Energy recovery from waste

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This article analyses the strategic role of energy recovery from waste in France as a means of supporting the implementation of circular economy, at the intersection of climate imperatives and energy sovereignty challenges. It presents the main recovery pathways –thermal recovery and biogas production– and their contribution to reducing greenhouse gas (GHG) emissions, as well as producing local and mostly renewable energy. Finally, it broadens the debate at the international level, highlighting the diversity of trajectories and the importance of coherent local and energy planning to deploy these solutions effectively.

The energy recovery from Municipal Solid Waste (MSW) – household and similar waste - is the penultimate step in the waste treatment hierarchy[1] before landfilling. It is an essential step in the circular economy, enabling the production of renewable energy as a substitute for fossil fuels. This article describes the different approaches to energy recovery and presents the figures for France.

[1] The hierarchy of treatment methods defined in European Directive (EU) 2018/851 of 30 May 2018 applies in the following order: prevention, recycling and composting, energy recovery, and landfill.

Waste as fuel

Waste can be a source of fuel and energy. After separate collection, the energy recovery from MSW meets urban energy needs and contributes to limiting landfilling to ultimate residual waste only. In this sense, it is an essential complement to material recovery.

Energy-from-Waste (EfW)[2] facilities for residual household waste

The first process, combustion with energy recovery, aims to eliminate non-recyclable residual MSW while simultaneously recovering energy (see Figure 1). It emerged as a logical continuation of incineration, developed in the 19th century, whose role was limited to sanitizing and reducing the volume of waste. Nowadays, EfW (Energy-from-Waste), also called WtE (Waste-to-Energy) facilities recover energy in the form of heat or electricity. French and European regulations govern their operation by setting requirements for energy efficiency, combustion performance and environmental compliance (gaseous emissions at the stack, effluents, by-products). In France, this sector is subject to the Tax on Polluting Activities. In line with the treatment hierarchy, its tax is lower than for landfill, and is reduced when energy recovery is significant: €15/t for EfW facilities compared to €65/t for landfills[3] .

[2] In line with the ISWA White Book on the topic, this article uses the term Energy-from-Waste (EfW) rather than Waste-to-Energy", because "[t]he terminology Energy from Waste puts more emphasis on energy than 'Waste to Energy' and is preferred to 'incineration', which originally did not have any energy recovery and is therefore no longer considered a viable option". ISWA (2023), "White Book on Energy-from-Waste (EfW) Technologies", ISWA – International Solid Waste Association, p. 6.

[3] See the 2025 scale for the French Tax on Polluting Activities component relating to waste, https://bofip.impots.gouv.fr/bofip/12765-PGP.html/identifiant=BOI-BAREME-000039-20250723

