WHITE PAPER

ON MUNICIPAL WASTE INCINERATION

UTILITALIA
water environment energy

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ON MUNICIPAL WASTE INCINERATION

Part I - Technical and environmental impact aspects

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Part II - Epidemiological surveys conducted in Italy and abroad in areas affected by the presence of incinerators and publications on the subject in scientific journals: annotated review.

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GLOSSARY

BAT: Best Available Techniques. Best Available Techniques applicable to industrial processes to minimise impact on the environment

EWC: European Waste Catalogue. This is the list of all possible types of waste generated in the European Union

RDF: Refuse-Derived Fuel. Material with good combustible characteristics obtained by mechanical and biological processing of residual municipal waste also indicated as SRF - Solid Recovered Fuel

RES: Renewable Energy Sources

OFMSW: Organic Fraction of Municipal Solid Waste, separately collected

SOF: Stabilised Organic Fraction. The "dirty" organic matter obtained by mechanical separation from RMW and subsequent biological stabilisation

PAHs: Polycyclic Aromatic Hydrocarbons

IPPC: Integrated Pollution Prevention and Control

ISPRA: Institute for Environmental Protection and Research

NCM: Non-Compostable Material. Foreign material found in the OFMSW, which must be separated

NMVOCs: Non-Methane Volatile Organic Compounds

PCB: Polychlorinated Biphenyls

PCDD/F: Dioxins and Furans

PM10: Fine Particulate Matter (size <10 microns)

SC: Separate Collection

SW: Special Waste

NHSW: Non-Hazardous Special Waste

HSW: Hazardous Special Waste

RMW: Residual Municipal Waste

MBT: Mechanical-Biological Treatment. Treatment applied to RMW that generates different types of output materials, such as RDF, SOF, waste

WFD: Waste Framework Directive


Termovalorizzatore - FORLÌ

INTRODUCTION

This White Paper consists of two distinct parts describing the results of two different research activities with different scientific coordinators.

The first, consisting of chapters 1, 2, 3, 4, 5, and 6, reports the results of the research on the "Technical aspects and environmental impact of incinerators" and was carried out by a working group composed of Professors Stefano Cernuschi (Scientific Coordinator), Mario Grosso and Federico Viganò of Politecnico di Milano; Maria Chiara Zanetti and Deborah Panepinto of Politecnico di Torino; and Marco Ragazzi of the University of Trento.

The second part had as its subject "Epidemiological investigations conducted in Italy and abroad in areas affected by the presence of incinerators and publications on the subject in scientific journals" and was conducted by a working group composed of Professors Francesco Lombardi and Andrea Magrini of the University of Rome 3 Tor Vergata.

The research activities carried out had the aim of highlighting what knowledge is currently available on the technology of incineration, with energy recovery, of residual municipal waste that cannot be recycled in order to reduce, and even eliminate, the use of landfill disposal.

In fact, with the introduction of the circular economy directives in the Italian law, in the next few years important actions will have to be planned and implemented, both in terms of waste management and treatment plants, in order to achieve the ambitious objectives of 65% effective recycling and reduction of landfill use to below 10%.

The technology of energy recovery through incineration of non-recyclable fractions can make a valid contribution to these purposes, also in view of the European pronouncements on the subject such as Communication No. 34 of 2017 of the European Commission, in which the role of energy recovery from non-recyclable waste is recognised in different forms, including waste incineration in dedicated plants.

The first part of the research, starting from the available data, highlights the irreplaceable support that waste to energy can provide in the management of flows that would otherwise be destined for disposal, such as, for example, waste from the treatment of organic fractions, waste from the sorting of plastics, waste from paper recycling and waste from the recovery of end-of-life vehicles.

In the description of the operation of thermal treatment, the environmental and energy balance of incineration is illustrated, highlighting how these processes are among the most controlled in the Italian and international industrial panorama and that the residues produced are now almost entirely sent for recycling, thus not burdening the nation's disposal quotas.

With regard to atmospheric emissions, the impact of the incinerator on the surrounding area is reported in several detailed case studies focusing on different contaminants. The impact of the incinerator is marginal for all the elements and compounds analysed and in some cases it is not significant at all.

It is important to underline the contribution of waste-to-energy plants to decarbonisation as a consequence of the emissions avoided to produce the same energy with the country's fuel mix and due to the alternative scenario of landfill disposal. This results in a positive contribution of more than 6 million tonnes of CO_2 avoided per year compared to landfill disposal.

Finally, the examination of the permitting and control aspects is not negligible in order to understand the high level of attention that characterises this waste recovery activity.

In the second part, dedicated to the analysis of epidemiological studies carried out in different areas of the world where incineration plants are present, it is highlighted that, in the most recent research activities and therefore more suitable to give evidence of the actual impact that incinerators currently in operation have on human health and the environment (plants complying with BAT, the Best Available Technologies, and complying with the legislation on waste incineration and consequently also with the limits on emissions), there is no evidence of the presence of cancer risk factors or negative effects on reproduction or human development.

I believe that, in every area of activity, taking informed decisions involves first and foremost giving a primary role to knowledge. Starting from this premise, the hope is that this work may constitute not only a contribution in an industrial sector that is fundamental for the achievement of autonomy in waste management with the closure of the integrated cycle, but also a document that confirms how important it is for the development of territories and societies to apply to processes - whatever they may be - a capacity for rigorous scientific analysis.

Renato Boero
Coordinator of the Utilitalia Treatment
and Disposal Plants Commission.

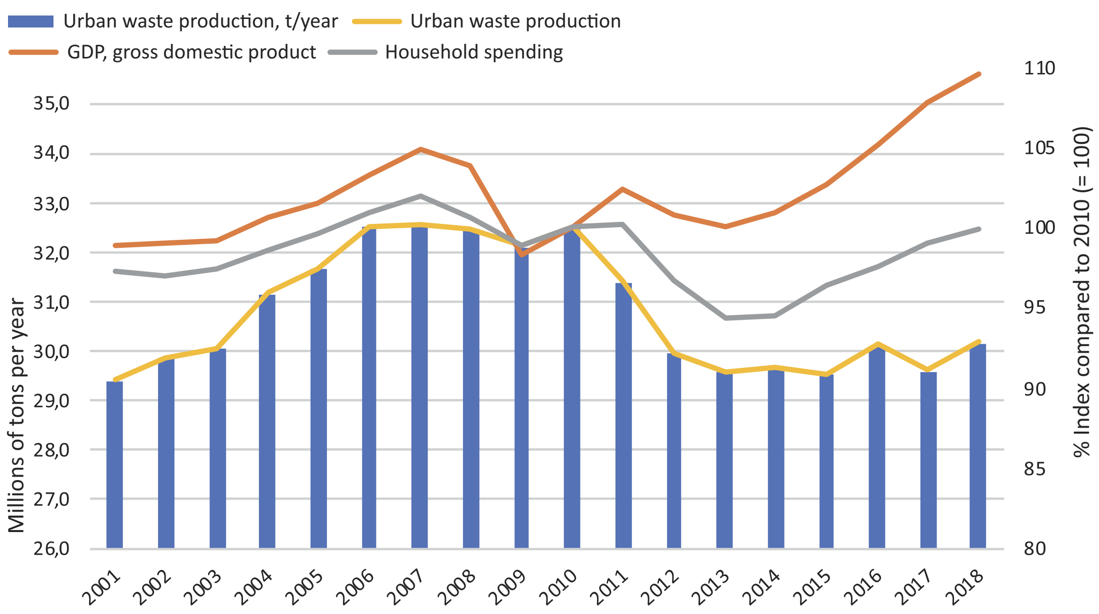
1. WASTE: GENERAL INFORMATION AND PRODUCTION IN ITALY AND EUROPE

Waste is "any substance or object which the holder discards, or intends or is required to discard". Waste produced by household users and waste of similar quality is classified as "municipal waste". The remaining types are classified as "special waste". A distinction is then made between "hazardous waste" and "non-hazardous waste" on the basis of certain hazard characteristics (content of certain substances, possibility of release of certain chemicals).
Finally, at a detailed level, waste is classified by means of an articulated system of EWC (European Waste Catalogue) codes that define its origin and main characteristics (including whether or not it is hazardous).

1.1 Production in Italy

Statistics on waste production and management in Italy are quite accurate for municipal waste, while in the case of special waste there are more uncertainties. This is partly due to the accounting systems in use and partly due to the characteristics of the classification system based on EWC codes. Indeed, municipal waste is subject to accurate accounting and is categorised by a limited number of waste codes (Chapter 20 of the EWC). Treatment processes applied to municipal waste (e.g. sorting, incineration) produce special waste. Consequently, special waste may also consist of material that is generated from the treatment of municipal waste, as well as from the treatment of special waste itself.
Official statistics for both municipal and special waste are prepared annually by ISPRA. Specifically, at the time of writing this document, the most recent statistics available are collected in the 2019 Municipal Waste Report, which contains all data up to the year 2018, and the 2018 Special Waste Report, which contains all data up to the year 2017.
In 2018, Italy produced a total of about 30 million tonnes of municipal waste, roughly in line with the average of the last twenty years. The chart in Figure 1.1 shows the annual municipal waste production in Italy from 2001 to 2018, as well as the corresponding trends in Gross Domestic Product (GDP) and household expenditure indicator, with reference to the year 2010. It is well known, in fact, that waste production has historically shown a strong correlation with economic trends.
The chart shows that in the last twenty years, the production of municipal waste in Italy went from a significant growth between 2000 and 2006- driven by a favourable economic period until it almost reached 33 million tonnes per year (Mt/y)- to a period of stagnation between 2006 and 2010, corresponding to the economic crisis, until the decrease in the years 2010 - 2013, then stabilising at the current levels of about 29 - 30 Mt/y, in line with the levels of the beginning of the millennium.

Figure 1.1 - Municipal waste production in Italy from 2001 to 2018 (data source: 2019 ISPRA MW Report) and corresponding trends at chained values (references to the year 2010) of Italian GDP and household expenditure indicator (data source: Eurostat)

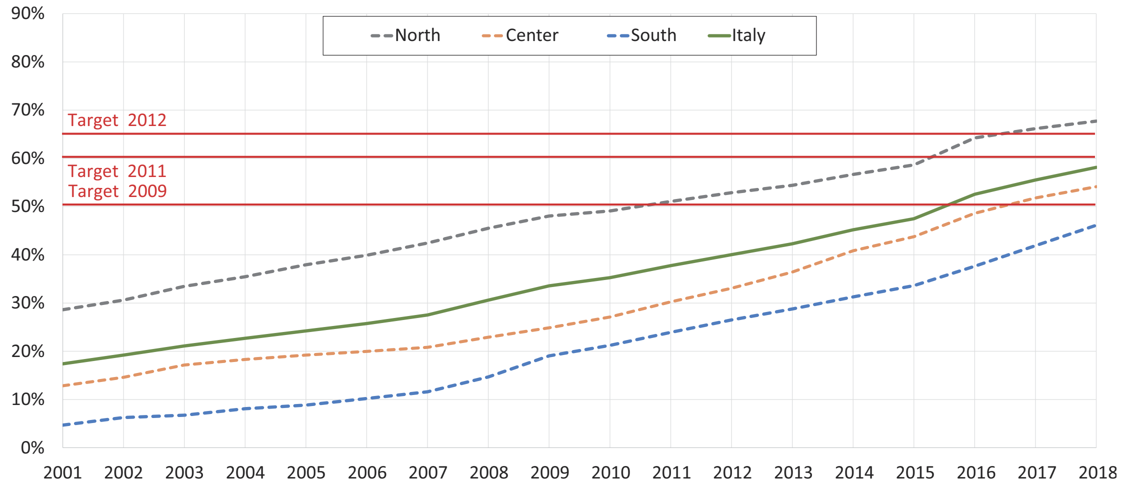


If in the period 2001 - 2013 the substantial correlation between the production of municipal waste and macroeconomic indicators is confirmed, from 2013 onwards it seems that this link has at least partially slackened, hopefully also as a result of the increased political attention to waste management (greater care in classification, accounting, introduction of techniques that lead, indirectly, to the reduction of the production of MW, such as separate collection, door-to-door collection, precise pricing), as well as greater attention paid by the population to the issue of waste reduction, including through behavioural change.

1.2 Separate collection and recycling rates

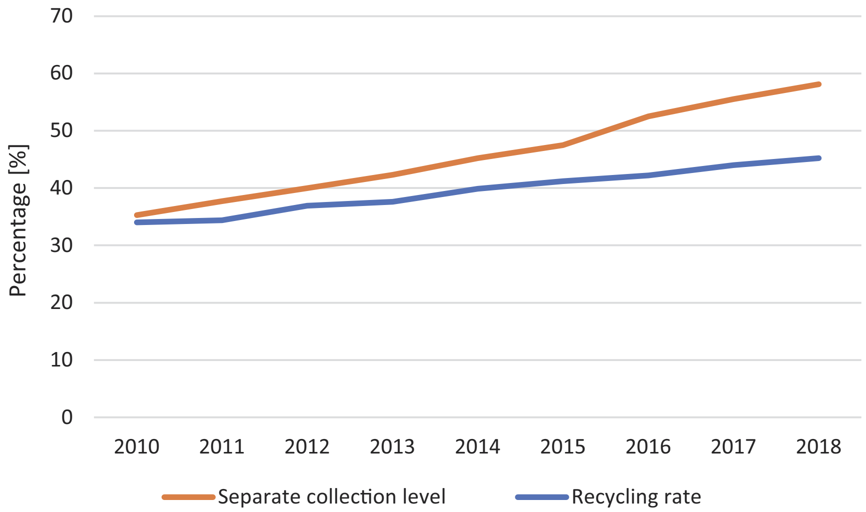
Separate Collection (SC) of municipal waste has steadily increased over time on a national average basis, as shown by the chart in Figure 1.2. This is, however, the result of a rather diversified situation among the various regions, with some engaged in the practice since the early 2000s and others where its introduction dates back only to recent years. It should be noted that the most ambitious SC target set by current legislation (65% in 2012) was achieved only by some regions and in any case later than prescribed.

Figure 1.2 - Evolution of SC over the years for Italy and the three macro-areas (North, Centre and South - data source: ISPRA Waste Cadastre)



In addition to the level of separate collection, the legislation also defines the recycling rate of municipal waste, taking into account only part of what is collected separately. In fact, some types of materials and a portion of the waste generated by sorting processes are excluded. Therefore, the recycling rate of municipal waste is lower than the level of separate collection and in recent years has shown appreciably lower growth than the increase in SC, as shown in Figure 1.3.

Figure 1.3 - Comparison between SC level and recycling rate (data source: 2019 ISPRA Municipal Waste Report)



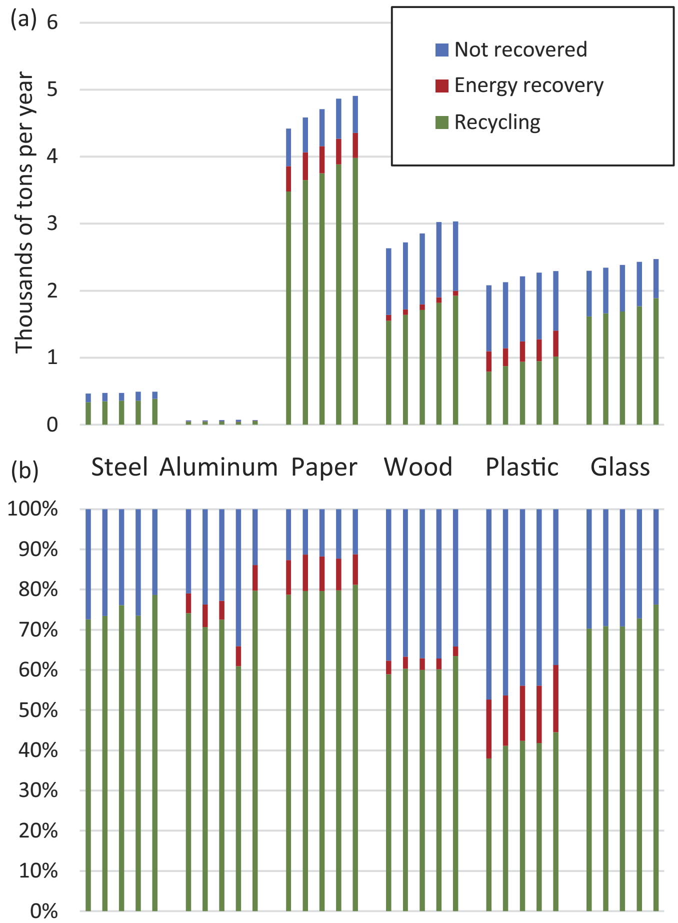
Finally, considering the different types of materials, it is possible to define recycling and recovery rates as ratios between the quantity of material actually sent for recycling (in jargon "recycled") / recovery and the quantity put on the market in the same year.

Current legislation defines recovery as "*any operation the principal result of which is to enable waste to play a useful role by replacing other materials which would otherwise have been used to fulfil a particular function, or to prepare waste to fulfil that function, either within the plant or in the economy in general*". Recycling, on the other hand, is defined as "*any recovery operation by which waste is treated in order to obtain products, materials or substances to use for their original function or other purposes*. *It includes treatment of organic matter but does not include energy recovery or retreatment to obtain materials for use as fuels or in backfilling operations*".

Figure 1.4 shows both the total quantities of packaging released for consumption, sent for recycling and energy recovery in the years 2014-2018, and the corresponding recycling and recovery rates. The chart shows that out of about half a million tonnes per year of steel packaging placed on the Italian market, between 70 and 80% is sent for recycling. Aluminium packaging, for which the market share is a few hundred thousand tonnes per year, is recycled between 60 and 80%, while there is a share of just under 10% of energy recovery, i.e. recovered from the combustion slag of incinerators. Almost five million tonnes of paper packaging are placed on the Italian market each year, of which between 60 and 70% is recycled, while just under 10% is recovered for energy purposes. Wooden packaging, which is released for consumption for about three million tonnes per year, is sent for recycling for a share between 25 and 35%, while the share of energy recovery is only 2-3%. Plastic packaging, put on the Italian market for more than two million tonnes per year, is sent for recycling for 40-45% and 10-15% for energy recovery. Finally, 70-75%

of glass packaging, which is released for consumption in the amount of just under two and a half million tonnes per year, is sent for recycling.

Figure 1.4 - (a) Quantities of packaging materials released for consumption, sent for recycling (in jargon "recycled") and sent for energy recovery in the years 2014-2018; (b) corresponding recycling and recovery rates (data source: "L'Italia del riciclo 2019" edited by Fondazione per lo Sviluppo Sostenibile (Foundation for Sustainable Development) - FISE)



1.3 Waste from waste treatment plants

Waste sorting treatments, aimed at being sent for recycling in subsequent plants, involve the production of residues potentially at all stages of processing. Here we are mainly concerned with certain solid wastes that are generated at various times in the processes involved.

1.3.1 Waste from the treatment of organic fraction

The current scenario for the management of the organic fraction of municipal waste (OFMSW) collected separately envisages either composting or anaerobic digestion, the latter generally followed by composting of the digestate.
In general, all materials that are not suitable for the process because they have been wrongly delivered, which are called Non-Compostable Material (NCM), such as, for example, plastics, metal elements, glass, must be removed from the plants. Another crucial element is the type of bags used for collection, which must be compatible with the plant technology. On the large numbers, it is still noted that many users use bags of unsuitable material (in non-biodegradable plastic, but also in biodegradable material however in times not necessarily compatible with the biological process that characterises the destination plant). This is why in some plants, particularly anaerobic digestion plants, all plastic or bioplastic bags are removed upstream, regardless of whether they are compliant or not.
It should also be pointed out that the waste actually generated by organic fraction treatment plants can be as much as four times the actual impurities detected in the input material as NCM (Corepla et al., 2017). This is due to carry-over effects (i.e., the Non-Compostable Material retains part of the organic matter) that occur during the separation of unwanted materials, facilitated by the very nature of plastic bags. The most appropriate destination for such a waste is incineration, if an economically viable remote plant is available. If they were to be delivered to the landfill, however, they would presumably have to undergo pre-treatment in order to be biostabilised in accordance with the regulations.

1.3.2 Waste from the production of Refuse-Derived Fuel (RDF)

Refuse-Derived Fuel (RDF) is a material that can be produced from Residual Municipal Waste (RMW) to generate a flow more suitable for energy recovery activities in industrial plants (typically cement plants). RDF production methods for this waste flow are discussed in Chapter 5. Instead, this section will discuss the issue of waste that is generated depending on the quality of RDF that is to be produced. The more the waste is processed to isolate its fuel component, and therefore improve its characteristics, the greater the quantity of materials to be disposed of with the secondary flows generated by the treatment. If one excludes materials extracted from the treatment process which have a value in themselves (iron, aluminium) or a recyclability at least in principle (aggregates), operations at the end of the treatment process may, for example, generate flows of fine fractions with different levels of biological stabilisation. We are therefore faced with waste that may require specific solutions to make it compatible with proper landfill disposal.

