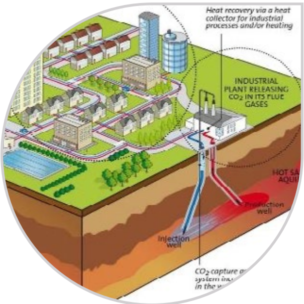
GEOTHERMAL CO_2 CAPTURE

n°11

Leveraging CO_2 dissolution capacity in cold versus hot water

R&D project to combine a deep geothermal plant with permanent CO_2 storage of incineration flue gases.

FRANCE – Greater Paris



The project aims to:

- Store 300,000 tons of CO_2 (40% fossil) in a deep aquifer.
- Recover heat from the geothermal aquifer to supply district heating.
- Reduce the amount of the future European tax on waste-to-energy emissions.

CLIMATE BENEFIT

- 300 ktCO_2 to be captured
- Harnessing renewable energy (heat)

CO- BENEFIT

- Research partnership
- Innovation can benefit others

syctom · brgm Géosciences pour une Terre durable · slb

WASTE TO RESOURCES

A WASTE TO RESOURCES INDUSTRIAL SYSTEM

n°12

A systemic approach to reduce landfilling, recycle materials, and produce energy

A municipal solid waste plant to valorize 80% of waste into new raw materials, solid fuels and biomethane:

FRANCE - Tarn

- Materials Balance : for 100,000 t/y of waste
  - Biomethane = 62 GWh/y
  - New raw materials = 6,000 t/y
  - Fertilising products = 12,000 t/y
  - Refuse Derived Fuel (RDF) = 150 GWh/y

CLIMATE BENEFIT

- 23 % reduction of CO_2eq emissions compared to baseline

CO- BENEFIT

- Increased income allows to stabilise waste treatment cost
- Landfill diversion
- Scalable and adaptable to various waste streams & energy needs

urbaser · Tarn TRIFYL

→ Un projet d'économie circulaire | Trifyl

HOLISTIC WASTE MANAGEMENT

IMPROVING HOUSEHOLD WASTE MANAGEMENT

n°13

TOGO - Lomé

Towards a sustainable urban transition in Lomé

Holistic domestic waste management system in the Grand Lomé: 1.8M people, 300 kt/y of solid waste.
An ongoing multi-tranch project since 2006:

- Improvement of the holistic solid waste management system and capacity building support.
- Implementation of engineered landfills with long term biogas and leachate management.
- Strengthening recovery & recycling initiatives.
- Improvement of the sector financial resources.
- Gradual increase of performance requirements.

CLIMATE BENEFIT

- Reduced GHG emissions through improved collection and landfill operation conditions

CO- BENEFIT

- Improved hygiene
- Reduced pollution and drainage blockages causing chronic flooding
- Capacity building

FOCUS La gestion des déchets solides
AFD - Agence Française de Développement (p. 62)

BEHAVORIAL SCIENCE

A WOMEN-LED INFORMAL WASTE COLLECTION SYSTEM IN HÀ NÔI

n°14

VIÊT NAM - Hà Nôi

Waste collection and recycling in a city overwhelmed by waste

Main highlights of this comprehensive study :

- 20% of urban waste is collected informally, mainly by women.
- The informal sector is complex and composed of street collectors, waste deposit managers and recyclers.
- Recycling practices are highly polluting for the environment and health.