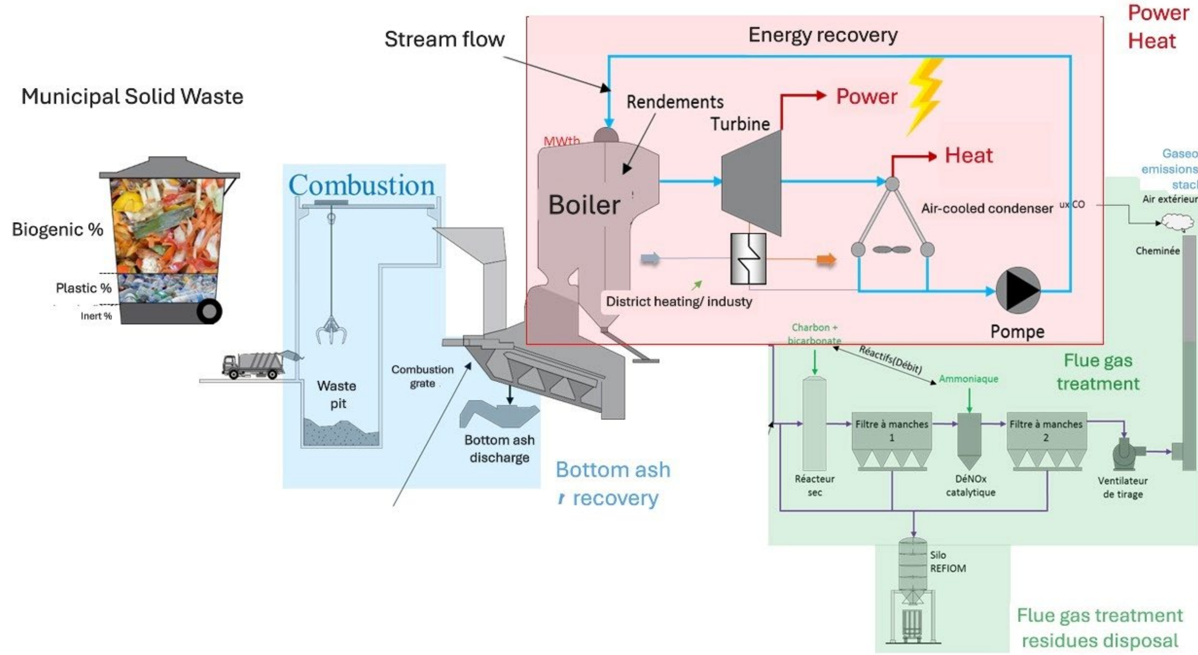

Figure 1: How does an Energy-from-Waste (EfW) plant work
(Source: Internal study, SN2E, Cabinet Merlin, 2025. Translated by Christophe Cord'homme).

EfW facilities[4] offer significant opportunities for reducing global Greenhouse Gas (GHG) emissions and increasing energy sovereignty by providing heat and electricity for local needs. On average, the combustion of 1 tonne of waste generates approximately 2,500 kWh of energy, around 60% of which is renewable due to its biogenic fraction.

A facility with a treatment capacity of approximately 100,000 tonnes of MSW per year can produce:

- electricity corresponding to the needs of a population of 30,000 to 50,000 inhabitants;
- heat (mainly in winter) and domestic hot water for a population equivalent to 6,000 to 10,000 households[5].

In 2022, 14.6 Mt of MSW were processed in France in the 117 operating EfW facilities according to the French environmental agency, ADEME (2024). The average age of these plants is 32 years. Three-quarters of the tonnage is recovered through cogeneration, producing heat and electricity. In total for France, EfW facilities produced 4,560 GWh of electrical energy and 15,369 GWh of thermal energy. This energy is the leading source of renewable heat in France. When including energy revenues and the Tax on Polluting

[4] An incinerator with energy recovery is classified as a EfW facility when it achieves a high energy efficiency, as defined in European Directive 2008/98/EC.
[5] Internal source, SN2E-Cabinet Merlin, 2025.

Activities, the median net cost of treating MSW in France is €106/t for EfW and €122/t for landfill (ADEME, 2025).

Refused Derived Fuel (RDF) facilities

The second process, with RDF facilities (boiler or cogeneration plants), has emerged more recently in France to meet industrial energy needs, replacing boilers that use fossil fuels (coal, gas) (see Figure 2). For example, numerous regional projects involving 20 MW RDF boilers are emerging, fuelled by around 40,000 tonnes of locally produced RDF, generally from non-hazardous industrial waste that was previously landfilled. This size of facility could provide around 100 GWh of industrial heat and 25 GWh of electricity per year[6] .

RDF is produced from non-hazardous waste that cannot be recycled as material. It is sorted and prepared in a dedicated unit to ensure high energy density and fuel quality control. The advantage is that RDF is transportable and storable. However, unlike EfW facilities, not all waste can be treated using this method, especially mixed MSW. In France, RDF facilities are not subject to the Tax on Pollutant Activities, but to CO_2 taxation. A 50 MW plant will be subject to the European Emissions Trading Scheme (EU ETS)[7] (CO_2 quotas) and must pay CO_2 taxes on its emissions from the combustion of fossil fuels (plastic, synthetic textiles, etc.). Thus, 150 kg of fossil CO_2/MWh is equivalent to €9/MWh (for a CO_2 price of €60/t in July 2025).