1.3.3 Waste from plastic sorting

Sorting plastic material flows from separate collection is a process that, despite technological developments in recent years, remains particularly complex due to the greater heterogeneity of the materials collected. In fact, it is clear that the increased pressure for separate collection, particularly of plastics, combined with the complexity of the packaging placed on the market, entails the risk of a deterioration in the quality of the material. For some types of plastics, typically rigid PET and HDPE (bottles and containers), separation is conceptually straightforward, as is the subsequent recovery in the recycling market. For other polymers, such as film plastics, which are constantly growing, recovery on the recycling market is much more problematic. Even in recent periods there have been negative market values for plastic film, i.e. there has been a need to pay for its disposal rather than being able to place it according to a given market price (Corepla, 2019).

In general, the processing of the flow of plastics collected separately generates a secondary mixed flow which is called Plasmix. This is the set of heterogeneous plastics, mixed with non-plastic impurities, which are not recovered as single polymers. In Italy the annual quantity of Plasmix is destined to increase with the increase in the level of separated waste collection, which is still low in some areas. Energy recovery is currently the dominant fate for this material; however, there has been a significant increase in the use of landfill in recent years, involving as many as 110,000 tonnes in 2018, compared to 12,000 tonnes in 2016. This is due both to the increase of the non-recyclable and non-energy recoverable extraneous fraction, present in the separate collection, and to the difficulty of finding available capacity in energy recovery plants, already saturated by the flows of residual municipal waste also coming from regions in emergency conditions.

1.3.4 Waste from paper recycling

The paper production sector generates on average 6.5% of recycling residues, which are sent to landfill or energy recovery. This flow is represented by pulper waste, a waste consisting mainly of mixed plastics. The amount of pulper waste generated in Italy is 300,000 t/year, and in principle this is a material that is certainly suitable for energy recovery (Assocarta, 2017).

1.3.5 Waste from the treatment of end-of-life vehicles: car fluff

This is the residue generated by the shredding and sorting of end-of-life vehicle scrap produced by auto wrecking plants. In Italy the quantities generated are around 180,000 t/year. Car fluff is mainly made up of materials with a high energy content: it consists of plastics, rubber, textiles, paper, wood and upholstery material with a minimum amount of non-combustible materials, the latter mainly metal. For this reason it is undoubtedly a particularly interesting material to be sent for energy recovery in suitable plants.

1.4 Special waste in Italy

The production of Non-Hazardous Special Waste (NHSW) and Hazardous Special Waste (HSW) in Italy is estimated, for 2017, at 129.2 and 9.7 million tonnes respectively. ISPRA indicates that the amount of NHSW includes more than 10 million tonnes of special waste resulting from the treatment of municipal waste.
The contributions of the main economic activities producing NHSW in 2017 are shown in Table 1.1 and indicate, as the main sectors, Construction and Demolition (C&D) with 57.0 Mt/y for about 44% of the total, Waste Treatment and Recovery activities, e.g. treatment sludge, with 32.9 Mt/y for about 26% of the total, and Manufacturing with 26.0 Mt/y for about 20% of the total.

Table 1.1 - NHSW production in Italy in 2017 by sector of economic activity (data source: 2019 ISPRA Special Waste Report)

Sector of activity	ATECO Code	Mt	%
Manufacturing activities	10-33	26.0	20.12
Waste treatment and recovery activities	38-39	32.9	25.46
Construction and Demolition (C&D)	41-43	57.0	44.12
Other sectors	-	13.3	10.29
Total		**129.2**	**100.00**

In addition to the information on the production of NHSW, the 2019 ISPRA Special Waste Report also shows the management methods, according to the coding of Recovery ("R") and Disposal ("D") operations defined by the regulations. These data are summarised for 2017 in Table 1.2.

Table 1.2 - Methods of managing NHSW in 2017 in Italy (data source: 2019 ISPRA Special Waste Report)

Sector of activity	Code	Mt	%
Energy recovery	R1	1.9	1.38
Other recovery operations	R...	110.8	80.52
Landfill disposal	D1	10.9	7.92
Incineration without energy recovery	D10	0.8	0.58
Other disposal operations	D...	132	9.59
Total		**137.6**	**100.00**

The quantities of NHSW generated and managed do not match due to a number of contributions, such as waste generated by waste management activities (which is waste already accounted for when first generated by other activities), waste undergoing storage operations with a view to subsequent recovery/disposal, waste undergoing intermediate treatment, process losses and, finally, the import/export balance with foreign countries.
R1 and D10 cover thermal treatment, distinguishing between energy recovery (operation R1) and incineration (D10) without energy recovery. However, this classification is not as clear-cut for NHSW as for municipal waste (see par. 2.4), since

current legislation does not define a single criterion for this type of waste similar to that for municipal waste. In fact, the ISPRA Report specifies that a large part of the NHSW sent for the D10 operation is treated in municipal waste incinerators that have R1 status. Consequently, this NHSW is recovered energetically, rather than disposed of by incineration as D10 would indicate. In total, R1 and D10 operations were applied in 2017 to approximately 2.7 Mt of NHSW other than those produced by the municipal waste MBT. This includes, for example, end-of-life tyres, solvents, processing scraps, treatment sludge, etc., as well as NHSW decaying from the treatment of municipal waste separate collection, such as sorting and material recovery waste. By processing the data reported by ISPRA (2019 Special Waste Report), it is possible to quantify the combustible NHSW not coming from municipal waste MBT, in at least 10 Mt/y. This result is reached considering the quantity of 2.7 Mt/y already sent to heat treatment, a share of what is currently sent to landfill (10.8 Mt) and a share of treatment sludge or the materials derived from it (currently subjected to biological treatment - R10) that the regulatory evolution in place seems to address, in the future, to heat treatment. It is considered that this quantity also includes the waste produced by material recovery operations, both for NHSW and municipal waste.

1.5 International scenarios and critical issues arising from flows to foreign markets

Non-industrial plastic waste and recycled pulp are no longer accepted in China since January 2018. This decision has put the recycling sector in Italy in crisis in view of the high percentage of separate collection flows exported to that country. Figure 1.5 shows the international picture of the import of plastic waste just prior to China's import ban of such waste (Berardi and Valle 2018): the dominant role China has played on a planetary scale is clear. Following the Chinese ban, some of the exports were spread to other countries, mainly in Southeast Asia, whose import capacity, however, is not equivalent to China's (Figure 1.6).

Figure 1.5 - International picture of the import of plastic waste just before the import ban on this waste in China

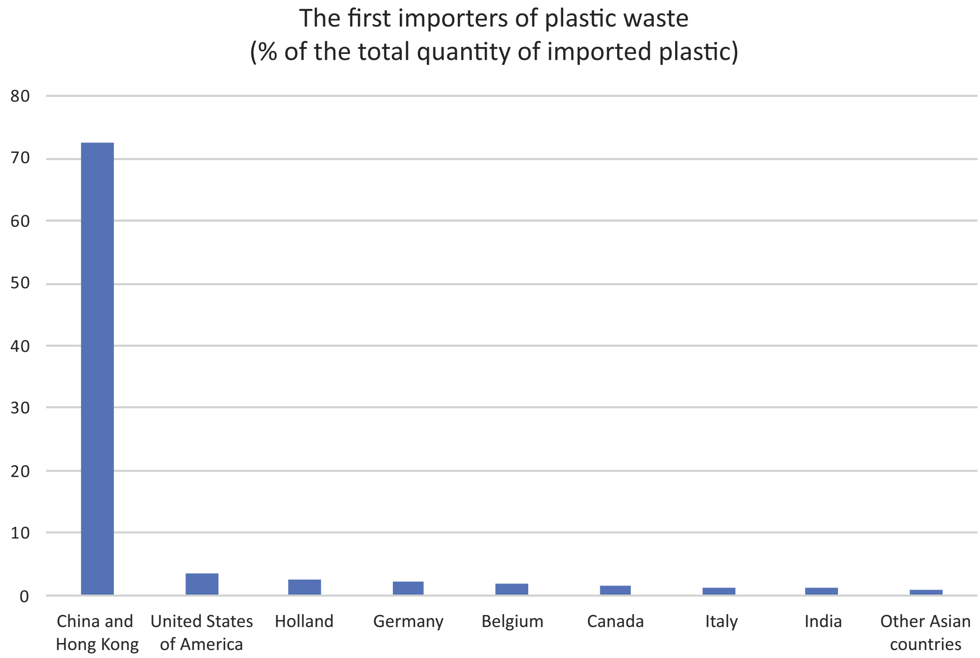
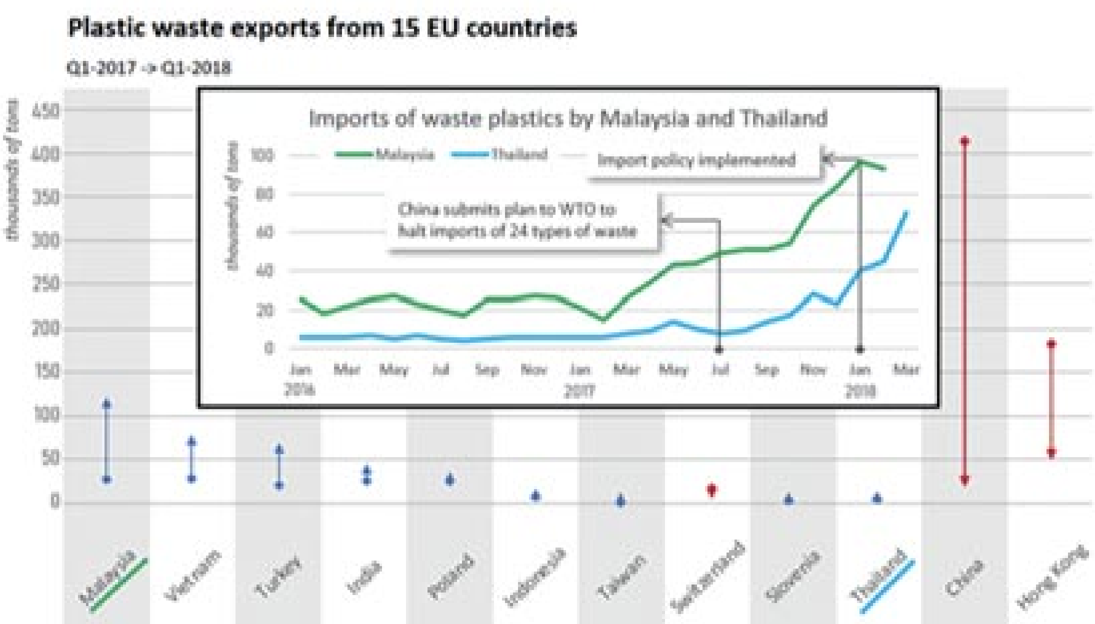


Figure 1.6 - Change in plastic waste exports following the closure of the Chinese market

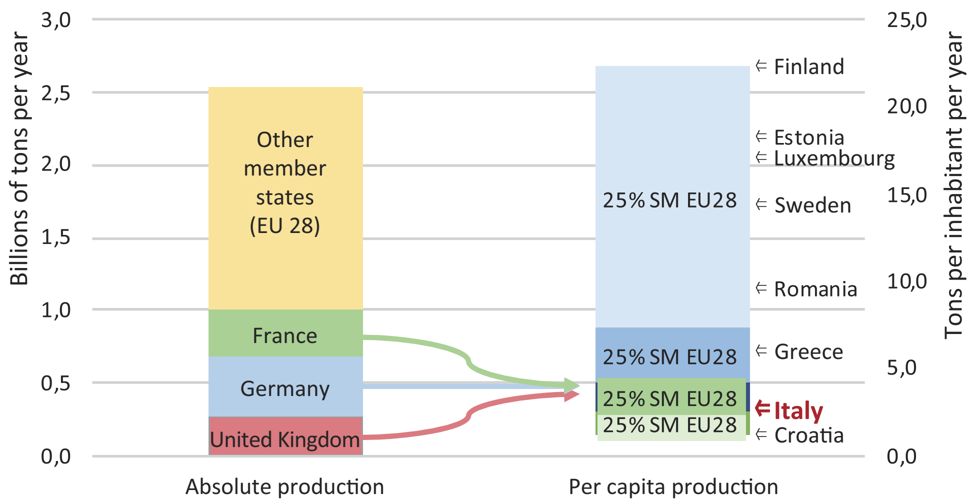


The crisis caused to the recycling chain of these flows can partly explain the increase in fires that occurred in Italian waste storage sites in the last period, mainly concerning stockpiles of plastic and cellulose materials, given the difficulty in finding suitable treatment in the national territory.
The case of China has highlighted the criticality of a management of the most problematic waste flows based on foreign countries. The inadequacy of plants for Italian waste management is also observed for RDF, a material of which exports are significant (see par. 5.2).
The export of fly ash and air emission treatment residues from incineration plants to disposal sites (typically underground mines authorised for the storage of hazardous waste) also appears to be a waste export practice, and as such may be subject to future problems such as those highlighted above.

1.6 The European context: waste production, separate collection and recycling rates

Total waste generation (municipal and special) in the EU28 (Union of 28 States) is quantified by Eurostat as 2,537 Mt for 2016, the latest year for which data is available. The main contributions (more than 10% of the total) came from Germany, France and the United Kingdom. Italy accounts for just over 6% of the total. The chart in Figure 1.7 shows both absolute waste generation and the statistical distribution of annual per capita generation, again referring to EU28 for 2016.

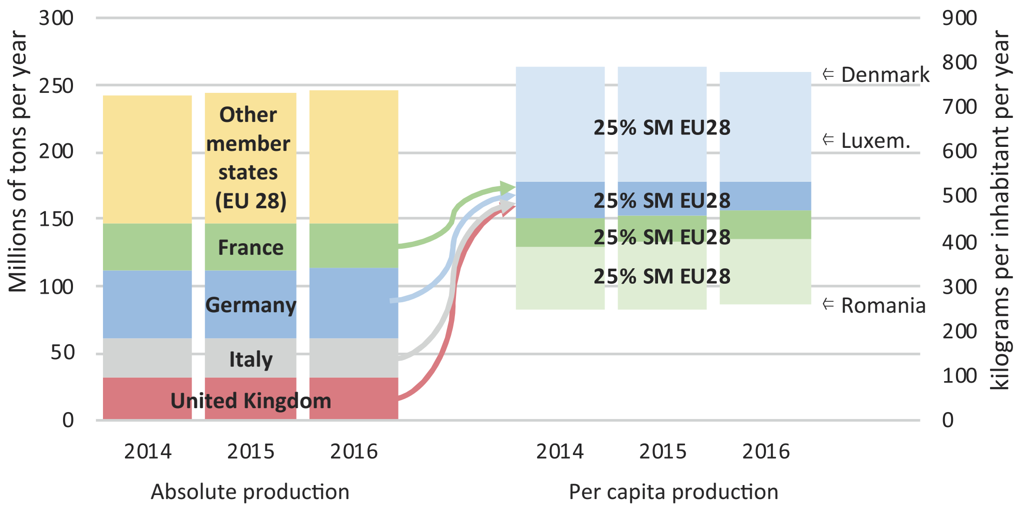
Figure 1.7 - Total annual absolute and per capita generation of waste (municipal + special) in EU28 (data source: Eurostat)



In terms of production per inhabitant, a wide variability is appreciated, with the lowest value achieved by Croatia with 1.3 t and the highest value by Finland with over 22 t. This situation is undoubtedly linked both to socio-economic factors (e.g.

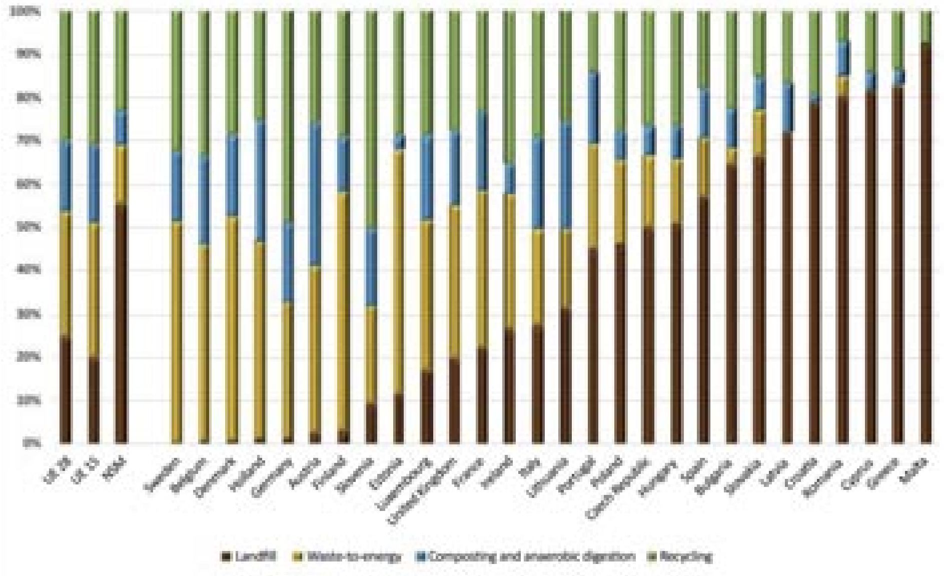
in Sweden and Finland a lot of SW is generated by forest maintenance) and to possible major differences in the way quantities are accounted for.
While maintaining an appreciable variability, the situation regarding municipal waste alone is more homogeneous, as shown in Figure 1.8, with reference to the years between 2014 and 2017.

Figure 1.8 - Annual absolute and per capita municipal waste production in the EU28 (data source: 2018 ISPRA Municipal Waste Report)



Total municipal waste production between 2014 and 2016 for EU28 was just under 250 Mt. The member states contributing most (more than 10% each) to this result are Germany, France, Italy and the United Kingdom. In per capita terms, the lowest production was achieved by Romania, with just over 250 kg/inhabitant*year, while the highest was in Denmark, with about 770 kg/inhabitant*year. Here too the differences are due to the socio-economic characteristics of the different countries, as well as to different ways of classifying municipal waste. Italy is in a central position, i.e. in line with the European average of about 500 kg/inhabitant*year.
The municipal waste management methods adopted in 2016 by the EU28 Member States are depicted in Figure 1.9, from which deep differences can be seen, especially regarding the use of landfill. In fact, the most virtuous countries, located on the left of the chart, have already achieved important objectives in reducing the use of this form of disposal. This has generally occurred thanks to a concomitant action of material recovery (recycling of packaging and biological treatment of the organic fraction) and energy recovery from the residual fraction.

Figure 1.9 - MW management modes adopted in the EU28 in 2016
(image taken from the 2018 ISPRA Municipal Waste Report).



1.7 European Community directives on waste management: current situation and strategic guidelines

Waste management in the European Union is regulated by the Waste Framework Directive (WFD-Dir. 2008/98/EC). In Italian legislation, this directive is transposed in the Consolidated Environmental Act (TUA, Italian Legislative Decree 152/2006). The WFD is based on a number of core waste management concepts, such as:

- reducing the use of resources;
- consideration of the entire life cycle of materials/products;
- achieving the best overall environmental result;
- application of the "polluter pays" principle through the mechanism of extended producer responsibility.

The hierarchy of operations that the Directive defines for waste management is as follows:

- prevention;
- preparing for re-use;
- recycling;
- other types of recovery, e.g. energy recovery;
- disposal.

This hierarchy specifies the priority for the application of management operations, according to which prevention of waste generation is preferable to any other management method. When the waste has been produced, it is preferable to first

prepare it for re-use and secondly recycle it. If none of these options are sustainably viable, then it is preferable to use other forms of recovery, such as energy recovery, before resorting to disposal.
The WFD also specifies that it is possible to deviate from this general hierarchy in particular cases if the greatest environmental benefit can be demonstrated on the basis of a *Life* Cycle Assessment (LCA).
The last amendment of the WFD was introduced at the end of May 2018 with the introduction of the so-called "Circular Economy Package", and was transposed by Italian Legislation in September 2020.
The "Circular Economy Package" reinforces some concepts that were already contained in the WFD, and clarifies some definitions also in order to improve the collection and processing of statistical data on waste management. Particular attention is paid to the target of keeping materials as long as possible within the cycle of production and consumption of goods, so as to minimise, on the one hand, the need for virgin material resources, and on the other the amount of waste to be subjected to other forms of recovery and/or final disposal.
The reinforcement of certain concepts is also pursued by introducing new objectives. For example, the following "preparing for re-use and recycling" targets have been introduced in the context of municipal waste management:

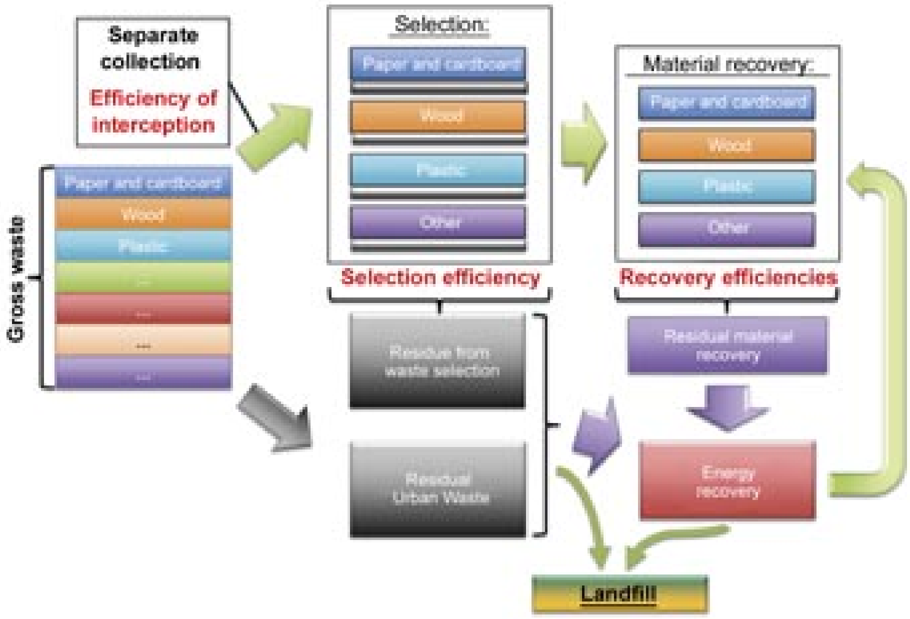
- at least 55% of municipal waste by 2025;
- at least 60% of municipal waste by 2030;
- at least 65% of municipal waste by 2035.