CLIMATE BENEFIT

Baselines for future policy development in order to

- Reduce the pollution and GHG emissions by improving the recycling techniques

CO- BENEFIT

Baselines for future policy development to

- Improve working conditions of women collectors
- Recognize and support the informal recycling system

Collecter et recycler les déchets à Hà Nôi - Acteurs, territoires et matériaux - (EAN13 : 9782709929660) | Un éditeur pour le développement (ird.fr)

CARBON SINK

BOLIVIA - El Alto & La Paz

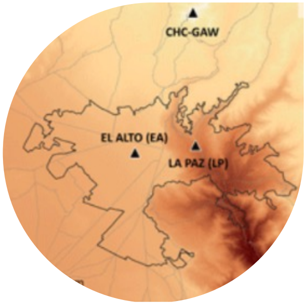
OPEN BURNING & AIR QUALITY

n°15

El Alto and La Paz – evaluation of airborne particle pollution sources

Evaluation of airborne particle pollution sources. Results show that:

- Local air pollution in La Paz is mainly due to road traffic but additional sources such as waste burning may have non-negligeable impacts.
- Waste burning contributes only 2 to 5 % of total PM10 but contains more than 50 % of the PAHs content which are carcinogenic components.



CLIMATE BENEFIT

Baselines for future policy development to

- Reduce the emissions of black carbon

CO- BENEFIT

Baselines for future policy development to

- Improve air quality for inhabitants
- Protect people's health

→ Mardoñez, V. et al.: Source apportionment study on particulate air pollution in two high-altitude Bolivian cities: La Paz and El Alto, Atmos. Chem. Phys., 23, 10325–10347, https://doi.org/10.5194/acp-23-10325-2023, 2023.

HOLISTIC WASTE MANAGEMENT/ BEHAVORIAL SCIENCE

SENEGAL - Dakar
& 3 northern regions

PROMOTING INTEGRATED SOLID WASTE MANAGEMENT IN SENEGAL

n°16

Promoting integrated waste management in Senegal (PROMOGED)

Provide integrated solutions throughout the sector serving 6M people (2020-2026):

- Improve the regulatory, financial and fiscal framework of the sector.
- Develop partnerships between the public authorities and private sector.
- Rehabilitation of the Mbeubeuss Dakar dumpsite integrating the informal sector.
- Foster a holistic waste management system.

CLIMATE BENEFIT

- 542 ktCO_2eq/y reduced compared to the uncontrolled dumpsite
- Reducing drainage blockages and associated flood risks

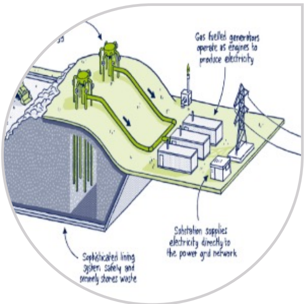
CO- BENEFIT

- 6 million people with improved quality of life
- Reducing pollution
- Job creation

→ FOCUS | La gestion des déchets solides AFD - Agence Française de Développement (p. 70)

WASTE TO ENERGY / METHANE REDUCTION

AN INTERNATIONAL MODEL



GREEN LANDFILL TO ENERGY

n°17

Integrated infrastructure to replace dumpsites

An innovative financing model for waste treatment in developing economies:

- Produce biomethane, produce electricity.
- Improve waste management from open dumpsites to environmentally controlled landfills.
- The case of Meknes, Morocco:
  - 200 kt/y of waste safely managed
  - 70% reduction in emissions by 2033
  - 5,500 MWh/y production capacity.

CLIMATE BENEFIT

- Methane capture
- Production of renewable energy

CO- BENEFIT

- Local land value enhancement
- Reduced pollution through leachate treatment
- Improved energy autonomy

SUEZ

→ A waste recovery centre in Meknès combines the fight against global warming with social innovation - SUEZ Group

HOLISTIC WASTE MANAGEMENT

SOUTH PACIFIC

STRENGTHENING NATIONAL POLICIES

n°18

Waste management and sustainable financing in insular territories

A regional initiative leveraging the cooperation between insular countries to prevent marine debris (plastic), used oil, post-disaster waste from degrading the environment :

- Support local authorities in drawing up comprehensive waste management policies.
- Strengthen their capacity for action.
- Improve existing infrastructures by setting up pilot projects.
- Promoting sustainable financing.