While questions remain about fuel quality, emissions and apparent competition with recycling, its promotion is linked to the need of reducing landfilling. In France, the 2015 law on energy transition and economic growth[8] sees it as a lever for reducing France's energy dependence on fossil fuels and supporting the objective of reducing landfill by 50% by 2025. The RDF sector is in a development phase, given a 2030 target of 10 TWh of RDF energy (i.e. 3 Mt of RDF, 50 times more than in 2022). Given the ambition of this target, public authorities aim to support these actions both through calls for projects from ADEME and by continuing to increase the Tax on Polluting Activities on landfill (Government, 2025). In 2022, in France, 13 RDF preparation facilities processing 1.6% of MSW (367 kt/year) showed significant fuel efficiency: 63% of outgoing flows were converted into RDF, while 29% constituted rejects (destined for a EfW facility or landfill) and 3% were metallic waste (ADEME, 2024). However, despite support for initial investment, RDF heat remains uncompetitive with gas. Recognition of its decarbonisation role (energy saving certificates, industrial balance sheets) is being promoted to help develop the sector.

[6] Internal source at SN2E - Cabinet Merlin.

[7] ETS: *Emissions Trading System*.

[8] Law No. 2015-992 of 17 August 2015 on energy transition for green growth (LTECV). Hereinafter "law on energy transition"

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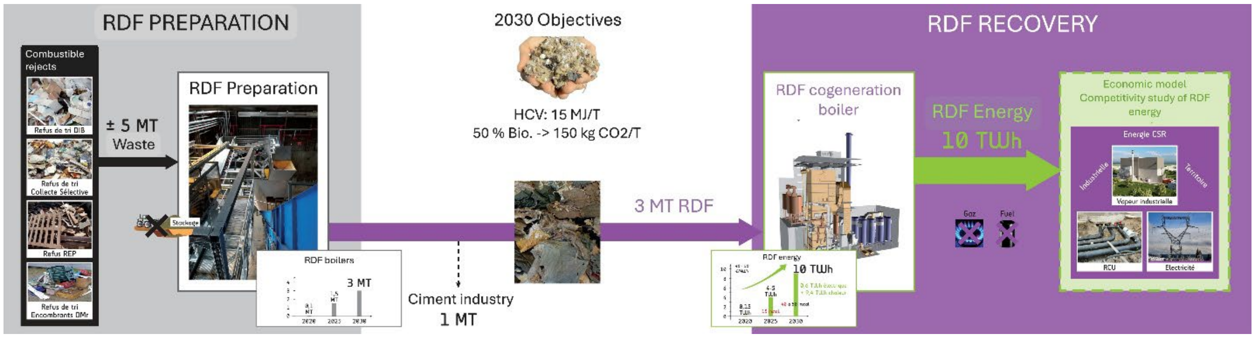

Figure 2: RDF lifecycle (Source: Internal study, SN2E, Cabinet Merlin, 2025. Translated by Christophe Cord'homme).

ORGANIC WASTE: A SOURCE OF BIOGAS PRODUCTION

Biogas is produced by the fermentation of organic matter under anaerobic conditions, in the absence of oxygen. Interest in this source of biogas has been revived, with the waste treatment hierarchy prioritising material recovery over combustion. Biogas is mainly composed of methane (CH_4) and carbon dioxide (CO_2), but it also contains trace compounds that require specific treatment. It is produced naturally in ESM-compliant engineered landfilled containing residual organic waste, or in a controlled environment, through biogas production in digesters.

Biogas production through anaerobic digestion

Anaerobic digestion is a mature technology at the heart of the circular economy, combining waste reduction with the production of biomethane, thereby substituting fossil fuels. On average, 1 tonne of putrescible waste generates 100 to 150 m^3 of biogas, or 250 to 400 kWh of energy.

Biogas production is a recovery solution for the 45% of MSW composed of organic matter (ADEME, 2017) (food waste, green waste, soiled paper and cardboard). It is still under-exploited today due to the poor quality of inputs, which leads to most of it being incinerated or landfilled. At-source separation makes it possible to simultaneously produce biogas and residual organic matter that can be recovered as soil amendment (digestate), as well as reducing the streams going to EfW facilities and landfills. Biogas production is a strategic national issue. In France, an anaerobic digestion facility processing 20,000 tonnes/year of organic waste covers the heating needs of around 2,600 households[9]. This treatment method is still emerging, with only 16 units in operation in 2022 (341 kt of waste treated) (ADEME, 2024). Unlike pyrolysis or other thermochemical pathways,

[9] According to GRDF, average consumption is around 6 MWh/year for a new gas-heated home.

biogas from anaerobic digestion (in anaerobic digestion facilities or storage facilities) is entirely biogenic.