In the case of Italy, these targets overlap with the objectives already set by Italian legislation in terms of separate collection (SC) of municipal waste (Art. 205, par. 1 of the TUA). As shown in Figure 1.2 above, the 65% SC target set by Italian law for 2012 has not yet been reached by all Italian regions, let alone by Italy as a whole.
As discussed in par. 1.2, the difference between the quantities of municipal waste sent to "preparing for re-use and recycling" and those subjected to SC lies mainly in the selection/sorting waste, i.e. the preliminary treatment carried out on waste from SC before being sent to the relevant material recovery (i.e. recycling) processes. These are the NHSWs produced by the municipal waste treatment processes, which have already been discussed in the previous paragraphs and which amount to quantities of several million tonnes per year.
Further waste can be produced by the actual recycling processes. For example, paper from single material SC is usually not sorted, but sent directly to the recycling plant, i.e. the paper mill. In the recycling process, "pulper waste", as explained in section 1.3.4, is then produced.
The data on SC are gross of all the waste produced by the subsequent treatment processes, while the data on "preparing for re-use and recycling" exclude the waste produced by the preliminary sorting of the material, although they include the waste produced by the recycling process. Figure 1.3 above shows how the two indicators have evolved in recent years in Italy, with the gap widening due to the growing content of impurities and foreign materials in waste from SC, as a consequence of the growth of SC. Although the data shown in this chart cannot be used directly to

quantify the extent of these differences, the progressive deviation of the lines indicates the inevitable increase.

Figure 1.10 schematizes the structure of a municipal waste management system organised according to the dictates of the WFD. In this scheme, it is pointed out that everything not suitable for recycling because it is collected in an undifferentiated manner, as well as all residues from the material sorting and recovery processes consequent to the SC, is by priority sent to energy recovery. Only those types of waste that cannot be recovered energetically are sent to landfill. Energy recovery is also considered to be an active part of the material recovery system, since a large part of the solid residues produced during the process are returned to the material cycle (e.g. metals extracted from bottom ash, as well as the inert fraction used as feedstock for cement and concrete production).

Figure 1.10 - Diagram of the structure of a municipal waste management system organised according to the dictates of the WFD



1.8 Plant situation in Italy

The 2019 ISPRA Municipal Waste Report and the Utilitalia Report on Energy Recovery from Waste - ISPRA (2019) report the presence, at the end of 2018, of thirty-eight municipal waste incinerators on the national territory. During 2019, the Ospedaletto (PI) and Ravenna plants ceased operations. The Macomer (NU) plant should soon be back in operation after a major technological upgrade. Moreover, the official statistics do not take into account the Manfredonia (FG) plant, considering it a co-incineration plant, despite the fact that it is dedicated exclusively to the incineration of RDF from municipal waste. At the time this document is being written, we can therefore consider thirty-eight installations in the national plant system.

The above-mentioned documents contain a variety of information on the characteristics of the plants and their distribution throughout the country. Table 1.3 re-processes this information, locating almost 68% of the treatment capacity in Northern Italy, slightly less than 10% in Central Italy and the remaining approximately 22% in Southern Italy and on the islands.

Table 1.3 - Municipal waste incineration capacity in Italy and relative territorial distribution and by type of treatable waste (data source: 2019 ISPRA Municipal Waste Report with some supplements and updates)

	Number of plants	Rated thermal load, MW					Treatment capacity, t/y		
		RMW	RDF4	RDF3	Total	%	RMW	RDF4	RDF3
Piedmont	1	206	0	0	206	6.95	530,229	0	0
Aosta Valley	0	0	0	0	0	0.00	0	0	0
Lombardy	13	910	34	196	1,139	38.37	2,337,582	67,220	335,495
Trentino AA	1	59	0	0	59	1.98	151,384	0	0
Veneto	2	119	0	0	119	4.01	306,212	0	0
Friuli Venezia Giulia	1	67	0	0	67	2.27	172,973	0	0
Liguria	0	0	0	0	0	0.00	0	0	0
Emilia Romagna	7	425	0	0	425	14.31	1,092,071	0	0
North	**25**	**1,786**	**34**	**196**	**2,016**	**67.89**	**4,590,451**	**67,220**	**335,495**
Tuscany	4	130	0	0	130	4.36	333,096	0	0
Umbria	0	0	0	0	0	0.00	0	0	0
Marches	0	0	0	0	0	0.00	0	0	0
Lazio	1	160	0	0	160	5.39	411,229	0	0
Centre	**5**	**290**	**0**	**0**	**290**	**9.75**	**744,325**	**0**	**0**
Abruzzo	0	0	0	0	0	0.00	0	0	0
Molise	1	47	0	0	47	1.58	120,799	0	0
Campania	1	0	340	0	340	11.45	0	672,202	0
Apulia	2	0	0	111	111	3.75	0	0	190,879
Basilicata	1	19	0	0	19	0.63	48,062	0	0
Calabria	1	0	0	60	60	2.02	0	0	102,807
Sicily	0	0	0	0	0	0.00	0	0	0
Sardinia	2	87	0	0	87	2.92	222,578	0	0
South and islands	**8**	**152**	**340**	**171**	**664**	**22.35**	**391,439**	**672,202**	**293,686**
Italy	**38**	**2,228**	**374**	**367**	**2,969**	**100**	**5,726,216**	**739,422**	**629,181**

Table 1.3 shows the treatment capacity of the plants both in terms of rated thermal load and of quantity of waste that can be treated annually. Both these characteristics have been differentiated according to the type of waste that can be treated by the plant considered.

The rated thermal load (expressed in MW) is the quantity that best quantifies the treatment capacity of a plant. The hourly lifting capacity of treated waste, expressed in mass (t/h), multiplied by its energy content, expressed as the Net Heating Value (NHV - GJ/t), provides the instantaneous thermal value which, under ordinary conditions, is equal to or less than the rated thermal value.

Three types of waste that can be fed to Italian incinerators have been considered here: RMW, i.e. Residual Municipal Waste, RDF4, i.e. Refuse-Derived Fuel with energy class 4, and RDF3, i.e. Refuse-Derived Fuel with energy class 3.

The RMW is the residual downstream of SC, i.e. the undifferentiated or dry fraction. An average NHV of 10 GJ/t was assumed for this waste, which is in line with the average for municipal waste incinerators.

RDF = "Refuse-Derived Fuel" is produced from the RMW by means of Mechanical Biological Treatment (MBT) plants, as described in chapter 5. For the RDF there is

a classification system defined by the technical standard UNI EN 15359, with five classes depending on the NHV. Since NHV is the parameter that more than any other defines the type of RDF and its compatibility with the combustion technologies adopted by the various plants, two types of this waste were considered.
RDF4, with an NHV of 13 GJ/t, falls into NHV class 4 and is representative of shredded waste suitable for feeding several Italian plants. RDF3, with an NHV of 15 GJ/t, falls into PCI class 3 and is representative of the former RDF (Refuse-Derived Fuel), for which several Italian incinerators have been designed.
Based on the rated thermal value, the type of waste that can be treated and an average annual plant utilisation rate of 81.5% (representative of the last few years), the last three columns of Table 1.3 show the annual treatment capacities available in the Italian regions for the different types of waste.
ISPRA's official statistics report a quantity of thermally treated waste in 2018 of about 6.3 Mt, of which almost 5.6 Mt of definitely municipal origin while the remainder, of about 0.7 Mt, is mainly made up of NHSW (some special hazardous waste is also treated, mainly hospital waste with risk of infection).
The assessments in Table 1.3 report an overall Italian system capacity of just over 7 Mt. The difference from what was actually processed in 2018 lies in several factors. First of all, plants that have recently completed their operations were excluded from the assessment and plants not considered by ISPRA were included. Therefore, the treatment capacity has been dedicated entirely and solely to municipal waste, while in reality a portion is dedicated (and sometimes reserved, as in the case of hospital waste) to SW that take away space from municipal waste. Often the treated SW has a significantly higher NHV than municipal waste and the treatment of one tonne of SW can reduce the treatment capacity of the municipal waste by two or more tonnes. Finally, the main source of this discrepancy is to be found in the strong recourse to waste pre-treatment, carried out mainly in the regions of Central and Southern Italy. This practice produces RDF4 to feed plants that can also receive RMW. The amount of material that can be treated by the plant decreases, while maintaining approximately the same energy input (thermal value). However, this produces significant amounts of waste from the pre-treatment of RMW, which is predominantly disposed of in landfills.
With a view to eliminating the use of landfill, these unwise practices should be avoided, favouring instead approaches that do not require landfill except for that small fraction of residues that cannot otherwise be re-used and have no energy content.
The production of RDF4 and RDF3 is also possible without recourse to landfill. By appropriately designing (or sometimes just regulating) the production processes, it is possible to obtain waste with energy characteristics similar to the original RMW and, therefore, which can be sent to the same destinations as this waste, i.e. primarily incineration. Figure 1.11 shows the conceptual diagrams of two Mechanical Biological Treatments (MBT) for the production of RDF4 and RDF3 respectively, with the simultaneous production of waste with similar energy characteristics to the starting RMW. The corresponding mass and energy balances are also shown.
In addition to incineration in dedicated plants and the use of landfill, the use of RDF (typically RDF3) to replace fossil fuels mainly in cement plants (about 0.22 Mt in 2018) also contribute to municipal waste management. Considering also the

presence of these "needs" for alternative fuels, the diagram in Figure 1.12 defines a municipal waste management system applicable to a generic area, in which everything that cannot be recycled before being disposed of in landfills, as is often the case today, is instead recovered energetically through incineration.

Figure 1.11 - Conceptual diagrams of two Mechanical Biological Treatments (MBT) for the production of RDF4 and RDF3 respectively, with the relative mass and energy balances

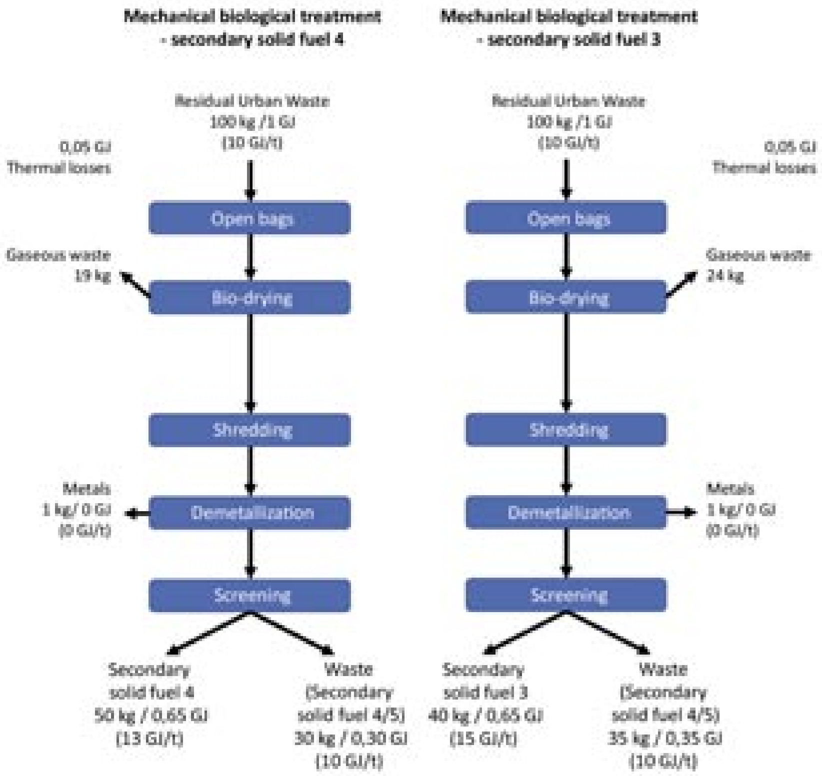
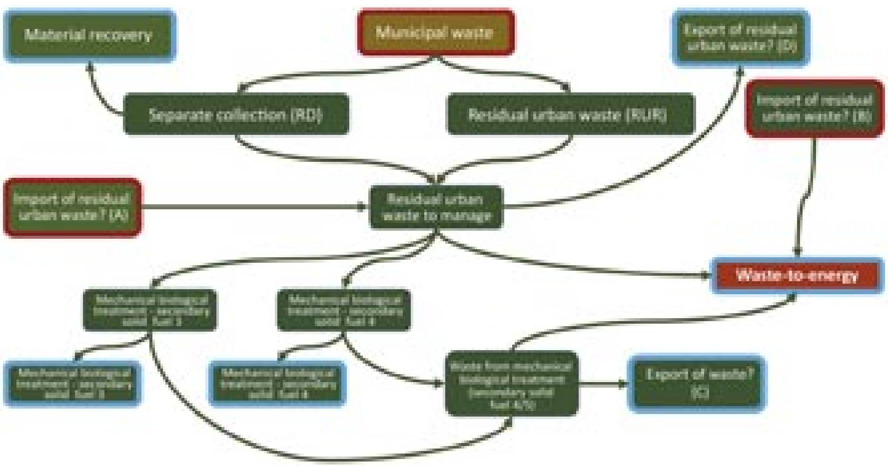


Figure 1.12 - Conceptual diagram of an "ideal" system for municipal waste management in a generic area.



For simplicity in cases of deficit or surplus of waste within the area considered, the possibility of importing/exporting RMW directly from the area has been foreseen, even if this conflicts with the regulations in force, which require the pre-treatment of such waste before sending it to management areas other than that of origin. In fact, the import/export of RMW is used for the sole purpose of quantifying the imbalance of the management system of the area considered.

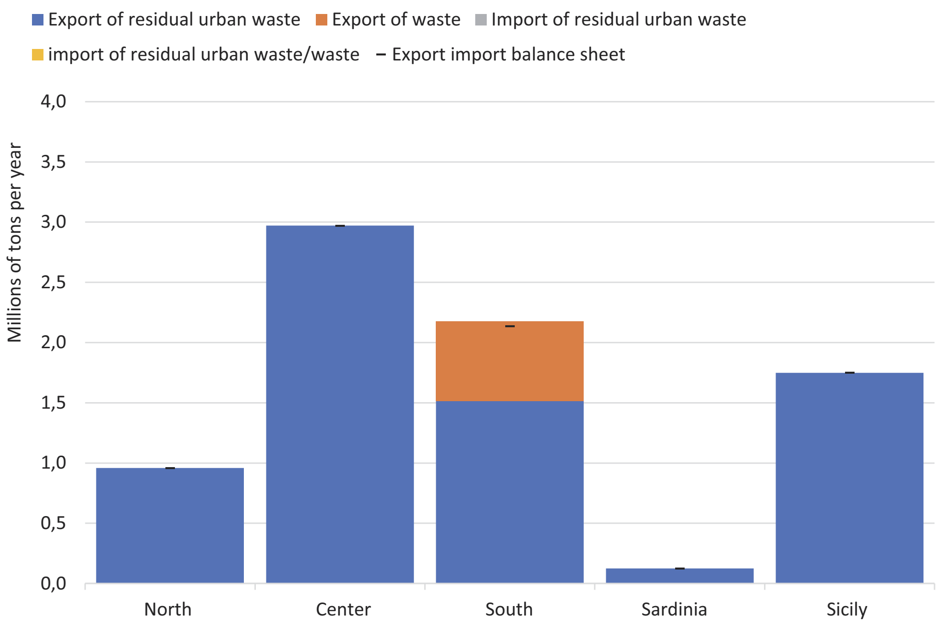
The adopted scheme gives priority to the use of the collected RMW and the waste produced by the SC for the production of the RDF required by the production system and by the plants in the area. In case this approach generates a shortage of RMW, the import of RMW is triggered via flow A. The production of RDF generates waste with energy characteristics similar to RMW, which is therefore sent to incineration if the plant equipment allows it, or is exported from the area with the C flow. The availability of RMW that exceeds the "needs" for the production of RDF is destined for direct incineration, if the plant capacity allows it, otherwise it is exported from the area with flow D. Finally, if the plant capacity is greater than the availability of RMW and waste in the area considered, there is the possibility of importing additional RMW with the B stream.

The area is fed by municipal waste production, but can be fed by two other optional inputs: the import of RMW for MBT (flow A) and the import of RMW or waste for incineration (flow B). The final destinations of the waste can be: material recovery (recycling), the production of RDF (energy category 4 or 3), incineration, or the export of waste from MBT (flow C) or RMW (flow D).

The simplification related to the import/export of RMW can be easily translated into a situation in accordance with the current legislation in which the RMW before leaving the area of origin is subjected to MBT for the production of RDF4. The size of the import/export flows would be reduced by 10-20% in terms of mass, while maintaining roughly the same energy content and thus requiring the same treatment capacity.

The diagram in Figure 1.12 has been applied to the three macro-areas of the peninsula, North, Centre and South, and to the two major islands, generating the results shown in the chart of Figure 1.13.

Figure 1.13 - Mass balances of the five areas considered according to the diagram in Figure 1.12, in terms of import/export flows to maintain balance without resorting to landfill

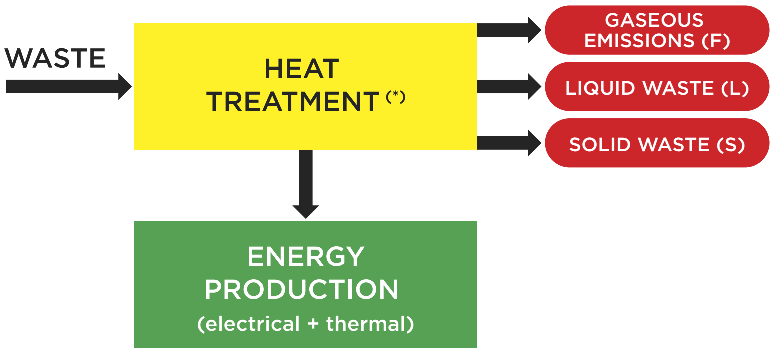


Leaving aside, for the moment, the incineration of NHSWs of non-municipal origin and focusing only on waste of municipal origin, the situation as of 2018 both at the macro-area level and on a national basis shows ample incineration under-capacity. For 2018, the overall imbalance of the Italian system indicates a need for almost 8 Mt of landfill. By pre-treating the waste before disposal in landfills, as required by current legislation, this quantity would be reduced to approximately 6.4 Mt, actually in line with the figure recorded in 2018 of 6.9 Mt (the marginal discrepancy is mainly attributable to the use, in 2018, of part of the incineration capacity for NHSW of non-municipal origin).

2. THE INCINERATOR

Thermal treatments are high-temperature chemical processes in which organic substances are broken down to produce others with a simpler chemical composition (Lindberg et al., 2015; Lombardi et al., 2015). The primary target of any thermal treatment is the transformation of the waste, with the production of substances that have less impact on the environment and on the human health, and the consequent reduction of the quantities and volumes of substances to be sent for final disposal, at the same time obtaining a recovery of the energy content of the material.

Figure 2.1 - Simplified diagram related to heat treatments (De Stefanis P., 2007)



***Including waste pre-treatment, combustion, treatment, etc.**

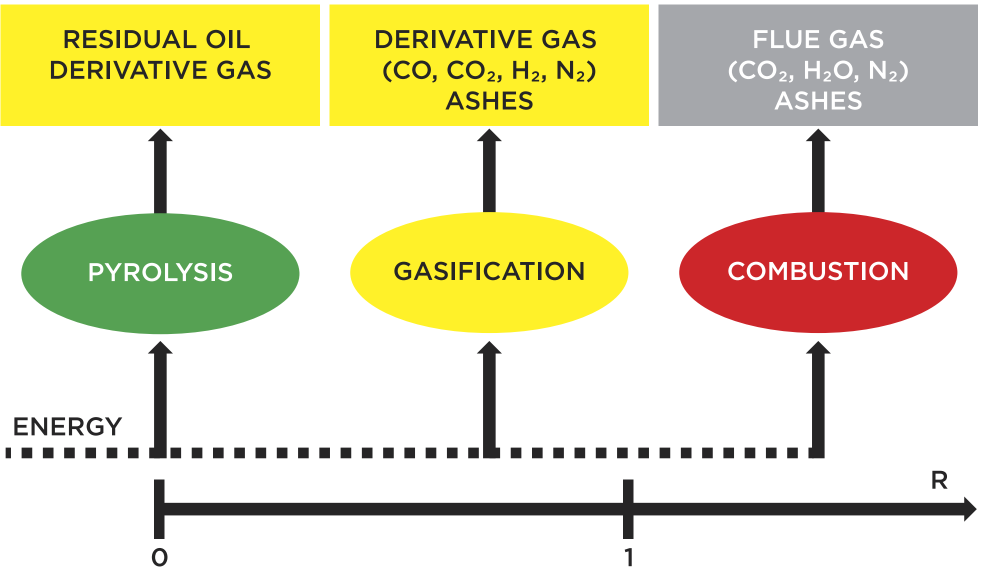
In the waste sector, the following heat treatments are applied:

- incineration;
- gasification;
- pyrolysis;
- plasma gasification.