CLIMATE BENEFIT

- Reduced GHG emissions from improved waste collection and treatment
- Reducing drainage blockages and associated flood risks

CO- BENEFIT

- Protecting ecosystems
- 200,000 people with improved access to essential public services
- Job creation

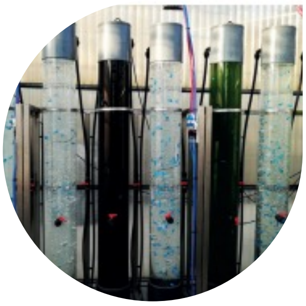
AFD GROUPE

SPREP PROE

→ FOCUS | La gestion des déchets solides AFD - Agence Française de Développement (p.66)

WASTE TO RESOURCES

FRANCE - Paris



syctom setec KTH POLYTECHNIQUE MONTRÉAL UNIVERSIDAD DE ALMERÍA blunomy

CAPTURE AND VALORISATION OF INCINERATION FUMES

n°19

Research on an innovative photobioreactor to capture CO_2 and produce algal biomass

An ongoing R&D project, since 2016 :

Microalgae have a capacity to fix CO_2 10 to 50 times more important than terrestrial land plants. 1t of produced biomass = up to 2t of CO_2 naturally captured during the growth of algae.

- Use of cyanobacteria rather than microalgae.
- Complete design of photobioreactors.
- Tested harvesting methods with yield of >95%.
- Ongoing research on remaining environmental, operational and economic risks – estimated 10 more years needed.

CLIMATE BENEFIT

- Ongoing research to innovatively capture CO_2
- GHG emission reduction
- Production of bioplastics

CO- BENEFIT

- Circular economy
- Synergies between industries
- Anticipated compliance with the upcoming European decision which includes waste incinera-tion in the CO_2 quotas as of 2028

→ Captation et valorisation du CO2 des fumées d'incinération - Syctom (syctom-paris.fr)

HOLISTIC WASTE MANAGEMENT

BENIN – Wémé region

gbobètô.bénin EngineeringX

CLEAN SCHOOL OPERATION BY GBOBÈTÔ

n°20

Clean School Operation to decrease open burning of waste

Since its creation, Gbobètô has diverted 600,000kg of waste, via the « clean school » operation, based on the 3Rs:

- Reducing: decreasing single-use plastics inside schools with reusable containers for catering.
- Reusing: allowing children to bring their recyclable waste from home to school.
- Recycling: producing compost from organic waste for use in the vegetable gardens in all of the 10 concerned schools.

CLIMATE BENEFIT

- Reduced open burning: 15,000kg of waste diverted
- Reduced black carbon emissions
- Reduced air and soils pollution

CO- BENEFIT

- Improved environment
- Improved health for the communities

→ Awardees (raeng.org.uk)

HOLISTIC WASTE MANAGEMENT

UGANDA – Mbarara City

REDUCING OPEN BURNING OF MSW

n°21

A multi-stakeholder approach to reduce the risk to human health and safety from open burning of municipal solid waste

Implementation of holistic waste management to improve the City's baseline situation of 41% collection efficiency and an estimated 59% of waste burnt in the open:

- Raise awareness among citizens, city policy makers and implementers, and other stakeholders.
- Encourage the formulation of policies to stop open burning and to improve the collection efficiency.
- Train company leaders and informal workers.

CLIMATE BENEFIT

- 573 tonnes of waste diverted from open burning
- Improved waste management: 67% collection efficiency

CO- BENEFIT

- Improved environment
- Improved health and safety

EngineeringX

→ Awardees (raeng.org.uk)

WASTE TO RESOURCES

FRANCE

NÉOLITHE, CARBON SEQUESTRATION AND MATERIAL RECOVERY

n°22

Technological innovations to sustainably treat non-recyclable, non-inert and non-hazardous waste

A unique process of circular economy and decarbonization:

- Step 1: post collection sorting and micronization to transform the material into powder form.
- Step 2: once micronized, the waste is mixed with a low-carbon binder. The mixture is then pressurized into the desired shape.
- Step 3: aging: the aggregate gains its mechanical properties by undergoing a crucial aging.
- The aggregates both serve as construction material and carbon sink.