Landfill biogas capture and recovery

Another source of biogas comes from landfills. Landfilled organic waste generates biogas over a period of 15 to 20 years. The capture and treatment of this biogas is mandatory in France and Europe[10] , but landfill is the main source of emissions in the waste sector (in France and worldwide). This is because not all of this biogas is captured and some of the methane escapes into the atmosphere, especially during the site's operational phase. Methane is a short-lived GHG with a global warming potential 28 times higher than CO_2 over 100 years, and 84 times higher over 20 years (MTE, 2024). Globally, waste accounts for 17% of anthropogenic methane emissions, but with significant disparities between countries (see Figure 3). Landfilling accounts for 80% of these emissions (EEA, 2022). Diverting the organic fraction of waste to other treatment methods, optimising methane management in landfills and recovering energy from it therefore offer a quick mitigation lever. In 2022, biogas capture from MSW landfills produced 935 GWh of electricity and 652 GWh of thermal energy (ADEME, 2024).

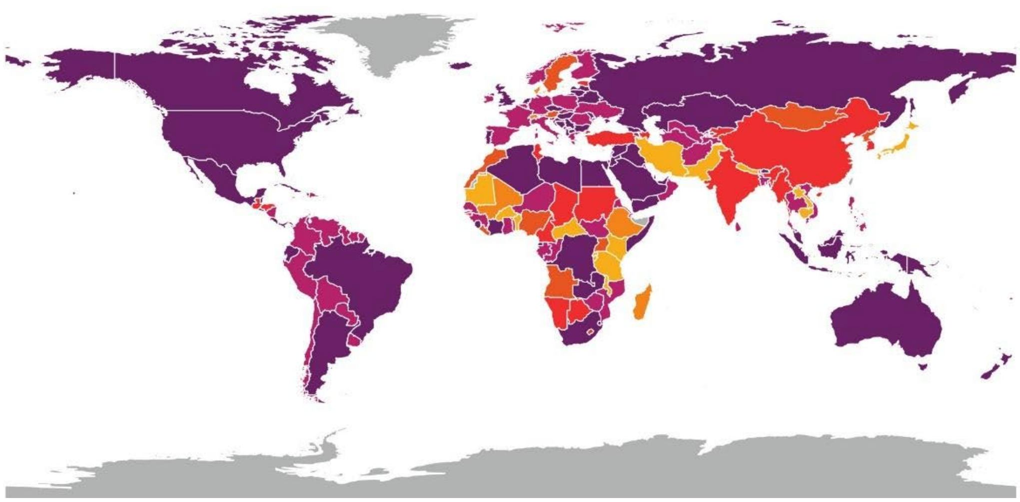

Figure 3: Contribution of methane emissions to total emissions from the waste sector (Source: Climate Watch, 2021, *in* FSWP, 2025).

In 2022, according to ADEME (2024), France had 165 ESM-compliant engineered landfilled, receiving 14.2 Mt of waste. With a decrease of only 7.4% in waste sent to landfill

[10] European Directive 1999/31/EC of 26 April 1999.

between 2010 and 2020, the 30% target set by the 2015 law on energy transition has not been met (MTE, 2025).

Whether through anaerobic digestion or in ESM-compliant engineered landfilled, the biogas produced can be recovered:

- by direct combustion in a thermal energy recovery boiler without prior treatment;
- through cogeneration: in engines producing both electricity and heat from engine cooling and combustion fumes;
- by injection: directly into the natural gas network in the form of biomethane, after a stage of extraction of the CO_2 fraction from the biogas (50%), purification, compression and odourisation. The purified gas can also be used as fuel for a fleet of lorries or buses.