Among these, incineration is the operation that has so far been most applied to solid waste, with experience on an industrial scale that is now very extensive; the other treatments have been developed as alternative technologies to incineration, which, however, have not yet given rise to significant experience on an industrial scale.
The incineration process is based on the direct combustion of waste with the use of the sensible heat of the flue gas to produce steam and from this to obtain electricity and/or thermal energy.
In contrast, alternative technologies essentially involve the production of a fuel gas (or of a gas and a liquid fraction), which can in turn be burnt on site to produce

energy or be used as feedstock for the production of potentially marketable fuels (hydrogen, light HC's) and/or feedstock (chemicals) for the chemical industry.
If we define R as the ratio between the actual amount of oxidizing agent (air and/or oxygen) and the theoretical (stoichiometric) amount, the main thermal processes can be represented schematically as shown in Figure 2.2.

Figure 2.2 - Schematic representation of heat treatment processes (ENEA, 2008)

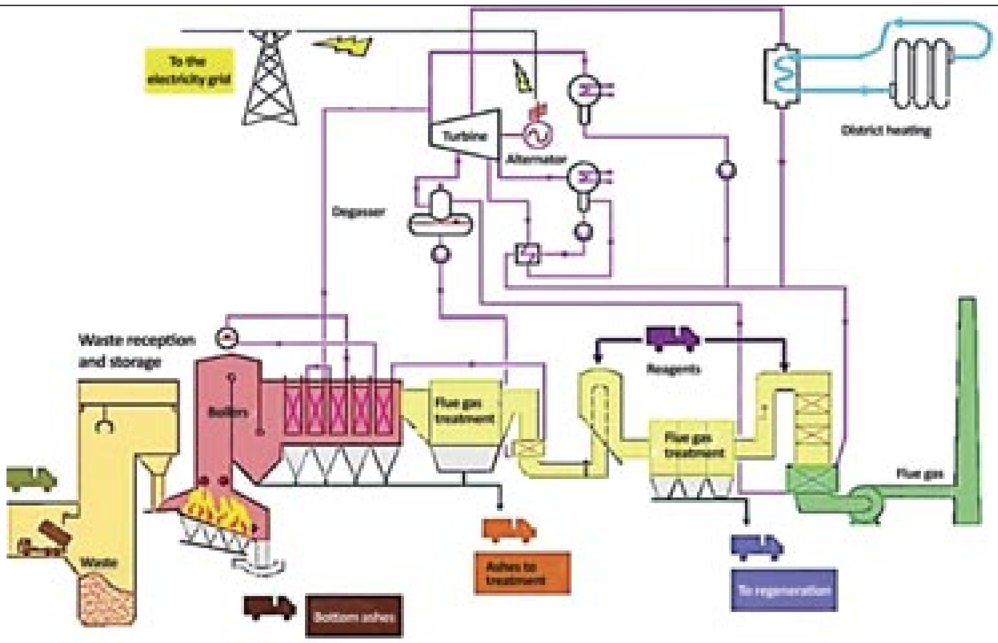


The incineration of municipal waste is a process of thermal oxidation of the waste, in which the fundamental elements constituting the organic substances contained are oxidized, giving rise to simple molecules and substantially to the gaseous state in ambient conditions (flue gas); the organic carbon is oxidized to carbon dioxide (CO_2), hydrogen to water (H_2O), sulphur to sulphur dioxide (SO_2), etc.; the inorganic part of the waste is eventually oxidized too and comes out of the process as a solid residue to be disposed of and/or recovered (heavy ash). Since the process is an oxidative one, the presence of oxygen is necessary for the reactions. Air is normally used, supplied in excess of the stoichiometric quantity to facilitate the chemical reactions.

2.1 Operation of incineration plants

The main sections of an incineration plant are the following (Figure 2.3): combustion chamber, flue gas treatment section, energy recovery section.

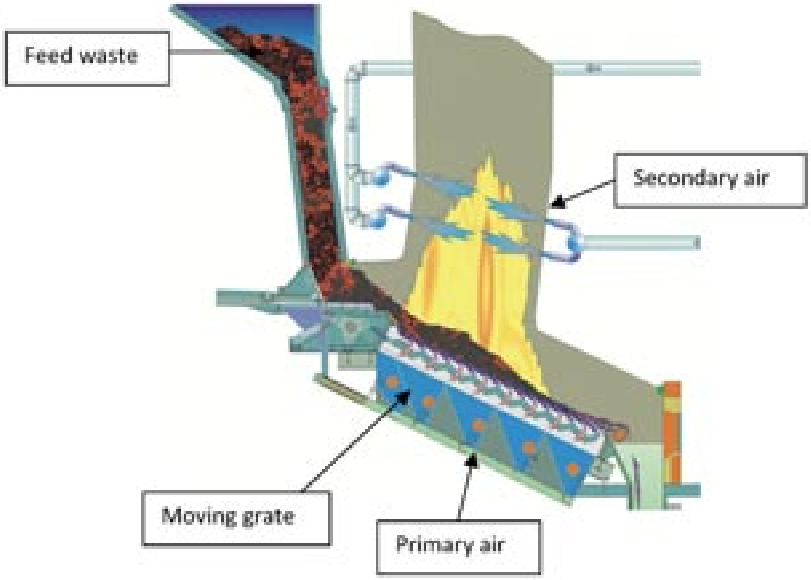
Figure 2.3 - Incineration plant diagram (TRM, 2019)



2.1.1 Combustion chamber

The most common combustion technologies for the treatment of municipal waste are the moving grate furnace and the fluidised bed furnace.
Grate furnaces are the most widely used technology thanks to their flexibility of operation and reliability resulting from the numerous applications. They consist of a grille, horizontal or inclined, on which a bed of waste several dozen centimetres thick is placed. The grille consists of a set of elements called “fire bars", arranged in such a way as to allow the passage of combustion air and its distribution over the entire bed of waste.
The combustion air is injected both under the grille and directly inside combustion chamber, i.e. inside the flue gas; the latter is also used for temperature control.
The residence time of the waste on the grille must be such as to guarantee the completion of the various phases of the combustion process and is generally between 30 and 60 minutes. The residual heavy ash from the process is discharged from the final part of the grille with appropriate systems into water bath accumulation tanks, which also cool it.
Temperature levels in the range of 950 - 1000 °C are considered sufficient, in correspondence with adequate oxygen contents (6 - 8%) and turbulence, to guarantee the almost complete oxidation of the organic components in the combustion processes, thus minimising the emissions of unburnt products.

Figure 2.4 - Functional diagram of the moving grille furnace (Bourtsalas, 2020)



The fluid-bed furnace consists of a combustion chamber inside which a certain quantity of inert material (the "bed") is kept, usually consisting of sand held in suspension ("fluid") by an upward current of air (which also acts as a comburent). The movement of the grit bed ensures good comburent-fuel contact, as well as considerable uniformity of temperature and mixing, which help to ensure constant and complete combustion.

This equipment, initially developed in the petrochemical industry, was later adapted to the combustion of rather homogeneous and small pieces of size substances. Municipal waste must therefore undergo pre-treatment consisting of at least screening and shredding operations.

2.1.2 Flue gas treatment section

An incineration plant generates gaseous, liquid and solid emissions (Figure 2.1).

Before being released into the atmosphere, the flue gas undergoes treatment with the target of substantially reducing the concentrations of contaminants. The flue gas treatment section is very articulated and complex, as a consequence of the increasingly strict limits imposed by the regulations and of a concrete technological progress, which has led in recent years to the development of sophisticated systems able to allow emission values at the limit of the measurable threshold to be achieved.

The contaminants present in the flue gas can be grouped into:

- macropollutants: substances present in flue gas in concentrations of the order of mg/Nm^3, such as powder, sulphur oxides (mainly sulphur dioxide, SO_2) and nitrogen oxides (NOx), carbon monoxide (CO) and halogen acids (mainly HCl and HF);

- trace pollutants: substances, present in emissions in much lower concentrations, which include both inorganic species, such as heavy metals (Cd, Cr, Hg, Pb, Ni, etc.), and organic species such as dioxins, furans and polycyclic aromatic HC's (PCDD, PCDF, PAHs).

The limit values for emissions of micro-contaminants are in the order of μg/Nm^3 (remembering that 1 μg = 0.001 mg), or even ng/Nm^3 (remembering that 1 ng is equivalent to one millionth of a mg) for dioxins and similar components, which are particularly dangerous to human health.
With regard to the reduction of these emissions, according to the current legislation one has to rely on BAT (Best Available Techniques, i.e. the best techniques currently available and industrially exploitable), defined in an official IPPC Bureau document for incineration plants (European Commission, 2019).
Summarising what is reported in the European Commission document [European Commission, 2019] for incineration plants we have the following:

- the most widely used particulate (fly ash) abatement devices are bag filters and electrostatic filters (or electric filters);
- the removal of gases with acidic behaviour, in particular hydrogen chloride (HCl), sulphur dioxide (SO_2), and hydrogen fluoride (HF), can be achieved in different ways (wet, dry or semi-dry washing method);
- emissions of nitrogen oxides are controlled by means of two different systems: the first includes measures to reduce their formation during the process, so that the concentration is lower than the legal limit; the second involves the removal of NOx through a chemical reaction with ammonia gas (NH3), which transforms them into elementary nitrogen. The removal can be carried out in two different ways: at low temperature (300 - 400 °C) in the presence of catalysts (SCR, Selective Catalytic Reduction) or at high temperature (950 - 1000 °C) in the absence of catalysts (SNCR, Selective Non Catalytic Reduction);
- as regards micro-contaminants (heavy metals and dioxins) injection of activated carbon is commonly practised. It should also be noted that organic micro-contaminants (dioxins and furans in particular) can also be abated within the SCR systems used to abate nitrogen oxides.

2.1.3 Energy recovery section

Energy recovery from incineration is commonly achieved through the cooling of flue gases that is necessary for their subsequent treatment. The recovery takes place in the form of production of electricity and/or thermal energy, obtained through the use of steam generated in a special boiler, conceptually constituted by a heat exchanger.
The plant layout is very similar to the typical one of thermoelectric power plants, even if the operating conditions (pressure, temperature) are much less severe, due to the presence of corrosive compounds and entrained ash in the flue gas, which can give rise to corrosion and erosion phenomena, as well as to the formation of material deposits on the heat exchange walls.
The steam produced by combustion of the waste may be used in one of the following ways:

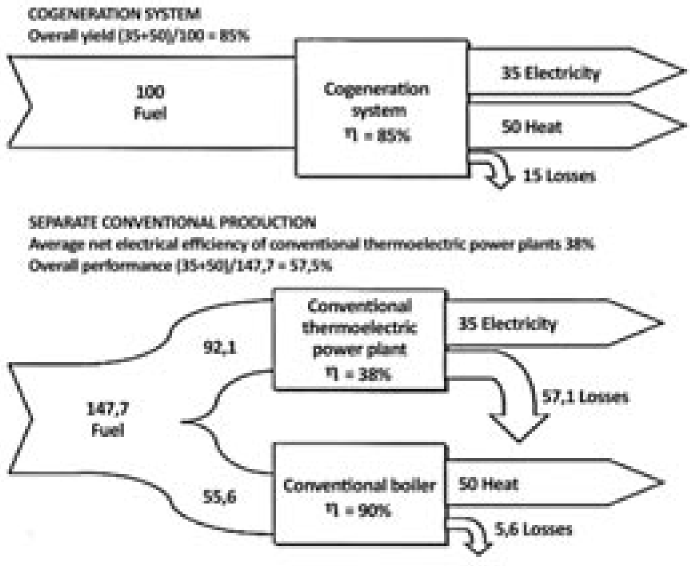
- direct supply of steam to industrial thermal users or of hot/superheated water to civil users, by means of a heat exchanger (heat only);
- production of electricity by means of steam expansion in a turbine with condensation cycle (electricity only);
- combined heat and power (cogeneration).

The energy production efficiency (i.e. the ratio between the amount of useful energy produced and the amount of energy contained in the waste, i.e. its thermal value) varies greatly in different operating arrangements. In particular, in the case of "only electric" set-up, the gross energy efficiency can reach a value close to or slightly above 30% (ATO-R/Politecnico di Torino 2009; ATO- R/Politecnico di Torino. 2010). In the case of cogeneration set-up the gross energy efficiency can reach or exceed 70% (about 20% electricity and 50% thermal energy) (ATO-R/Politecnico di Torino 2009; ATO-R/Politecnico di Torino. 2010).
The most recent technological developments make it possible to further increase these levels of efficiency, through the use of:

- condensation of the flue gases to recover also the latent heat of condensation of the humidity contained in them (this is basically the same operating principle of condensing boilers for domestic use);
- trigeneration systems, i.e. the generation of electricity, heat and cold through the integration of heat pump systems. Such an operation is already in operation at the Spittelau incinerator in Vienna.

The diagram in Figure 2.5 illustrates, as an indication, the differences that can be expected from the use of a cogeneration plant compared to the separate production of the same quantities of energy.
It can be seen that, in order to obtain the same amount of final usable energy (35 units of electricity and 50 units of heat), an amount of primary energy equal to 147.7 is required in the case of separate production. [Gabbar et al., 2018].

Figure 2.5 - Comparison between combined and separate production of the same quantities of electricity and heat



2.2 Residual fractions

Two types of solid residues originate from the waste heat treatment process:

- bottom ash, the characteristics and quantities of which are closely related to the treatment process and the type of waste input. Municipal waste incineration plants in Europe typically produce 150 - 250 kg of heavy ash per tonne of waste treated;
- fly ash removed through the flue gas treatment system, normally disposed of in hazardous waste landfills.

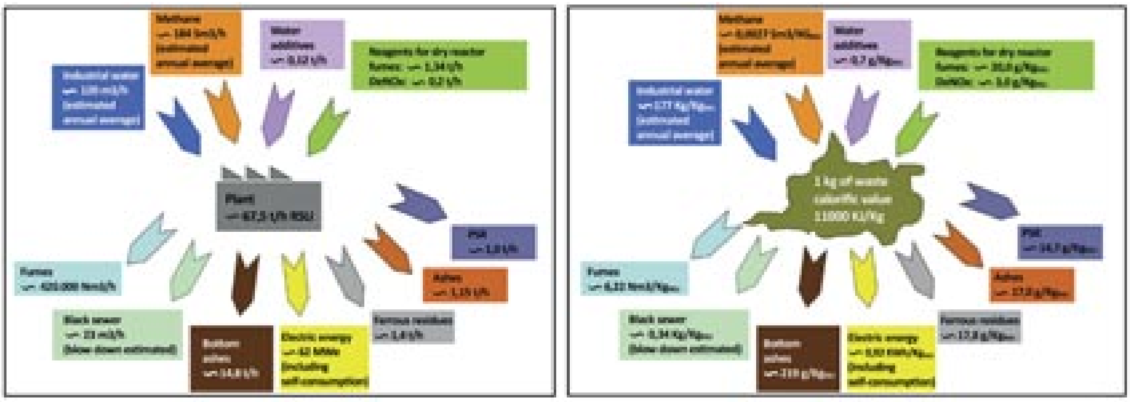
Then there are the salts from flue gas treatments, the characteristics of which depend on the type of reagent used (e.g. RSP - Residual Sodium Products, in the case of using sodium bicarbonate). These are generally hazardous wastes that can be disposed of in special landfills or even sent to recovery processes. The possibility to re-use or recycle solid residues is basically determined by their characteristics in terms of organic matter content and leachability of metals and salts.

2.3 Mass balance of an incinerator

In order to define the mass balance of an incinerator, the example of the plant located in Turin is given below.
The Turin incineration plant, which started operation in 2014, was originally authorised to treat 421,000 t/a of residual municipal waste from separate collection (RMW) and special waste similar to municipal waste (special waste), having an average thermal value of 11 MJ/kg.
The combustion of the waste takes place at ~1,000/1,200 °C on 3 mobile reverse

thrust screens. Each grille, with a surface area of 76.5 sq. m, consists of 4 parallel sections, divided into 5 cross-sectional areas.
Figure 2.6 shows the mass balances referring to the whole plant (about 67.5 t/h of waste input) and to one kg of treated waste (TRM, 2019). In figure 2.6 the inputs (water, natural gas, additives, reagents for flue gas treatment) and outputs (flue gas, water, electric energy, solid residues) of the system are well explained.

Figure 2.6 - Hourly mass balance and balance for 1 kg of waste treated by the Turin incineration plant



2.4 Technical/regulatory index R1

Current legislation classifies municipal waste incineration as a recovery operation (in particular operation "R1", i.e. "energy recovery") when it is carried out achieving a defined level of energy efficiency on an annual average basis. Therefore, an appropriate "energy efficiency" called "energy efficiency R1" is defined, as well as the threshold values to be reached or exceeded in order to qualify the operation as "energy recovery" instead of "disposal" (see Figure 2.7). These threshold values are differentiated for plants built before a certain date and those built more recently.
The energy efficiency R1 is not a physical quantity, but a normative index that aims to quantify in what proportion the municipal waste incineration operation contributes to the sustenance of the energy system compared to its potential. This quantification is carried out with a view to saving primary energy sources resulting from the energy recovery of waste.
It should be stressed that failure to reach the required threshold values does not mean that the plant does not recover energy, but rather that it does so at a level of efficiency that is not considered sufficiently high. Energy recovery is in fact compulsory by law, according to EU and national regulations.

Furthermore, the physical meaning of the formula R1 is that of a comparison between the efficiency of the analysed incineration plant and that of an average European conventional thermal power plant. This explains the origin of the coefficients 2.6 and 1.1 used in the formula, which are mathematically related to the average efficiencies of these plants. In particular, if the application of the formula gives a result equal to 1, the plant has an energy recovery efficiency equal to the average efficiency of conventional thermoelectric power plants. This means that the result can also be greater than 1, as is frequently the case for plants located in Northern Europe.

Figure 2.7 - Definition of "R1 energy efficiency" (Note to Annex C of Part IV of the TUA and EC the interpretation of the R1 formula, June 2011).

Energy efficiency R1

The municipal waste incineration operation is considered "energy recovery" (R1) if the energy efficiency R1 achieved by the incineration plant on an annual basis reaches or exceeds the value of 0.60 for plants built before 1/01/2009 or the value of 0.65 for plants built after 31/12/2008.

$$R1 = \frac{E_P - (E_F + E_I)}{0{,}97 \times (E_W + E_F)} \times CCF$$

E_P annual energy production in the form of electricity and/or heat;

E_F energy supplied annually to the installation from fuels other than waste, that contributed to useful energy production;

E_W energy supplied annually to the plant from the waste treated;

E_I annual import of energy other than that counted in EW and EF;

0,97 correction coefficient taking into account the losses due to slag discharge and irradiation;

CCF *"Climate Correction Factor"*(currently in the range 1.00 - 1.25; in the future between 1.00 and 1.12 depending on the local climate).

All forms of energy should be converted into terms of equivalent primary energy using conversion factors of 1.0 for energy contained in fuels (expressed as net heating value), 2.6 for electricity and 1.1 for heat (thermal energy).


Waste to energy plant - BRESCIA

3. IMPACT OF INCINERATION ON THE ENVIRONMENT

3.1 Generalities

The general evaluation of the impact of air emissions from incineration on air quality is based on two criteria. The first is purely technological, i.e. based on the expected performance of the available flue gas treatment systems and/or on the comparison with the emissions of all the other sources active in the area of interest. The second considers the additional contribution of the plant's emissions to the atmospheric concentrations of contaminants in the area, which can be obtained using modelling simulation tools. Both criteria are usually integrated in order to properly complement the assessment in terms of the cause-effect interactions that can be expected for the plant.