CLIMATE BENEFIT

- Diversion of non-recyclable waste from landfilling, incinera-tion and associated emissions
- Interruption of the natural deg-radation of biogenic carbon to sequester around 400 kgCO_2eq

CO- BENEFIT

- Local circular economy loops and synergies between local industries, particularly in the construction sector

NÉOLITHE

→ Néolithe - La Fossilisation des déchets non-recyclables (neolithe.fr)

HOLISTIC WASTE MANAGEMENT

FRANCE

A FRENCH EXAMPLE OF PAY-AS-YOU-THROW (PAYT)

n°23

Objective to reduce waste and fairly cover management costs

An incentive-based fee composed of:

- **A constant component** comprised of the constant costs of the service which includes, as for example in the case of the Presqu'île de Crozon:
  - glass collection in voluntary drop-off points,
  - 15 lifts/year for the mixed household waste,
  - unlimited lifts of sorted organics and packaging waste,
  - 15 admissions/year to bulk waste collection centers.
- **A variable component** for additional lifts or additional admissions to waste collection centers.
- Users follow their waste generation on a website. **The success relies on the maturity and discipline of users.**

CLIMATE BENEFIT

- Waste volume reduction

CO- BENEFIT

- Social justice and fairness
- Constant fiscal revenues
- Local waste management system sustainability

→ Quels sont les tarifs de la redevance incitative ? Comment payer ma facture ? - Com Com Crozon (comcom-crozon.com)

ORGANIC WASTE MGT. AND GHG MITIGATION

INDIA-Indore

Indore Municipal Corporation

INDORE BIOMETHANE PLANT

n°24

Largest Single Site biomethanation Project in Asia with source Segregated Organics Waste as Feedstock

550 Tons of source-separated organic MSW processed and converted into biomethane and compost:

- Single site facility to treat the organic fraction of the MSW of 3.3 Mn. inhabitants.
- PPP Project with Revenue sharing, zero investment by the Municipality, run by private operators.
- Wastewater treatment prevents the discharge of Nitrogen (2.39 tons/year) and Phosphorus (0.85 tons/year) in Water Bodies.

CLIMATE BENEFIT

- 130,000 tons of CO_2eq reduced/year
- 17 TPD of Biomethane and 110 TPD of Compost produced
- 1 Mn $ annual revenue from Carbon Credits

CO- BENEFIT

- 450 direct local and indirect jobs created
- Approximately 77,400 running km/day Equiv. fuel for 430 buses of Public Transport

→ Home-Public Private Partnerships in India (pppinindia.gov.in)

HOLISTIC WASTE MANAGEMENT

SENEGAL - Touba

CARBON MARKETS SUPPORTING A COMPOST FACILITY IN TOUBA

n°25

A methane emissions reduction program integrated in Senegal's Nationally Determined Contribution (CND)

New composting facility to divert organic solid waste from unmanaged land-fills is eligible to carbon market funding:

- In 2020, the total amount of waste deposited in the Touba Peykouk landfill was 110,172 tons, where organic matter decomposes anaerobically, producing methane.
- Senegal has an unconditional NDC target to reduce waste management GHG emissions by 11%.
- The project presents the potential of 65% reduction in emissions by 2030 compared to the baseline situation. The GHG reduction exceeding the 11% committed as "unconditional" is eligible to carbon markets funding.

CLIMATE BENEFIT

- Estimated 10 400 tCO_2eq reduced per year over 15 years (2024-2038)

→ Development of a compost facility in Touba (allcot.com)

CO- BENEFIT

- Improved soils with compost in place of chemical fertilizers
- Improved public health and quality of life
- Increased agricultural production
- Collection and sale of plastic waste as additional revenue for the community