This latter recovery process is currently being promoted in new projects in France through public financial assistance instruments (CRE, 2024a), as it provides a resource (biogenic CH_4 molecule) that is much rarer in France than electrical energy. In addition, it facilitates the recovery of CO_2, which also is biogenic and can be recovered (agriculture, agri-food industry, etc.) or sequestered. The 2015 law energy transition plans to increase the share of biomethane to 10% of annual gas consumption by 2030. Each kWh of biomethane injected avoids approximately 200 gCO_2e. At the end of 2023, a cumulative capacity of approximately 12 TWh HCV/year was in service, enabling the production of 9 TWh of injected biomethane (CRE, 2024b). In 2025, the biomethane production capacity of ESM-compliant engineered landfills in France is 650 GWh and will increase in the coming years[11].

In order to make the most of the mitigation and circularity opportunities offered by energy recovery, the generated by-products (ash, bottom ash, digestate, leachate, flue gases) must be managed properly. Bottom ash from combustion contains recoverable metals and minerals. Ash and other air pollution control by-products, while present in much smaller quantities, require specific treatment as they are classified as hazardous. However, their richness in essential metals makes them a potential "ore of the future". Whether through the production of biogas or fuel, it is also important to remember the effect of "avoided emissions" made possible by energy recovery: the recovery of energy from waste replaces energy produced from fossil fuels, but these benefits remain largely invisible in national GHG emissions reports, as they are accounted for within the energy sector.

[11] Waga Energy Communication

ENERGY RECOVERY AROUND THE WORLD: CURRENT SITUATION AND OUTLOOK

The choice of waste treatment methods depends on political, cultural and economic considerations, and therefore varies across the world. Globally, energy recovery from waste remains a minority practice. In 2016, biogas capture was applied to only 8% of landfilled waste worldwide. Biogas is mainly flared due to a lack of economic viability. In the same year, 11% of global waste was incinerated (Kaza *et al*., 2021). According to available data, more than 2,500 EfW facilities are in operation worldwide (ISWA, 2023). Air quality issues (flue gas, odours) are key factors for the social acceptance of MSW EfW. While concerns sometimes arise regarding pollution from waste combustion, technologies such as those described in Europe in the BREF document[12] and the associated monitoring requirements, enable EfW plants to operate with very limited, or even near-zero pollution impacts. Anaerobic digestion, which remains poorly documented globally, and RDF production are also developing as strategies both for reducing landfill and for energy recovery.

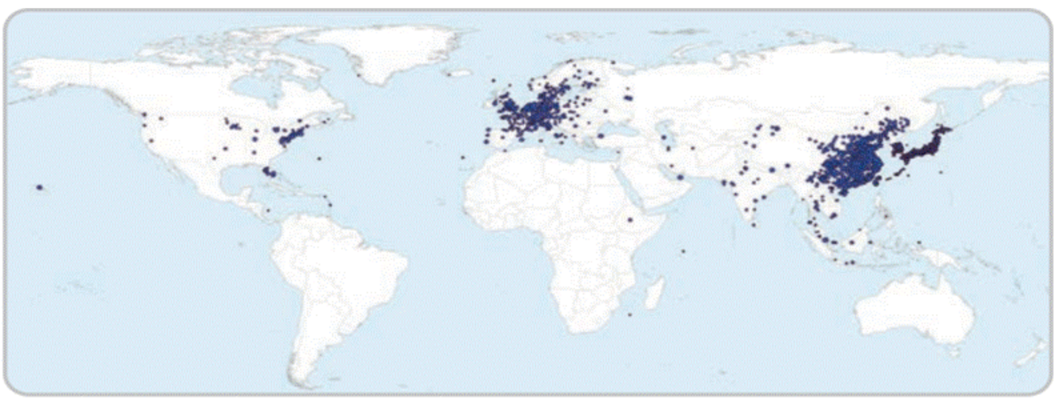

Figure 4: Global distribution of EfW facilities (Source: ECOPROG, 2022, *in* FSWP, 2025).

These treatment methods require rigorous territorial planning and integration into development policies. A structured energy market and clear contracts (price, volume, duration and quality) are necessary to guarantee revenue. Suitable distribution networks (electricity, gas, heat, transport) are essential for the viability of projects. Finally, local operational capacities must be assessed. The various recovery approaches involve an increasing level of technical complexity, regulatory requirements and sector organisation: recovery of biogas from landfill; biogas production from the organic fraction of waste; thermal recovery (EfW or RDF).

[12] BREF is the reference document for best available techniques (BAT) for the European Union.

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