3.2 Concentrations of contaminants at the stack

Pollutants in flue gas from incinerators include both compounds associated with any other combustion process and specific substances that are typical of waste combustion. The former include particulate matter (i.e. particles matter of different size entrained in the gaseous flow), acid gases (SO_2 and NOx) and compounds adopted as tracers of combustion quality (CO and TOC - total organic carbon). The latter include other acid gases (HCl and HF), as well as a range of toxic species present at trace levels and consisting of some heavy metals (cadmium and mercury in the first place) and organic aromatic, chlorinated (PCDD/F -dioxins and furans-, PCB -polychlorinated biphenyls-) and non-chlorinated (PAH - polycyclic aromatic HC's) molecules. The latter are the ones mainly involved in both the authorization processes and the public discussions on the acceptability of plants.
The national regulatory framework of the sector, which derives from the implementation of the corresponding European directives, is based on two approaches. The first, following conventional regulations air emissions, includes flue gas concentration levels not to be exceeded, while the second, strictly based on technological assessments, is represented by the indications contained in the already mentioned reference documents associated with the best available techniques in the sector (BREF - BAT Reference Document), published by the European Commission as part of the IPPC (Integrated Pollution Prevention and Control) regulatory framework launched in 1996 (Directive 96/61/EC). The BREF contains emission values achievable through the use of Best Available Techniques (BAT) without any legal binding for their adoption in the regulations. Nevertheless, they represent an important reference for the Authorities in charge of the authorization procedures that, using them as "secondary" supporting legislative elements, are able to fully exploit their possibilities to further limit the emissions from the plant and the consequent environmental effects in more or less critical

contexts situations. The intrinsic value of BREFs, which are documents available to the public domain, is therefore very significant in terms of application due to their information content, which is periodically updated with extensive surveys on different types of plants and full-scale treatment systems, making it possible to take a snapshot of technological and system capacities in emission control. Their basic background approach relies on "continuous improvement" of technologies and the consequent need for their progressive application within the activity sector, in order to improve continuously the reductions in environmental impact.
The summary of the performances expected from the current treatment systems introduced by the latest revision of the BREFs is reported in Table 3.1 where, by way of comparison, the emission limits contained in the European regulations for the sector are also included for comaprative purposes. The measured data set framework utilised for deriving BREFs shows a situation that is fully compatible with the regulatory limits, with significant margins of compliance for some of the contaminants of greatest interest, especially dioxins and toxic metals (Figure 3.1). All this, it should be remembered, within general requirements for emission limits that are actually the most stringent between most of other source sectors, both from stationary combustion than from industrial activities.
The national situation appears to be mostly comparable with the European context, as shown by recent measurements available for some of the most significant plants operating in Italy and reported in Figure 3.1, in terms of annual values recorded by continuous systems or obtained from periodic monitoring and transmitted to the control authorities. The emission values recorded essentially arise from the mostly common inclusion in the operating authorizations (Integrated Environmental Authorisation - AIA) issued by regulatory authorities of emission limits based on BAT AEL rather than on specific sector regulations, with a more stringent compliance assets for plant exercise. This general regulatory situation gives a flue gas treatment layout adopted in modern and recently revamped plants characterized by the following technical options:

- almost exclusive application of the bag filter as the main particulate removal device unit: the very high performance achievable on the removal of most of the particle size of interest, even for the finest fractions, allows to obtain a simultaneous effect on achieving very effective removal efficiencies for all trace contaminants carried by particles (dioxins, semivolatile metals). The fabric filtration process gives also excellent support to the dry or semi-dry adsorption system, due to the residence time of the solid material on the filter bags bewtween cleaning interventions. The adoption of a double electrostatic filtration device upstream fabric filter, gives further enhancement in removal efficiency, whilst keeping separate flows of removed dust with different characteristics and thus different final treatment and recover/disposal requirements. Stack concentration of particulates obtained in cleaned flue gases are actually close to the same order of magnitude of those measured in ambient air in urban environments;
- general adoption of SCR catalytic systems for the reduction of nitrogen oxides, capable of obtaining emissions close to the lower limits of the BAT range and of carrying out additional conversions of toxic organic compounds (dioxins and furans), very effective as their final control before release into the atmosphere;

- large utilisation of dry systems for acid gases treatmant (HCl, HF, SO2), integrated with the addition of particulate matter adsorbents (typically activated carbons) dedicated to the removal of toxic volatile species (mercury, dioxins and furans) in configurations that, as already mentioned, often include a double filtration layout, both with two fabric filters in series or with an electrostatic filter upstream of a final fabric stage.

Table 3.1 - Current emission limits (2010/75/EU, Industrial Emissions Directive) and emission ranges associated with BAT (daily average values expressed in mg/m³ unless otherwise stated).

Contaminant	2010/75/EU, IED	BAT[1]
Particulate matter	10	<2-5
HCl	10	<2-8
HF	1	<1
SO_2	50	5-40
NO_x (as NO_2)	200	50-150 (180 without SCR)
TOC	10	<3-10
CO	50	10-50
Hg	0,05	0,001-0,02
Cd + Tl	0,05	0,005-0,02
Other metals	0,5	0,01-0,3
PCDD/F (ng_{TEQ}/m^3)	0,1	<0,01-0,08
NH_3	–	2-10
PAHs (μg/m³)	10	–

[1] values reported in the "Conclusions on best available techniques for waste incineration" of 3 December 2019

Figure 3.1 - Comparison of emission limits for European installations and ranges associated with sector BAT levels

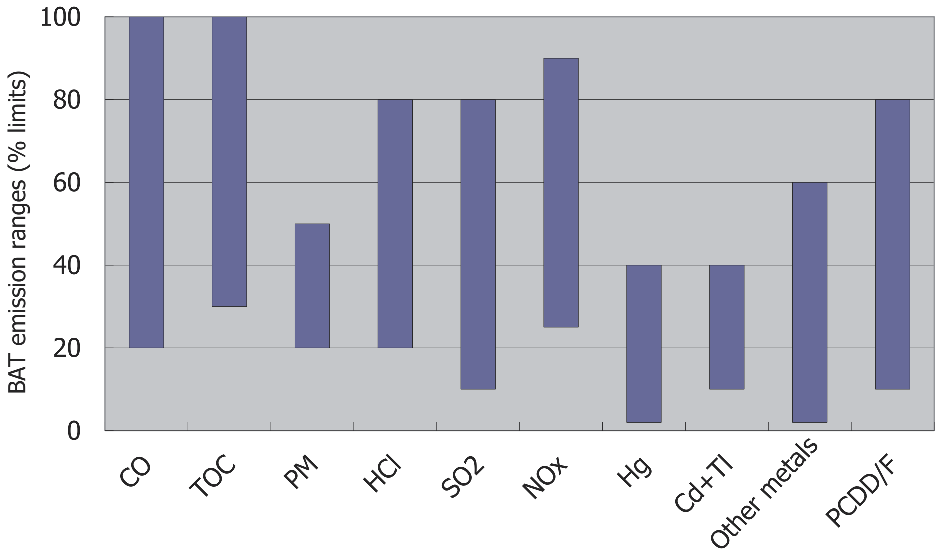
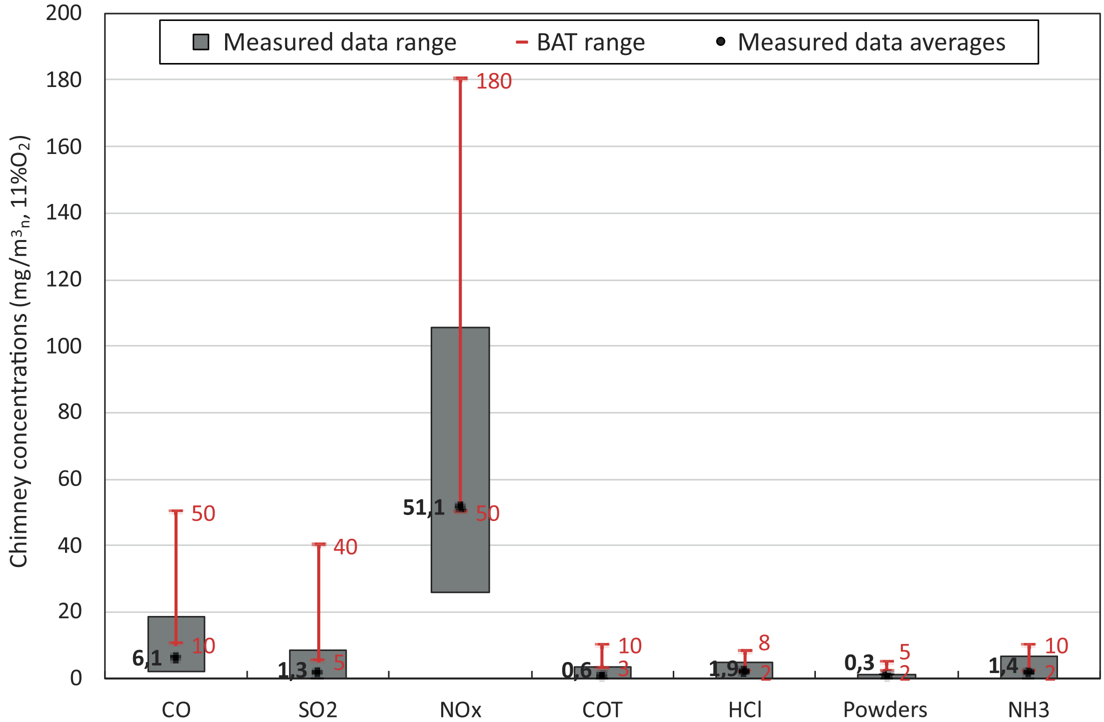
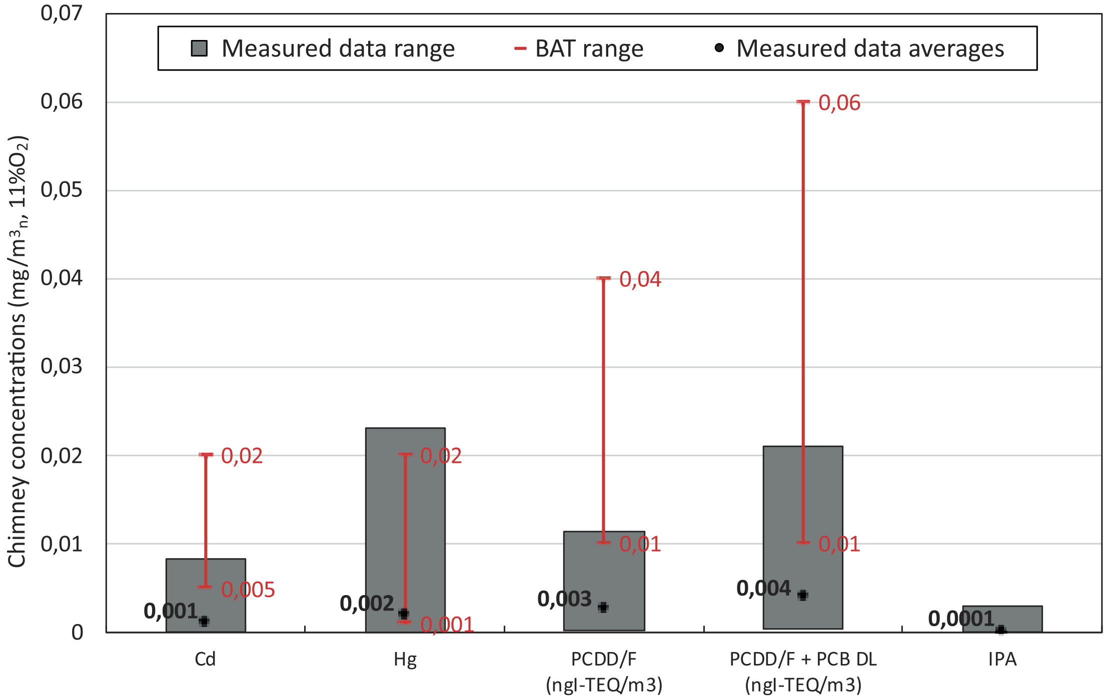


Figure 3.2 - Comparison of emission measurementsduring three-year period 2016-2018 in Italian plants and ranges associated with BAT levels for conventional (a) and trace toxic contaminants (b).





3.3 Contribution within air emission inventories

Inventories of emission sources of air contaminants are an important tool to estimate the contribution of installations on air quality. The data available for European countries are represented by the summaries that, annually updated, the Commission publishes on the basis of the information received from member countries, processed for the main contaminants with a common approach by grouping the different sources by homogeneous activitiy type (e.g. energy production, heat production, manufacturing of products, vehicular traffic). The latest edition of the inventory for Italy, updated to 2018 and developed by ISPRA (Sinanet-ISPRA, 2020), is reported in Table 3.2, which summarizes the national data of the main contaminants of interest for years 2000 and 2018. The values show that incineration contributes, with shares of less than 1% for both macro-pollutants and the main trace contaminants, and with a visible downward trend, despite the increase in the annual quantity of waste sent for energy recovery, which has almost tripled in the period considered. A similar emission situation, which finds broad similarities in the European context (EEA, 2018), can also be found in those Italian areas where the practice of incineration appears more utilised, typically in some northern regions of the country. The archives of regional emissions available for Lombardy and Emilia-Romagna, both evaluated with the INEMAR methodology and therefore to be considered homogeneous, are a good illustration of this type of situation and are reported in Table 3.3. Although not entirely superimposable with the national situation due to the completeness of information on some contaminants and the typical estimation differences that normally affect some parameters adopted for the estimations in different inventory sources, the essential cdata result in very substantially similar relative contributions for urban waste incineration activities, contained below a few percentage units.

Table 3.2 - Annual emissions from municipal waste incineration activities in Italy in 2000 and 2018 for the contaminants of interest for the sector (processing of ISPRA data, 2020)

	2000			2018		
	Quantity emitted	% out of total	Waste treated (t/year)	Quantity emitted	% out of total	Waste treated (t/year)
SO_2 (t/year)	9778	1,3%	2.236.774	110	0,1%	6.329.000
NO_x (t/year)	2360	0,16%		3798	0,1%	
PM_{10} (t/year)	35,3	0,01%		37	0,03%	
CO (t/year)	83,4	0,002%		447	0,02%	
Cd (kg/year)	140	2%		62,3	1%	
Hg (kg/year)	124,9	1%		202	2,2%	
Pb (kg/year)	2597	0,3%		6357	2,2%	
PCDD/F (gI_{TEQ}/year)	21,4	5,3%		0,6	0,2%	
PAHs (kg/year)	65,5	0,1%		3,3	0,004%	

Table 3.3 - **Annual emissions from municipal waste incineration activities in Lombardy and Emilia-Romagna in the latest update of the INEMAR regional inventory available**

	Lombardy (2017, 13 installations)			Emilia Romagna (2015, 8 installations)		
	Quantity emitted	**% out of total**	**Waste treated (t/year)**	**Quantity emitted**	**% out of total**	**Waste treated (t/year)**
SO_2 (t/year)	116,8	1%	2.295.220	11,8	0,10%	1.108.126
NO_x (t/year)	1171,9	1,05%		461,5	0,6%	
PM_{10} (t/year)	8,3	0,05%		3,9	0,04%	
CO (t/year)	119,3	0,05%		56,3	0,05%	
Cd (kg/year)	8,6	0,6%		1,9	0,3%	
Hg (kg/year)	39,7	2,1%		n.a.		
Pb (kg/year)	39,8	0,2%		65,8	1%	
PAHs (kg/year)	0,05	0,0006%		n.a.		
Benzo-a-pyrene (kg/year)	0,0096	0,0004%		0,02	0,001%	

A further element of interest in the inventory data is the comparison with emissions from other activities, give generally important contributions. To this end, Table 3.4 summarizes the situation arising from the data of the most recent national inventory, relating to 2018, regarding the share of the sectors whose activity regime results frequently simultaneous with with incineration, either because of their contemporary presence in the area or because of similar energy production address. Despite the national inventory involves an area with source activities characteristics and presence different from those arising from more restricted situations, the regional estimates confirm a very limited, if not almost negligible, contribution of incineration emissions compared to those of all other sources. For conventional contaminants, the archive still shows remarkable effects of residential and commercial combustion, in particular for particulate matter (almost 60%) and CO (about 64%) which also affects, although with less affordable results due to the higher uncertainties in their emission factors, some trace species, especially PAHs. Still as recorded within former years, road transportation is confirmed as the main contributor to NOx, mainly from diesel engines. The incineration situation for trace pollutants is substantially similar to the contributions recorded for conventional compounds, both in the metals sector than for organics, dioxins in particular, whose main sources might be associated with the industrial sector activities (combustion and production processes) and with residential heating sources.

Table 3.4 - Incidence of annual emissions of the main sectors of activity in Italy in 2000 and 2018 for the contaminants of greatest interest (processing of ISPRA data, 2020)

2000	Residential and commercial combustion	Energy production and distribution	Combustion in industry	Production processes	Road transportation	waste incineration
SO_2	3,5%	66,4%	14,2%	3,4%	1,6%	1,3%
NO_x	11,7%	11,6%	12,2%	0,4%	50,6%	0,16%
PM_{10}	35,0%	8,1%	8,6%	7,2%	21,2%	0,01%
CO	22,1%	1,2%	6,7%	2,6%	63,5%	0,002%
Cd	25,0%	0,0%	62,5%	12,5%	0,0%	2%
Hg	7,7%	46,2%	23,1%	23,1%	0,0%	1%
Pb	2,7%	0,5%	16,0%	6,9%	72,5%	0,3%
PCDD/F	41,7%	2,2%	22,0%	29,9%	4,2%	5,3%
PAHs	79,6%	4,0%	0,0%	12,6%	3,3%	0,1%

2018	Residential and commercial combustion	Energy production and distribution	Combustion in industry	Production processes	Road transportation	waste incineration
SO_2	9,4%	33,3%	24,0%	12,4%	0,4%	1,2%
NO_x	13,0%	7,0%	9,4%	0,8%	43,5%	0,8%
PM_{10}	53,8%	1,0%	4,7%	9,3%	11,8%	0,02%
CO	61,9%	1,9%	4,1%	3,6%	19,9%	0,04%
Cd	9,4%	3,3%	38,1%	29,1%	7,7%	1,2%
Hg	7,0%	19,3%	27,4%	43,0%	2,6%	2,6%
Pb	6,8%	1,1%	44,8%	40,6%	5,1%	2,7%
PCDD/F	37,5%	1,7%	20,2%	32,1%	3,8%	0,2%
PAHs	78,1%	0,7%	0,8%	13,9%	3,8%	0,007%

While the results emerging from the inventories are influenced affected by the local sources present and the extension of the area investigated, additional comparative considerations can be obtained from the analysis of emission factors. For the European Community, the reference database in this regard is developed by the European Environment Agency (EEA) under the EMEP programme (EMEP, 2019). The values reported there for the combustion sources of greatest interest with respect to incineration, integrated with more detailed information available in the reference literature for some sectors, are summarised in Table 3.5 for the most significant conventional pollutants and in Table 3.6 for the trace components of importance. Regarding conventional pollutants, incinerators show particularly low emission levels, both in terms of European reference data than of those obtained directly from measurements on Italian plants. The comparison with small to medium scale residential heating sources shows the potential environmental benefits of including incineration in district heating networks, not only for substituting most relevant emission sources (small biomass units) but also for the replacement of

conventional and better quality fuel boilers. Further considerations of interest can also be obtained from the data on road transportation, an almost ubiquitous and contextual presence in the areas where the plants are located. The emission factors reported in Table 3.5, corresponding to those of the average circulating fleet in Italy in terms of the type of vehicle classes (fuel supply, engine capacity, regulatory approval category) and their average travel regime (urban, extra-urban, motorway), show specific emissions from incinerators which, with the only exception of SO2, result essentially neglectable with respect to any type of vehicle, with differences reaching two orders of magnitude in the case of particulates and CO and almost one order of magnitude for NOx. The comparison with traffic, a very significant source in the site areas of the incinerators, appears more imediately perceived if we translate it in terms of the distance covered by a vehicle to emit the same amount of contaminants produced by a plant with a pre-established capacity. For instance, if we adopt for this comparison the annual quantity of waste per inhabitant processed by incineration, corresponding in Italy to just under 100 kg/year, this results in annual distances travelled between 3 and 24 km for particulate matter (PM10) produced by diesel heavy duty and passenger vehicles, respectively, and between 13 and 390 km, again for petrol heavy and passenger vehicles. Basically, the comparison confirms that the relative contribution of the incinerator is of little significance, especially for contaminants with frequent important negative effects on air quality in the location sites of incinerators, like particulate matter that, as already observed, results in the higher relative contribution from diesel engines and heavy duty vehicles matter which, as is to be expected, shows the categories of greatest relative impact in diesel engines and heavy vehicles.
The similar comparative situation for trace contaminants is more difficult to establish, as the reference values for the activities of interest are subject to greater uncertainties due to the much reduced availability of measurements compared to conventional pollutants. Nevertheless, in general terms, incineration does not seem to be characterized by significantly different emissions from other combustion activities, with emission factors that, especially for the more modern plants controlled in line with BAT, have average values located at lower levels than those of other activities, also for some of the trace components used as characteristic indicators, such as toxic metals (Cd and Hg, Table 3.6) and especially dioxins (Table 3.7). Still on the subject of dioxins, the comparison with other emission sources confirms, as observed from the inventories already illustrated, that at present incineration seems to share a minor significance with respect to other activity sources. Beyond industrial production sectors that are already known in this field, such as metal and steel production industries, particulraly when raw materials of residual origin are employed (second smelting or secondary processes), other potentially significant sources include heating appliances where proper combustion is difficult to achieve or poorly controllable , such as the already mentioned small residential boilers. Accidental fires and uncontrolled combustion of various kinds play a very special role, and the few data available show their extremely significant emission potential, when they involve residues and waste of various kinds, especially plastics.

Table 3.5 - **Emission factors from combustion activities (mass emitted per unit mass of fuel consumed) for conventional contaminants**

Activities	NO_x (kg/t)	CO (kg/t)	PM_{10} (g/t)	SO_2 (KG/t)	Reference
incineration - European reference	0,8-1,5	0,007-0,25	1,1-8,3	0,02-0,5	EMEP, 2019
incineration - Italian average as of 2010	0,62	0,07	6,1	0,02	ISPRA, 2019
incineration - latest generation Italian plants	0,2-0,9	0,01-0,1	0,25-11,4	0,0001-0,09	Processed from Environmental Statement 2015/18
Domestic heating - small biomass users	0,6-2,8	18,5-185	7000-28000	0,15-0,7	EMEP
Home heating - open fireplaces	n.a.	n.a.	2800-30000	n.a.	Vicente et al., 2018
Home heating - wood stoves	n.a.	n.a.	400- 2800	n.a.	
Home heating - pellet stoves	n.a.	n.a.	50-2600	n.a.	
Civil heating - medium/smal coal-fired boilers	4,5 - 6	6-90	2300-7200	13,5-30	EMEP
Civil heating - medium/small natural gas boilers	1,6-5,4	0,9-2,2	14-88	0,01-0,1	EMEP
Civil heating - medium/small diesel fuel boilers	2,2-6,6	0,9-3,5	30-3500	3,7-6,2	EMEP
Petrol passenger vehicles	2,3-3,1	16,2-58,5	352,7-568,2	0,011	Average vehicle fleet in Italy, 2017 update (ISPRA, 2019)
Passenger vehicles Diesel	10,2-13,4	0,5-2,2	645,8-841,2	0,016	
Petrol vans	2,6-4,7	13,7-91,5	276,7-484,3	0,011	
Diesel vans	12,3-16,7	2,8-4,7	971,9-975,8	0,016	
Heavy duty vehicles	20-24,3	5,6-6,6	863,5-998,7	0,016	
Motorcycles	4,2-9,9	140,6-235,5	623,2-3863,2	0,011	
Thermoelectric power production (average Italian plant 2017)	1,2	0,7	23,1	0,4	ISPRA, 2018

Table 3.6 - Emission factors from combustion activities (mass emitted per unit mass of fuel consumed) for toxic trace contaminants

Activities	Cd (mg/t)	Pb (mg/t)	Hg (mg/t)	PCDD/F (µg/t)	Reference
incineration - European reference	1,1-19	12-280	7,3-48	0,02-0,2	EMEP
incineration - Italian reference to 2010	10	1040	30	0,1	ISPRA, 2019
incineration - latest generation Italian plants	1,3-27,7	n.a.	0,05-61	0,002-0,07	Processed from Environmental Statement 2015/18
Civil heating - small biomass users	9,2-1606,2	9,3-2185	3,6-17,9	0,4-92,5	EMEP
Civil heating - small and medium-sized coal-fired boilers	30-150	2400-9000	150-270	1,2-15	EMEP
Civil heating - medium/small diesel fuel boilers	3,3-26,4	110-1760	1,1-8,8	0,1-0,9	EMEP
Civil heating - small and medium-sized natural gas boilers	0,005-0,03	0,04-0,16	0,07-35,4	0,02-0,12	EMEP
Petrol passenger vehicles	10,3-18,0	87,7-453,6	n.a.	0,19	Average vehicle fleet in Italy, 2017 update (ISPRA, 2019)
Passenger vehicles Diesel	10,8-15,6	75,8-429,1	n.a.	0,54	
Petrol vans	5,9-12,2	97,2-440,6	n.a.	0,14	
Diesel vans	8,0-13,3	70,1-482,0	n.a.	0,46	
Heavy duty vehicles	4,4-6,0	245,9-480,6	n.a.	0,22	
Motorcycles	15,3-21,6	50,9-1087,5	n.a.	0,49	
Thermoelectric power production(average Italian plant 2017)	2,6	70,5	18,4	0,10	ISPRA, 2018

Table 3.7 - Comparison of dioxin emission factors from activities potentially involved in their release into the atmosphere

Activities	Emission factor (μg TEQ/t)	
municipal waste incineration - European reference	0,02-0,2	EMEP, 2019
municipal waste incineration - Italian reference to 2010	0,1	ISPRA, 2019
municipal waste incineration - latest generation Italian plants	0,002-0,07	Environmental Statement 2015/18
Forest and wasteland fires	0,3-30	UNEP, 2005; Gullett 2008-2003
Accidental fires of waste, houses, vehicles, wood, rubble	120-1000	UNEP, 2005
Uncontrolled burning of household waste	2-13000	Hedman, 2005; Gullett 2010
Uncontrolled burning of household waste with different chlorine content (0 to 7%)	14-4916	Zhang et al., 2015
Uncontrolled combustion of electronic scrap	92 (printed circuit boards) 11900 (plastic sheathed cables)	Estrellan, 2010
Accidental combustion of uncontrolled landfills	62-2300	Wiedinmyer 2014, Solorzano 2012
Domestic biomass combustion	100-1500	UNEP, 2005
	0,4 - 92,5	EMEP, 2019
	7,4	ISPRA, 2019
Lead production	0,5-80	UNEP 2005, EMEP 2019
Zinc production	0,3-1000	UNEP, 2005
Copper production	≤ 0,01-800	UNEP 2005, EMEP, 2019
Aluminium production	0,3-100	UNEP, 2005
Iron and steel production	0,01-10	UNEP, 2005
Cement plants - BAT (dry kiln with pre-calciner and cyclone preheater)	$0{,}03 \cdot 10^{-3}$-0,6	EMEP, 2019

3.4 The contribution of plant emissions on air quality

Model simulations realized within authorization procedures (AIA, EIA) for assessing air quality impacts of plants show that for modern, well operated installations the effects are generally very limited, both with respect to the background levels than for air quality standards. The adoption of the best available techniques options (BAT) in more recent plants, as well as in upgrading or revamping interventions, confirms its potential in maintaining acceptable variations in air quality levels, both for conventional contaminants and for toxic trace components typical of the source. Some example results available are summarised in Table 3.8, in terms of NOx and PM10 concentrations simulated for several plants in Italy. The comparison of modelling results with background monitored data for the locations sites, also reported in the table, results in essentially no appreciable contributions estimated for the plant in all the different case studies reported.

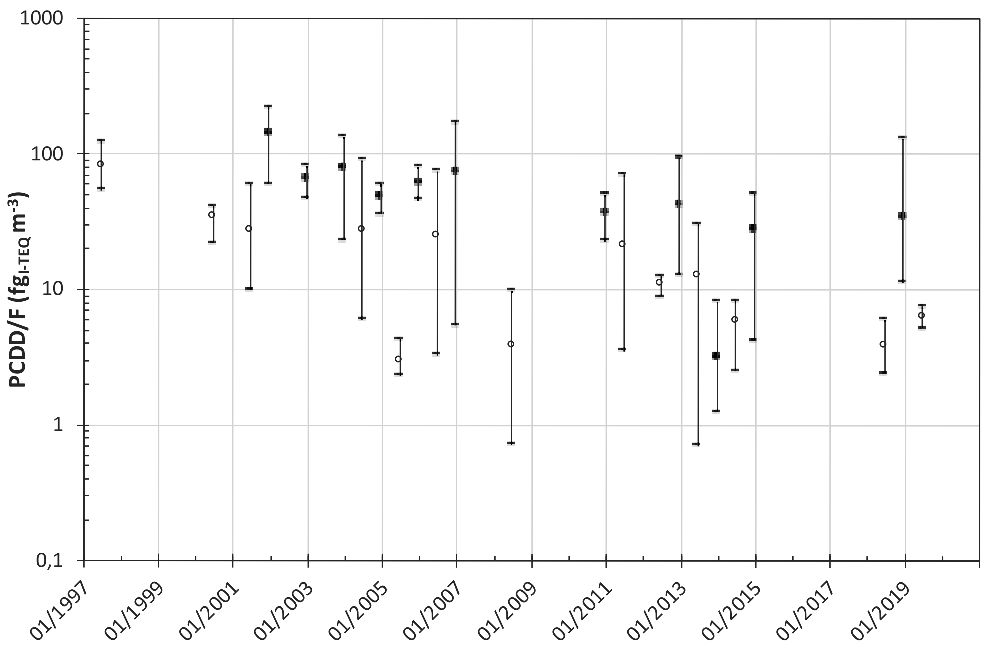
Table 3.8 - Comparison between annual average NO_x and PM_{10} concentrations estimated by model for the plant emissions and the presence detected in the area of plant settlement for some Italian case studies.

	NO_x (as NO_2)		PM_{10}	
Plant	**Waste to energy plant (µg/m³)**	**Presence of background in the area (µg/m³)**	**Waste to energy plant (µg/m³)**	**Presence of background in the area (µg/m³)**
Milan(1)	0,17	34-56	0,0003	34-40
Turin(2)	0,02 (max 0,3)	50-67	0,0004 (max. 0,005)	54-62
Bolzano(3)	0,015 (max. 0,4)	31,3	0,0003 (max. 0,01)	17
Brescia(4)	1,1 (max)	44-70	0,005 (max)	39-54
Acerra(5)	0,29 (max)	25-34	0.03 (including secondary particulate matter)	35-56
South Milan(6) (project not completed)	0,08	39-55	0,008	48-60
Schio(7)	0,08	21	0,0006	25

(1) ATS Milan, 2019; (2) Panepinto, 2014; (3) DICAM, 2017; (4) Brescia Municipality, 2011; (5) CNR ISAFOM, 201; (6) DIIAR, 2009; (7) AVA, 2020

Supplemental very similar informations can also be obtained from the results of periodic monitoring at the sites of operating plants, performed for assessing the long-term atmospheric presence of contaminants typical of the source, such as dioxins. For example, values measured in the areas of some plants in the Po Valley, reported in Fig. 3.3 (Lonati, 2020), result in relatively homogeneous levels over time for the different sites, with the most appreciable effect associated with the less favourable meteorological conditions for atmospheric dispersion typical of the winter regime, that enhance the impact of ground level diffuse sources (traffic and ambient heating) the impact of low-lying sources (traffic and heating) with respect those arising from elevated point sources, such as thermal power plants, industries and incinerators themselves. Higher levels of dioxins that occur in cold seasons are also affected by the activity of heating sources, especially those of small size and less advanced design such as fireplaces and wood stoves. Beyond the inter-annual variations expected from the combined effect of meteorology and emission regimes, monitored concentrations for individual areas appears to be relatively stable over time, without any appreciable nor systematic contribution from the incinerators located in the areas with respect to the other anthropogenic sources in the same areas. The levels of dioxins measured do not further present specific differences with those expected in similar urban areas, with or without incinerators, nor do they result in specific problematic issues with respect to reference levels adopted to assess their effects on health, which are all largely respected.

Figure 3.3 - Seasonal concentrations (mean, minimum and maximum weekly samples) of dioxins measured in different monitoring sites in the area of incineration plant location in the Po Valley (empty indicators: summer season; full indicators: winter season)



THE CASE STUDY OF THE DESIO PLANT.

The Desio incinerator has recently been the subject of a comparative study (Lonati et al., 2018), aimed at identifying the significance of the plant's role on air quality with respect to that of traffic in the area, which quantitatively represents an important source of emissions, together with residential heating in the winter period. The assessment involved contaminants typically adopted for identifying the effects of both sources, consisting of NOx, PM10, Cd and dioxins, and was performed by the application a dispersion model with emissions flow rates input for the plant derived from stack monitoring measurements. Emissions from traffic were obtained through the utilization of a simulation model for vehicle's flow of the area, combined with the corresponding emission factors of the average fleet circulating in Lombardy, when possible, or at the national level. The plant, processing approximately 90,000 tonnes/year of municipal and assimilable waste recovers energy through combined electricity and heat production, with the latter delivered to the district heating network of the municipality. Its general layout has an overall configuration included within the with the BATs for the sector, with a flue gas treatment line consisting of an electrostatic precipitator, a dry system with bag filter and activated carbon and neutralising reagent addition and a final selective catalytic reduction (SCR) unit. The simulation results show extremely low, if not almost not appreciable, contributions from the incinerator, both in terms of maximum expected values than average values for the municipal area, with concentration levels several orders of magnitude lower than those deriving from traffic (Table 3.9). All this despite the probable underestimation of emissions from traffic itself, both for the approximations in some of the assumptions on the characteristics of the local circulating fleet and for the practical needs to exclude, in the traffic model, the flows associated with the secondary road network, considering only those along the main roads.

Table 3.9 - Desio plant - Maximum and average concentrations for the municipal area resulting from the modelling simulation of emissions from the incinerator and traffic

Contaminant	Parameter	Emission source	Values
NO_2 (µg/m³)	Maximum	incinerator	0,08
		traffic	20
	Municipal area average	incinerator	0,05-0,07
		traffic	6-10
PM_{10} (µg/m³)	Maximum	incinerator	0,00044
		traffic	6
	Municipal area average	incinerator	0,0002-0,00035
		traffic	2-3
Cd (ng/m³)	Maximum	incinerator	0,0005
		traffic	0,1
	Municipal area average	incinerator	0,0003 - 0,0004
		traffic	0,02-0,03
Dioxins (fg_{I-TEQ}/m^3)	Maximum	incinerator	0,00081
		traffic	3
	Municipal area average	incinerator	0,0005-0,0007
		traffic	0,5-1

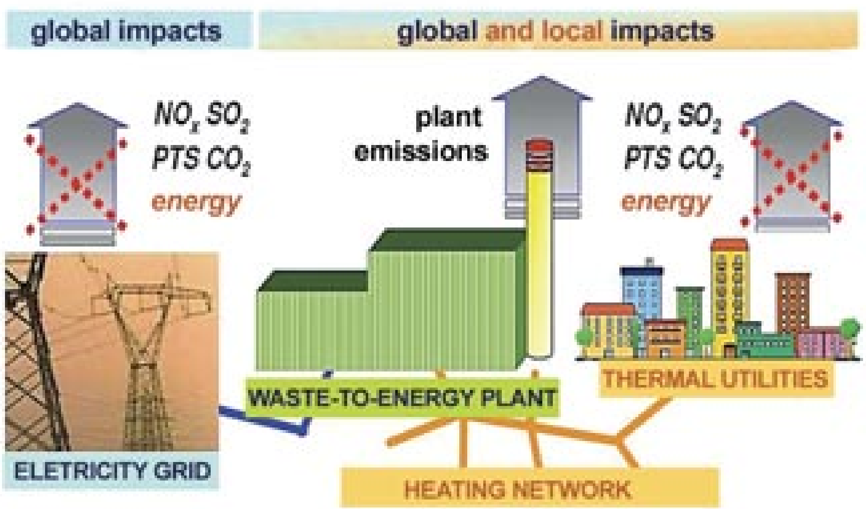
4. THE ENVIRONMENTAL IMPACT OF THE INCINERATOR

4.1 Electric and thermal energy produced, environmental benefits for avoided emissions and fossil fuel reduction

As previously reported (Chapter 2), a plant can operate in electrical-only mode, or in cogeneration mode, with the combined production of electrical and thermal energy. The electricity fed into the grid replaces a portion of centralised electricity production and consequently avoids the related environmental impacts, expressed as primary energy consumption and emissions into the atmosphere.
In the same way, the supply of heat through district heating makes it possible to replace the operation of the users' thermal power plants and the related impacts such as primary energy consumption and emissions into the atmosphere. In this case, the avoided impacts coincide unambiguously with those of the plants actually replaced.
In drawing up an environmental balance (ISPRA, 2018), the two avoided impact components represent a compensation for the environmental load introduced by the incinerator.
In the analysis, attention should be paid to the fact that all contributions (both added and avoided) have to be assessed on different spatial scales (in particular emissions). Depending on their origin, they must be considered (as shown in Figure 4.1):

- on a local scale, i.e. in the same territorial context on which the impacts of the incinerator insist (municipal or supra-municipal territory);
- on a global scale, i.e. in a much larger territorial context (national territory).

Figure 4.1 - Environmental balance of energy recovery from waste



This compensation can be calculated using a simple balance sheet:

Emissions (added/subtracted) = incineration plant emissions - emissions replaced (by thermal and/or thermoelectric plants)

However, it should be borne in mind that the outcome of an environmental balance is not directly linked to changes in air quality. In fact, the type of added/subtracted emissions is very different in terms of the dynamics of contaminants in the atmosphere (for example, the incinerator flue is characterised by dispersed emissions at a higher rate than those deriving from the replaced domestic boilers). Therefore, in order to assess the effects on air quality, the implementation of contaminant dispersion and fallout models will be necessary.
By way of example, the situation regarding the Turin incineration plant is given below. In 2018, the plant treated an amount of waste equal to 530,040 t producing an amount of electricity equal to 399,111 MWh (TRM). Thanks to the production and feeding into the national distribution network of the electricity produced, it was possible to achieve, on a global scale, a reduction in CO_2 emissions of 212,000 t/y (about 0.4 t_{CO2}/t incinerated waste).

4.2 Environmental balance with respect to landfill; summary environmental indicators of the incinerator

If we want to compare the emissions produced by an incineration plant of municipal waste with the emissions deriving from the disposal of the same in a landfill, it is first of all necessary to highlight how in an incineration plant the emissions are conveyed to a single point and purified until obtaining contaminant concentrations lower than the legislative limits, while those deriving from the landfill are partly diffused and untreated emissions. In fact, it is physiologically impossible for a landfill to capture all the biogas generated. The only contaminant parameter that does not undergo purification treatment in either disposal system is carbon dioxide CO_2. It may therefore be useful to take stock of this parameter (in terms of CO_2 equivalent) in order to make assessments. This topic is addressed in several studies in the literature (Ragossnig et al., 2009; Panepinto et al., 2016; Panepinto and Zanetti, 2018). In particular, in the study conducted by Panepinto and Genon (2014) a comparison expressed in terms of CO_{2eq} balance is made between the management of waste produced in the Turin area by incineration and by landfill (in this second case, in addition to carbon dioxide emissions, natural gas emissions were also evaluated). The result of this study shows an environmental benefit related to the use of incineration: in this case there is an emission of CO_{2eq} equal to 0.42 tCO_{2eq}/t waste treated, while in the case of landfill disposal this factor is equal to 3.28 tCO_{2eq}/t disposed waste. We can therefore conclude that the impact in terms of CO_2 emissions of landfilling is about 8 times higher than that generated by disposal by heat treatment.

4.3 Reduction in the use of inert materials thanks to the recovery of bottom ash

The assessment of the environmental sustainability of the waste incineration process cannot disregard the analysis of the contribution of solid residues, consisting, as already specified, of bottom ash and flue gas treatment residues. With particular reference to bottom ash, which represents the most significant residue in terms of mass, landfill disposal is now almost completely abandoned in favour of increasingly advanced recovery and re-use practices.

Bottom ash contains several recoverable components: first of all, ferrous and non-ferrous metals that, present in the initial waste, are then concentrated in the solid residue of combustion. The content of ferrous metals varies on average between 7 and 10% by weight of bottom ash, while the content of non-ferrous metals is between 1 and 2.5%, of which the predominant fraction (about two thirds) is represented by aluminium, followed by copper (Lamers, 2015a; Allegrini et al., 2014; Biganzoli et al., 2013). The mineral fraction, predominant component of the ashes (up to 90% in weight), can instead be used as an inert material mainly in the production of cements and concretes, or in civil engineering for the construction of road foundations or asphalt mixes. From this point of view, incineration is a technology that allows waste to be treated, enabling both thermal energy and electricity, and materials, to be recovered which, once in undifferentiated or residual waste, would not otherwise be recoverable.

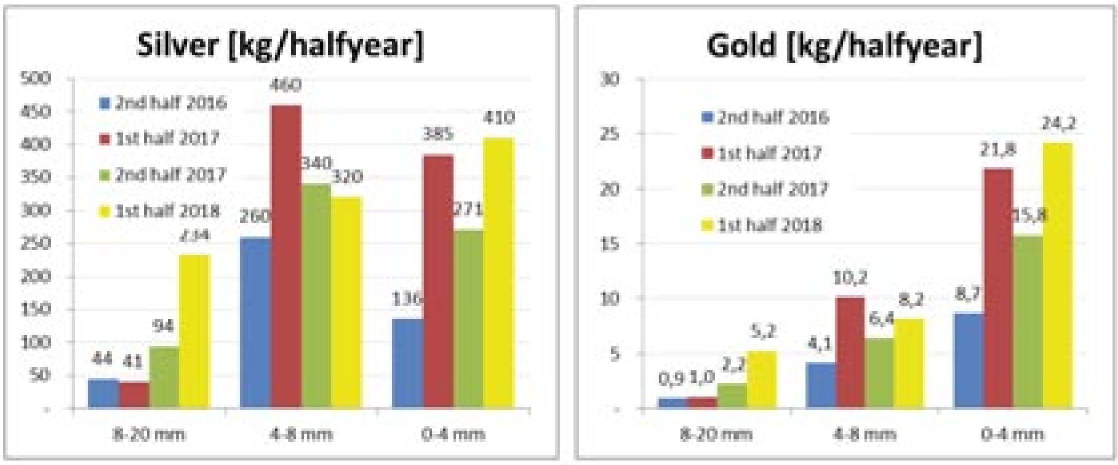
As previously noted, the bottom ash treatment sector has undergone a major development in Italy and Europe, with the construction of highly sophisticated recovery plants. Particular mention is made of the Danish, Dutch and Swiss experiences.

In Denmark, the Afatek plant in Copenhagen, which is centralised and serves a number of incinerators, has an extended outdoor curing period to reduce the water content and stabilise the material through natural carbonation processes by absorbingCO_2 from the atmosphere. Subsequently, deferrization treatments and extraction of non-ferrous metals are carried out on different grain sizes, up to below 1 mm. The inert material component is intended for use as road sub-bases, even in the upper layers (near the asphalt), where it can replace more economically valuable natural materials. A different approach is adopted at the Hinwil plant in Switzerland, again a centralised unit serving incinerators in the Canton of Zurich, all of which feature a dry bottom ash extraction system. The total lack of moisture in the material allows excellent separation of metals even from very fine fractions (down to below a millimetre), as well as the extraction of high quality glass to be sent for recycling. The mineral fraction, although almost metal-free, is landfilled in accordance with Swiss regulations and the almost zero market demand for inert materials in a country like Switzerland.

Figure 4.2 - **Heavy non-ferrous metal component recovered from dry extracted incineration bottom ash. In particular, the presence of copper is evident**

Finally, in the Netherlands, the new Heros plant in Terneuzen will use the inert fraction as construction material for road foundations and building foundations, and as aggregate for concrete, asphalt and the ceramic industry, in line with the "Green Deal"[5]. With regard to metals, the non-ferrous component undergoes a further upgrading process by separating light metals (aluminium) from heavy metals, thus increasing their respective value compared to the original mixed flow. It should be noted that the heavy non-ferrous component consists mainly of copper, but with a significant presence of precious metals such as gold and silver.

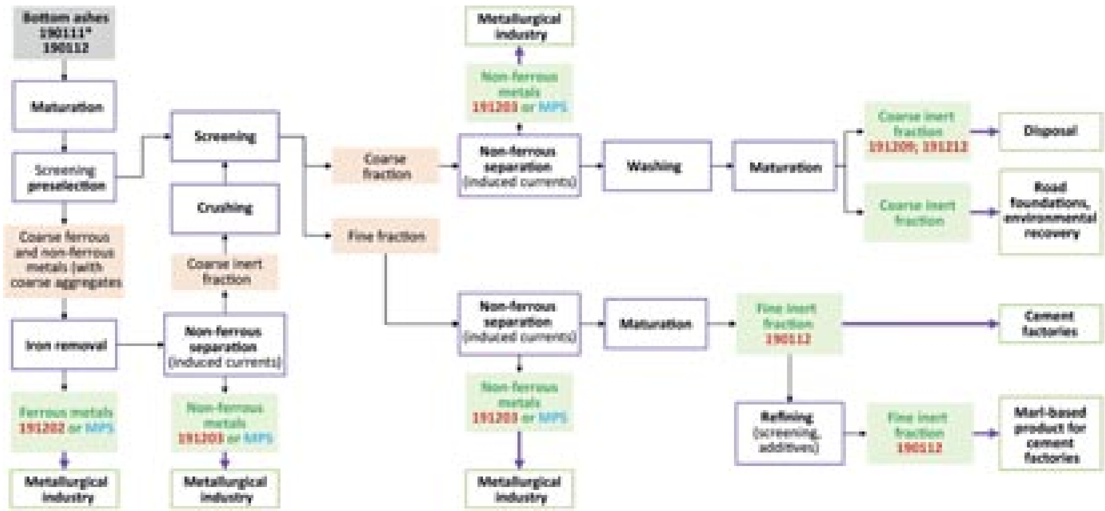
Figure 4.3 - **Quantities of silver and gold recovered from heavy ash at a treatment plant in the Netherlands (Born, 2018). It is noted, in particular for gold, the significant presence in the fraction less than 4 mm**



[5] The "Green Deal" is an agreement between the Dutch Association of Waste Managers and the Dutch Ministry of Infrastructure and Environment, aimed at producing inert materials from heavy ash that can be used in unconfined applications. The Green Deal also sets very ambitious targets with respect to the recovery of metals from heavy ash (Lamers, 2015b)

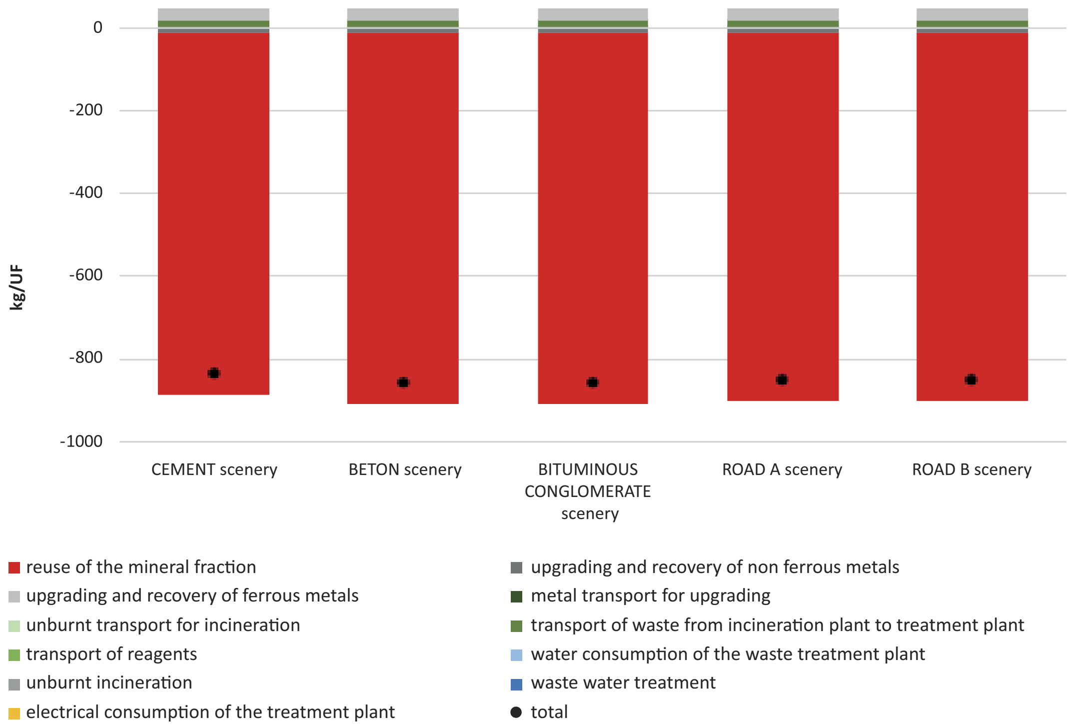
In Italy, bottom ash treatment takes place in medium-large size plants located mainly in Lombardy and Emilia-Romagna, where the main incinerators are concentrated. The main companies include RMB and Officina dell'Ambiente, which have been active in the sector for a long time, and are characterised by very advanced treatment, in the first case aimed at maximising metal recovery, and in the second case at enhancing the value of inert components. Of particular interest for the latter is the production of materials with numerous product certifications, not only of a performance type (Declaration Of Performance - DOP) but also environmental (Environmental Product Declaration - EPD), which allow them to be adequately valued even within sustainable building schemes (e.g. LEEDS certification), in terms of bonuses for the use of recycled materials.

Figure 4.4 - Example of heavy ash treatment plant



Several studies have evaluated the environmental benefits of bottom ash recovery by adopting a life cycle approach (LCA). Among these, particular mention should be made of those conducted by the Milan Polytechnic, both in the study carried out on behalf of CiAl and Federambiente in 2009 (CiAl, 2010) and more recently for Utilitalia. With reference to the latter, which was based on the analysis of an average Italian ash treatment situation, the recovery of metals and mineral fraction generates overall environmental benefits for all the impact categories considered, regardless of the specific fate of the mineral fraction. The environmental impacts, mainly associated with the transportation of bottom ash from incineration plants to the treatment plant, the incineration of unburned ash or the recovery of the mineral fraction, are in fact more than offset by the benefits generated by the recovery of scrap metal, both ferrous and non-ferrous. For the mineral fraction, an average saving of more than 800 kg of natural minerals per tonne of bottom ash sent for treatment is generated (Fig. 4.5). The recovery of the mineral fraction of bottom ash as a substitute for natural aggregates in the production of cement, concrete, asphalt and cement mixes plays a key role in this case. Such recovered material, consisting largely of sand, may play an important role in light of some recent findings inherent in the concrete risks of scarcity in the availability of such material globally (UNEP, 2014).

Figure 4.5 - Indicator of natural mineral resource consumption associated with the treatment of 1 tonne of heavy ash and recovering the metals contained therein and the resulting mineral fraction, for five different alternatives of using the latter



5. PLANTS CREATED IN EMERGENCY SITUATIONS (MBT AND BIODRYING PLANTS)

5.1 General outline on plants objective and efficiency, environmental balance (LCA)

The acronym MBT refers to Mechanical Biological Treatment plants, essentially of residual municipal waste (RMW), which, through the integration of mechanical operations and biological processes, transform the incoming flow into sub-flows of materials with different destination/valorisation.

With reference to the various possible combinations, it is useful to classify this plant engineering into two main categories: single-flow plants and separate-flow plants. In the first case, the plant scheme foresees that all the incoming waste undergoes the biological process, typically biodrying. It is a process that within 1-2 weeks reduces the presence of moisture in the waste making it more suitable for the subsequent separation of non-combustible materials and the production of a refuse-derived fuel. In the second case, a sub-fraction of the incoming waste arrives at the biological process due to the presence of a selective screen before the biological process itself, typically biostabilization. The screen is a mechanical device capable of separating fine fractions (rich in organic matter) from coarse fractions (drier and rich in combustible materials such as plastic and paper). The two biological processes mentioned and their location in a MBT plant are schematized in figures 5.1 and 5.2 below. Both biological processes are aerobic, i.e. they require air flow to support the biochemical process.

As can be seen, the two biological processes are supported by mechanical operations. With reference to the first figure, pelletizing is a mechanical treatment to obtain an RDF of reduced size and homogeneous characteristics, more interesting for specific industrial applications where the fuel pieces of size can play a relevant role. However, pelletizing results in the production of waste that is mainly destined for landfill.

Figure 5.1 - Diagram of an MBT with biodrying process

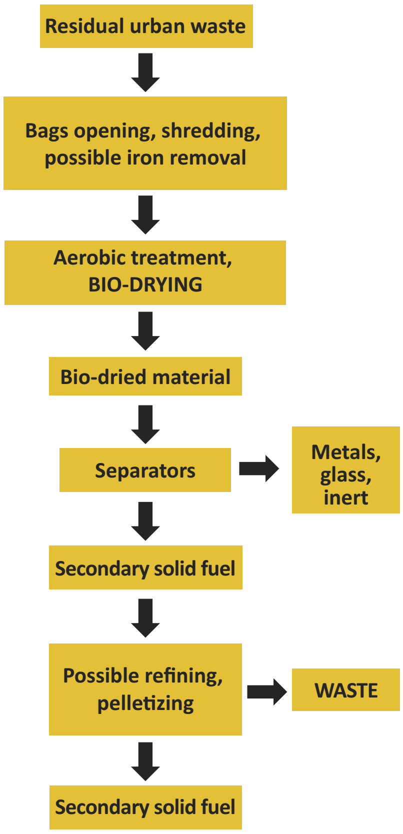
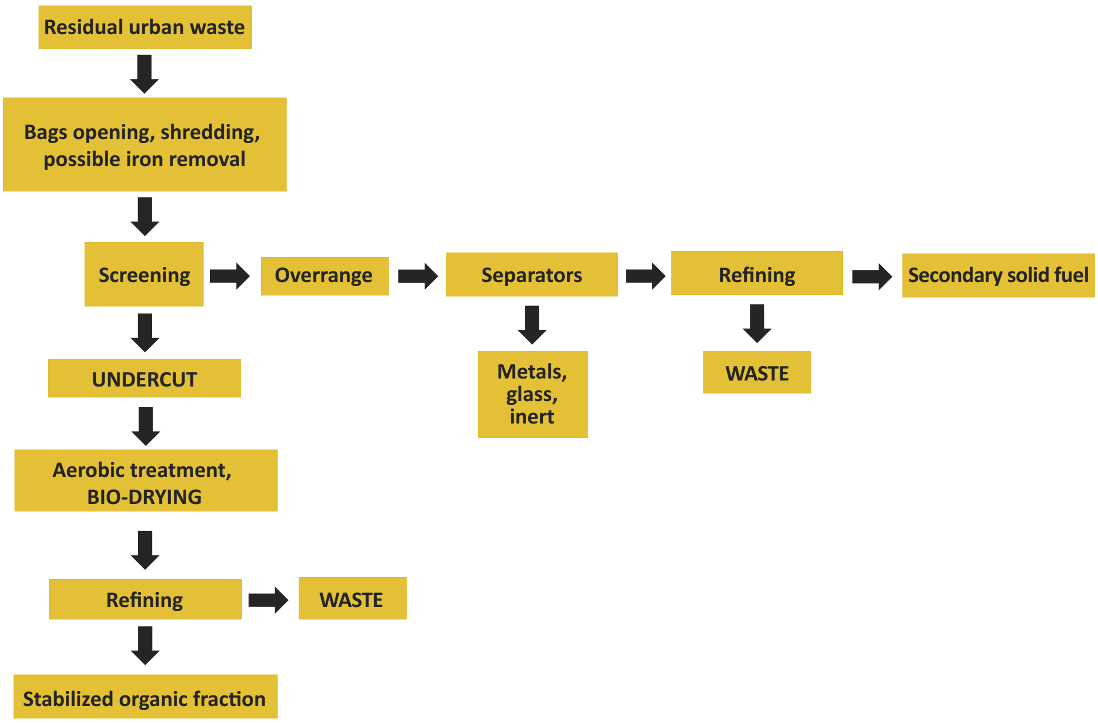


Figure 5.2 - Diagram of an MBT with biostabilisation process



With reference to the second figure, the indicated shredding has essentially a bag-opener role, being placed upstream of a screen that selects according to pieces of size. Refining units are not mandatory, but depend on the treatment target. The acronym SOF indicates Stabilised Organic Fraction, which can be used for particular environmental restoration; here, however, reference will be made to biostabilisation as a pre-treatment prior to landfilling.

5.2 National and European cases

According to ISPRA data (MW Report 2018, Ispra) MBT plants treated in Italy, in 2017, almost ten million tonnes of RMW and more than one million tonnes of other waste.

Regarding the final destination of waste/materials produced by mechanical biological treatment in the year 2017, ISPRA's analysis shows that about half is disposed of in landfills, while about one fifth is sent to incineration plants. Almost one million tonnes of waste are sent for co-incineration (in cement plants, etc.). It is mainly RDF and includes about 137 thousand tonnes of waste co-incinerated abroad, in particular in Hungary, Austria and Portugal.

With reference to the study by Consonni et al., referring to the Italian context, compared to solutions of RMW pre-treatment before energy recovery, direct combustion benefits from positive impact indicators and lower landfill requirements. This is due to the fact that pre-treatment of RMW always requires a consumption of electricity that cannot be recovered a posteriori; furthermore, the more extensive the pre-treatment, the greater the amount of waste produced that must find a suitable collocation.

The work of Panagiotis Psaltis and Dimitrios Komilis (WM 2019) similarly highlights how pre-treatment of RMW reduces net energy production. The energy savings achievable with direct combustion instead of biodrying pre-treatment followed by combustion was reported to be 5%.

A study by Giugliano et al (2011) draws attention to the fact that in the scenarios analyzed, MBT would not find space, considering that with an optimized separate collection, the RMW is destined directly to an incinerator, without having to pass through a MBT. In fact, with a high level of separate collection, the quantity of organic matter present in the RMW becomes incompatible with the construction of an MBT and the materials recoverable from the RMW become negligible.

As far as the European cases are concerned, a comparative LCA study covering eight scenarios including MBT plants showed that performance is highly dependent on energy and material recovery efficiency. In particular, increased automation of material recovery should be a priority option and the destination of organic fraction should be functional for biogas production. This type of approach, however, clashes in part with the European Union's requirement for functional landfill pre-treatment to negate biogas generation, due to fugitive emissions that have a significant impact as greenhouse gases (Monteio et al., 2013).

More generally, it should be noted that a number of comparative LCA studies are available to *decision makers* in the industry literature. The main problem for the valorization of their contents and results is related to the fact that the reference scenario is not stable, for example in terms of emission factors of some contaminants, as the technology improves over time, but also in terms of CO_2 balance with reference to electricity generation on a national basis. It is therefore advisable to have always updated evaluations and referred to individual cases of interest in order to correctly decide a strategy of energy valorization of RMW. It should also be noted that, apart from MBTs for the production of RDF, these types of plants are part of contexts that are lagging behind in achieving an optimal waste management situation.

6. AUTHORIZATION ASPECTS AND FRAGMENTATION OF RESPONSIBILITIES AND COMPETENCES

The current Italian legislation governing the authorization for the construction and operation of waste incinerators is defined by Legislative Decree no. 152 of 2006, which implements several European Directives.

The subject of permits, which is closely linked to the concept of "impact on the environment" and the related assessment, is dealt with in Part II of the decree.

The realization of some categories of works, among which waste incinerators, requires that an Environmental Impact Assessment (EIA) be carried out with a favourable outcome, i.e. an administrative procedure in charge of a competent Authority that has to assess the compatibility of the probable or possible environmental impacts caused by the realization, the operation and the future decommissioning of the work in question, with the protection of public health, the preservation of the environment and natural resources. For waste incinerators, the competent authority is normally the territorially competent Region, which can delegate individual provinces and metropolitan cities. Next to the EIA, there is another authorization tool that is essential for the operation of a waste incinerator, which is the Integrated Environmental Authorization (AIA). In accordance with the law, the operation of a plant is carried out in compliance with the AIA, while its construction or the introduction of significant changes also requires the EIA procedure.

Normally, an EIA measure contains:

a) the conditions for the implementation, operation and decommissioning of the project, as well as those relating to possible malfunctions;
b) the guidelines to be followed in the subsequent design development phases of the works to ensure the application of environmental criteria aimed at containing and limiting significant and negative environmental impacts or increasing the environmental performance of the project;
c) the measures envisaged to avoid, prevent, reduce and where possible offset significant and adverse environmental impacts;
d) the measures for monitoring significant and adverse environmental impacts, as well as the type of parameters to be monitored and the duration of the monitoring.

The AIA measure, on the other hand, contains all the measures necessary to achieve a high level of protection of the environment as a whole. Specifically:

a) a description of the processes carried out;
b) the definition of the authorised size of the different activities;
c) identification of the types of probable/possible polluting emissions into the air,

water and soil;

d) the limit value requirements for these emissions both under normal operating conditions and in the event of any malfunction and/or outside normal operating conditions;
e) further requirements ensuring the protection of soil and underground water, appropriate provisions for the management of waste generated by the installation and for the reduction of noise impact, as well as appropriate provisions for the maintenance and periodic inspection of the measures taken to prevent emissions into soil and underground water;
f) the appropriate emission monitoring requirements, the measurement methodology and frequency, the conditions for assessing compliance, the relevant assessment procedure, as well as the obligation to report to the competent authority periodically, and at least once a year, the data necessary to verify compliance with the conditions of the integrated environmental permit;
g) the scheduling of specific monitoring at least once every five years for underground water and at least once every ten years for soil, unless different or more frequent monitoring arrangements have been established on the basis of a systematic risk assessment;
h) inspection activities at the plant, carried out at the expense of the operator, by the control authority and which include the examination of the entire range of environmental effects induced by the plant;
i) measures relating to conditions other than normal operating conditions, in particular for start-up and shut-down phases, fugitive emissions, malfunctions, and definitive cessation of operations;
j) provisions regarding the drafting of improvement projects, to be submitted, or the achievement of certain additional environmental performance within a set timeframe, committing the Manager to identify the techniques to be implemented for this purpose;
k) the provision of adequate financial guarantees, to be provided within 12 months of the issue of the authorisation in favour of the Region or the competent territorial area in accordance with the relevant Ministerial Decrees.

When a plant is built *ex novo*, an integrated authorization procedure is normally used which, in addition to including EIA and AIA, also includes a series of other permits and authorizations necessary for the construction and operation of the work. Both the legislative decree and the European Directives that it acknowledges, establish that the participation of the interested populations and, more in general, of the whole Society, in the decisional process that leads to the authorization of a work subject to VIA / AIA procedure is an essential element of the democratic exercise of the administrative function of the Institutions.
Consequently, in addition to providing for dedicated moments to collect the observations of citizens and associations on the projects to be authorised, the possibility of adopting a path of public discussion prior to the presentation of the Project authorisation application is also envisaged. Legislative Decree No. 50 of 2016 regulates the conduct of this phase of debate / public inquiry.
The EIA or Single Integrated Authorisation application submitted by a Proponent

to the Competent Authority must include:

a) the final design of the work;
b) the environmental impact study;
c) the non-technical synthesis;
d) information on any transboundary impacts of the Project;
e) notice to the public;
f) a copy of the receipt of payment of the contribution due;
g) the results of any public debate procedure carried out pursuant to Legislative Decree No. 50 of 2016.

The environmental impact study is a document containing at least the following elements:

a) a description of the Project, including information on its location and design, size and other relevant features;
b) a description of the likely significant effects of the Project on the environment, both during construction and operation and decommissioning;
c) a description of the measures envisaged to avoid, prevent or reduce and where possible offset likely significant and adverse environmental impacts;
d) a description of the reasonable alternatives considered by the Proposer, appropriate to the Project and its specific characteristics, including the zero alternative, with an indication of the main reasons behind the chosen option, taking into account environmental impacts;
e) the design for monitoring potential significant and adverse environmental impacts arising from the implementation and operation of the Project, which includes the responsibilities and resources required to implement and manage the monitoring;
f) any additional information relating to the particular characteristics of a specific project or type of project and the environmental factors likely to be adversely affected.

A non-technical summary that can be easily understood by anyone must be attached to this Environmental Impact Study.
The EIA petition can also contain one or more Impact Assessments, i.e. the outcome of preventive studies aimed at quantifying the possible impact of the Project on Natura 2000 network sites, either individually or jointly with other plans and projects and taking into account the conservation objectives of the sites themselves. The Natura 2000 network is a catalogue of Sites of Community Interest (SCI), Special Areas of Conservation (SAC) and Special Protection Areas (SPA). It is the main instrument of the European Union's policy for the conservation of biodiversity.
The Public Notice of a Single Integrated Permit Application is a text prepared by the Proponent for public notice of the commencement of the permitting process for a Project. It shall indicate at least:

a) the Proponent, the name of the project and the type of authorization procedure required for the implementation of the Project;

b) whether an EIA application has been made and whether the provisions for transboundary consultations apply;
c) the location and a brief description of the Project and its possible main environmental impacts;
d) the web address and methods for consulting the documentation and acts prepared by the Proposer in their entirety (except for any parts covered by confidentiality restrictions);
e) terms and specific arrangements for public participation;
f) the possible need for impact assessments;
g) the list of all authorisations (including EIA and AIA), understandings, concessions, licences, opinions, concerts, nulla osta and consents, however named, necessary for the construction and operation of the Project.

The preliminary procedure and the issuing of the single integrated authorization is a complex administrative process of which the following is a possible sequence of steps:

1. The Proponent submits an application for a single authorization procedure, containing the request for all authorizations (including EIA and AIA), understandings, concessions, licenses, opinions, concerts, nulla osta and consents, however named, necessary for the realization and operation of the Project;
2. The application must contain all the documentation and project drawings required by the sector regulations to allow for a complete technical-administrative inquiry aimed at issuing all the authorisations, understandings, concessions, licences, opinions, concerts, nulla osta and consents however named. All the documents required by the EIA procedure must be present, in addition to those required for the issue of other permits;
3. Within 10 days from the presentation of the request, the competent authority verifies the basic requirements for procedural eligibility and publishes on its institutional website the documentation received which is not covered by confidentiality constraints (some information/documents may be designated by the Proponent as industrial secret and/or commercially confidential). It therefore notifies all the bodies concerned and/or called upon to express an opinion and/or competent to issue specific authorisations;
4. Within 30 days of publication of the documentation, the competent authority and the bodies involved, each for their own areas of competence, verify the adequacy and completeness of the documentation submitted and formulate any requests for integration;
5. The competent authority sets a deadline of maximum 30 days for the Proponent to process the requests for integrations;
6. On receipt of any additions, the competent authority and the other competent bodies have 15 days to express their opinion on the completeness of the information received.
7. If the applicant does not send the requested integrations within the established deadline, or if the competent authority considers them to be incomplete, the authorisation request is, respectively, considered withdrawn by the applicant or

inadequate and, in both cases, to be filed by the competent authority;

8. At the end of the assessment of adequacy and completeness, all documentation received and not covered by confidentiality is published on the institutional website of the competent Authority, together with the public notice prepared by the Proponent;
9. From the date of publication of the above notice and for a period of 45 days, the public concerned may submit comments on the environmental impact assessment and, where necessary, on the impact assessment and the integrated environmental authorisation;
10. Within the following thirty days, the competent Authority can ask the Proponent for possible integrations, assigning him a term not exceeding thirty days, which can be extended, once only, upon motivated request of the Proponent, positively evaluated by the competent Authority, for a period not exceeding one hundred and eighty days;
11. If the applicant fails to submit the requested supplementary documentation, the application will be considered withdrawn and the competent authority will proceed with the archiving of the application ex officio;
12. Should the competent authority reasonably consider that the modifications or integrations are substantial and relevant for the public, it shall order, within fifteen days from the receipt of the supplementary documentation, that the Proponent send a new notice to the public, to be published on the institutional site of the competent authority;
13. Therefore, a new public consultation is opened, limited to the modifications or integrations made to the Project and to the relative documentation. For this consultation, the time limits laid down in point 9 above shall be reduced by half. However, the Competent Authority may arrange for this public consultation to take place in the manner of a public inquiry, as described below;
14. Within ten days from the conclusion of the public consultation, or from the receipt of the eventual documental integrations, in the case that the further public consultation is not considered necessary by the competent Authority, the latter convenes a Conference of Services in which the Proponent and all the competent or potentially interested Administrations participate in order to release the EIA measure and the authorization titles necessary for the realization and operation of the Project requested by the Proponent;
15. The Services Conference has a maximum of one hundred and twenty days from the date on which it is convened;
16. The reasoned decision concluding the Services Conference constitutes the single authorization measure and includes the EIA measure and the authorization titles issued for the construction and operation of the Project, bearing the explicit indication of the same.

The fundamental step in which the technical validity and environmental value of the proposed Project is verified is the Services Conference, i.e. the discussion table in which, in addition to the Proponent and the competent Authority, all other institutions interested and/or called to participate and/or competent on specific authorisations required for the construction and operation of the work participate.

In the case of the construction of a waste-to-energy plant, there may be more than thirty entities involved in the services conference, each of which is entitled to express opinions and/or make observations, which in most cases require appropriate counter-deductions from the Proponent. Several of these entities are also entitled to request additions to the project documentation in the preparatory stages to the establishment of the Conference.

The overall duration of the procedure may easily exceed one year, considering that the activity of the Services Conference may take up to one hundred and twenty days and more than six months may be granted to the Proponent, upon justified request, to prepare all the integrations requested by the entities involved. The time limits set out here reflect the latest provisions in this area, which were introduced in July 2020 and resulted in a significant contraction of the maximum time allowed.

It is also the power of the Competent Authority to provide that one or more collections of comments from the public take place in the form of a public debate, as defined by Legislative Decree No. 50 of 2016. This is likely to be the case when such a public debate has not been held beforehand and is requested by the regional council of the region concerned, or by the municipal councils representing at least fifty thousand residents in the areas concerned, or by legally recognised associations representing at least fifty thousand members.

Any public debate shall be carried out at the expense of the Proponent and must take a period of time that cannot exceed ninety days in total. If this instrument is used during the authorisation process, it is therefore highly likely that the overall timeframe will be further extended.

Once the authorization for the construction and operation of the work has been obtained, it is possible to proceed with the tenders for the assignment of the executive design and the construction of the plant. However, since the authorization is an administrative act, it can be challenged before the competent Regional Administrative Court (TAR) within the appropriate timeframe, also with requests to suspend the effectiveness of the act.

Any administrative disputes concerning this type of authorisation may take up to several years to reach the first level of judgement (that of the Administrative Court), against which it is in any case possible to appeal again before the Council of State. Even in the case of the second instance, the timeframe is difficult to predict and can also be significant. Finally, in some cases, there may also be a third level of judgement through an appeal to the President of the Republic against the decision of the Council of State. The whole path of administrative justice can lead to waiting several years before arriving at the certainty of an effectively enforceable authorisation. During this period, some of the conditions on the basis of which the authorisation was granted may change, requiring a re-examination of the authorisation with the risk, by generating new administrative acts, of exposure to further appeals.

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Waste to energy plant - GERBIDO

Epidemiological surveys conducted in Italy and abroad in areas affected by the presence of incinerators and publications on the subject in scientific journals: annotated review

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1. ANNOTATED REVIEW OF EPIDEMIOLOGICAL STUDIES

The general principles of environmental protection, adopted in the implementation of articles 2, 3, 9, 32, 41, 42 and 44, 117 paragraphs 1 and 3 of the Constitution and in compliance with international obligations and Community law, are based on the promotion of the quality of human life, to be achieved through the protection and improvement of the conditions of the environment and the prudent and rational use of natural resources.

All legally relevant human activity must comply with the principle of sustainable development, in order to ensure that the satisfaction of the needs of the present generation cannot compromise the quality of life and opportunities of future generations.

In this context, the necessary assessment of the health status of the population exposed to risk factors arising from incineration plants should also be considered, without forgetting that, at Community and national level, waste incineration is included among the techniques that meet the criteria of the best available techniques (BAT). Thus, this technique responds to "*the most efficient and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values and other permit conditions designed to prevent or, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole*". It is considered a BAT because, inter alia, as recognised in the BAT reference document or 'BREF' published by the European Commission, it adopts "*the most effective techniques for achieving a high level of protection of the environment as a whole*".

The pressure and contamination factors affecting all environmental matrices come from a wide variety of activities and have multiple consequences on the environment and the populations living and working in these areas. Health consequences are also mediated by social and economic factors, which add complexity and make it difficult to know and describe how health and quality of life are affected, positively and negatively, by the concomitance of these activities. All of these factors can lead, to widely varying degrees, to strong environmental pressures and important risk factors with multiple residential, occupational and para-occupational exposures.

Very often it happens that, in such contexts in which among the activities in question may be present also that of a waste incinerator, there is a tendency to attribute to the waste incineration the predominant negative role on the health of the population living there.

In this brief note we would like to deal with the problem from a technical-scientific point of view, based only on the bibliographic findings of the last 20 years, in particular with regard to studies on epidemiological effects in areas affected by the presence of incinerators, in Italy and abroad.

In addition, we want to highlight the actions taken on plants that have recently come into operation and aimed at the Surveillance of the Health of the Population in the vicinity of waste-to-energy plants, with the general objective of constantly monitoring and periodically assessing the potential adverse effects on health due to any environmental pollution in the areas surrounding the waste-to-energy plant, through the interaction and sharing of both operational and monitoring data (environmental and health) between operators, institutional controllers (e.g. ASL, ARPA, ISS, etc.) and the communities involved.

1.1 Article "REF 1

In the publication **(REF 1**) of the National Academies of Sciences Engineering Medicine of the United States of America, entitled "Waste Incineration and Public Health **(year 2000**, ISBN 978-0-309-06371-5, DOI 10.17226/5803, PDF at http://nap.edu/5803), a specific chapter (5 - UNDERSTANDING HEALTH EFFECTS OF INCINERATION) is devoted to the effects of waste incineration on human health. The publication was prepared by the Committee on the Health Effects of Waste Incineration to Assess the Relationship between Human Health and the Incineration of Hazardous Waste, Municipal Solid Waste, and Hospital Waste established by the National Research Council (NRC). In this report, the committee explains its findings and recommendations on waste incineration and public health. In the conclusions of Chapter 5, the following considerations/deductions are highlighted in particular:

“*Estimates of large increments in ambient concentrations of various pollutants attributable to existing incinerators, particularly heavy metals and dioxins and furans, led to legitimate concerns about potential health effects*”.
“*On the basis of available data, a well-designed and properly operated incineration facility emits relatively small amounts of those pollutants, contributes little to ambient concentrations, and so is not expected to pose a substantial health risk*”.
“*Epidemiologic studies assessing whether adverse effects actually occurred at individual incinerators have been few and were mostly unable to detect any effects. That result is not surprising, given the small populations available to study; the presence of effect modifiers and potentially confounding factors (such as other exposures and risks in the same communities); the long periods that might be necessary for health effects to be manifested; and the low concentrations (and small increments in background concentrations) of the pollutants of concern. Although such results could mean that adverse health effects are not present, they could also mean that the effects may not be detectable using feasible methods and available data sources*”.

This shows that among the pollutants attributable to existing incinerators (i.e. built and in operation well before 2000), heavy metals, dioxins and furans support concerns about potential health effects. According to the available studies, already at that time, a well-designed and properly operated incineration plant emitted relatively small amounts of these pollutants and contributed insignificantly to the concentrations released into the environment and, in these cases, did not pose a substantial health risk. However, doubts were raised about the effectiveness of the studies conducted at the time in assessing epidemiological side effects in relation to the number of studies conducted, the time of the investigation, and the methods used. All this led to the conclusion that, although almost all the results of the studies carried out did not show any direct negative health consequences, there were real doubts that negative effects on human health might not have been detected, given the ineffectiveness of the methods used at the time.

1.2 Article "REF 2

In the article **(REF 2**) "Health Effects of Waste Incineration: A Review of Epidemiologic Studies" (Suh-Woan Hu & Carl M. Shy, **year 2001**, published in Journal of the Air & Waste Management Association, 51:7, 11001109, DOI: 10.1080/10473289.2001.10464324), there is a review of some epidemiological research on the potential health impact of waste incineration. In the article, the following considerations/deductions are noted in particular:

"*In conclusion, these epidemiologic studies consistently observed higher body levels of some organic chemicals and heavy metals, and no effects on respiratory symptoms or pulmonary function. The findings for cancer and reproductive outcomes were inconsistent. More hypothesis testing epidemiologic studies are needed to investigate the potential health effects of waste incineration on incinerator workers and community residents*".
"*The studies of health effects of waste incineration among community residents showed some similar and some inconsistent results. First, the results for reproductive effects were conflicting*". "*Second, the findings for cancer risk were inconsistent*". "*Third, prevalence of several respiratory symptoms was not significantly related to living in an area with a waste incinerator in both studies reviewed*".
"The exposure sources are not similar for workers and residents of communities with incinerators".

For workers at incineration plants, the authors point out the following:

"*The studies of incinerator workers consistently showed higher frequency of urinary mutagens and promutagens and increased blood levels of certain organic compounds and some heavy metals*".
"*The findings for lung cancer mortality were conflicting—significantly increased in one study, but decreased in another study*".

The studies taken as reference by the authors of the review showed similar and statistically insignificant results for epidemiological purposes, both for reproductive effects and carcinogenic risk. The occurrence of several respiratory symptoms were also assessed as non-significant.
Slightly different is the picture that would be outlined for the workers in these plants, all of which date back to the 80s and 90s of the 20th century, even though a concrete picture would have required more in-depth methodological and

investigative studies. For these workers, the evidence that led to these assessments was the finding of organic chemical compounds and heavy metals accumulated at body level in the workers at higher levels than those found in a normal person. Also for this evidence, some studies have shown associations between epidemiological effects and waste incineration (for the most obsolete and poorly managed plants at the time), but as many studies have not found significant effects in this respect. Therefore, the results were, in general, evaluated as inconsistent with each other and therefore not substantiating the hypothesized evidence.
The authors concluded the study by highlighting the need to conduct further epidemiological follow-up studies by examining inconsistent cases in depth, to investigate the potential health effects of waste incineration on incinerator workers and community residents.

1.3 Article "REF 3"

In the document **(REF 3**) "Environmental and health surveillance in areas close to incinerators: indications from the European ENHance Health Project" **(year 2007**, Erspamer L. et al., Sorveglianza ambientale e sanitaria in aree prossime ad inceneritori: indicazioni emerse dal Progetto europeo ENHance Health. Roma: Istituto Superiore di Sanità, Rapporti ISTISAN 07/41), a methodological approach is explained in order to establish themes and modalities for knowledge activities aimed at the surveillance and prevention of environmental and health effects in the interested areas.
As explained by the authors in the introduction, this need arises from the problems related to planning, monitoring and evaluation of areas affected by the presence of incinerators, which are often heterogeneous and complex realities.
In fact, "*pressure and contamination factors affect all environmental matrices, come from a wide variety of activities and have multiple consequences on the environment and on the populations that live and work in these areas*. *The health consequences, which are of interest to this contribution, are also mediated by social and economic factors, which add complexity and make it difficult to know and describe how health and quality of life are affected, positively and negatively, by the set of determinants present*".

"*Numerous epidemiological studies have been carried out to assess the health impact of waste incinerators, which are very heterogeneous in method and results. It is often difficult, if not impossible, to compare the various studies because of differences due to the geographical context, the populations examined, the different types of plants or waste considered*".
"*Moreover, these epidemiological studies often do not allow to demonstrate a univocal cause-effect relationship of environmental risk factors related to the waste cycle, precisely because in the areas involved there are numerous environmental pressure factors and criticalities referable to socio-economic factors*".
"*Therefore, this complex scenario implies a delicate communication problem and emphasizes the need to apply effective interventions, some of which are already*

implemented at the healthcare level".
"*To this end, it seems important to activate integrated monitoring systems for health status and exposure factors*".

The paper highlights the fundamental need to identify a methodological approach that will then allow the various studies to be properly evaluated and compared.

1.4 Article "REF 4

In the publication **(REF 4**) of the Emilia-Romagna Region "The effects of incinerators on health. Epidemiological studies on the population in Emilia-Romagna" **(year 2012**, Quaderni di Moniter, 06>12) reports the results of a series of investigations aimed at clarifying the environmental and health effects of municipal waste incinerators in the region. Five technical and scientific lines of action have been carried out: investigation into the atmospheric emissions of the plants, investigation into the environmental fallout and effects, identification of the population exposed to incinerators over the past decades and epidemiological investigation into their health (230,000 people, about 5% of the regional population), laboratory research into the toxic effects of emissions from the plants.
The results of the activities presented were shared in methodology, procedures and outcomes by the Scientific Committee ("*nucleus of essays*"), consisting of scientists and specialists unrelated to the design and conduct of the research and devoid of any interest conflicting with the role of guarantors attributed to them.
In the publication, the following objectives and conclusions are acknowledged:

1. "*To evaluate the possible association between exposure to pollutants emitted from MSW incinerators and the following pregnancy events: sex ratio at birth (SexR), multiple births (MB), preterm births (PTB), small for gestational age (SGA), and low birth weight (LBW) in term births*".
   "*For none of the outcomes considered are there significant differences between the areas under study and regional averages. However, considering the occurrence of each outcome within areas in relation to exposure levels, varied results are manifest. Incinerator exposure shows no effect on sex ratio, twin births, low birth weight. The small outcome for gestational age, not explored in any previous study, shows a weakly significant trend for increasing levels of exposure, but with no occurrence of the outcome significantly higher than the reference level at higher levels. Instead, the study found a consistent and statistically significant association between exposure levels to incinerator emissions and preterm births. The results of this work must be incorporated into the body of pre-existing knowledge and contribute to the overall process of recognizing the harmful potential of an agent/exposure, i.e., to the construction of a progressively less uncertain level of evidence. The results of the study contribute to the evaluation of the health component in the overall view of waste management policies. A further contribution to the improvement of knowledge will come from the continuation of the study over a more recent period, which will also make it*

possible to assess whether the plant changes that have occurred in the meantime have led to a change in the model estimates of exposure and in the outcomes reported here".

2. "To *analyse the occurrence of miscarriage in women aged 15-49 years residing in an area of 4 km radius from 7 MSW incinerators present in Emilia-Romagna in the period 2002-2006, using appropriate indicators*".
   "*The study suggests an association between incinerator exposure and spontaneous abortions. The results appear consistent with the observation of an increase in preterm births associated with incinerator exposure, already observed within the Moniter Project.* It*is plausible, in fact, that spontaneous abortions and preterm births share some causal factors capable of determining the untimely interruption of pregnancy, either early (spontaneous abortion) or later (preterm births)*".
3. "*To evaluate whether the prevalence of malformed births, diagnosed in the first year of life, is significantly associated with exposure to pollutants emitted by incinerators*".
   "*The weak signals that have emerged do not provide evidence for the attribution of a causal link between malformations and exposure to pollutants emitted by incinerators and suggest analyses on larger case series. The study has provided important indications of the paths to be taken to improve the effectiveness of the instruments of detection of malformations, a fundamental requirement to allow a more advanced surveillance and epidemiological studies*".
4. "*To evaluate the natural mortality and for some causes of death as well as the incidence of malignant tumors in relation to exposure to emissions from municipal solid waste incinerators present in Emilia-Romagna for longer time*".
   "*The long-term effects of exposure to municipal solid waste incinerator emissions are the subject of numerous studies, the results of which were recently analyzed by two reviews, which considered studies related to each outcome or only to mortality outcomes, respectively. No evidence of a causal relationship with exposure to municipal solid waste incinerators has been produced for any of the outcomes considered, but limited evidence of association exists for soft tissue sarcomas, non-Hodgkin's lymphomas, and, among solid tumors, those of the stomach, colorectum, liver, and lung. For non-cancer causes, none of them even present limited evidence, but there are only isolated reports of excesses for respiratory diseases, acute and chronic. Overall, the study did not show a consistent association between exposure levels and mortality or cancer incidence. Some tumor sites, colon in women and non-Hodgkin's lymphoma, for which there was already a weak a priori evidence, were found to be associated with the exposure under study in the Modena cohort, although with different strength of the association. Liver cancer, also already reported in the literature, was found to be variably associated with exposure in the different cohorts investigated. Finally for pancreatic cancer, not explored in other studies, an association with exposure was observed in males in the larger cohort. These associations, whose causal relationship with exposure to municipal solid waste incinerators cannot be assessed, represent the only clues to the possible carcinogenicity of emissions from incinerators*".

1.5 Article "REF 5

In the document **(REF 5**) "Waste and human health: Evidence and needs" **(year 2015**, WHO Meeting Report, World Health Organization, Regional Office for Europe), as explained in the introductory abstract, builds on concerns about the possible health impacts of waste movement, management and disposal, particularly in relation to informal practices and outdated technologies, and re-assesses the available scientific evidence on waste-related health effects which although inconclusive, suggests the possible occurrence of serious adverse effects including mortality, cancer, reproductive health and milder effects affecting well-being. In the document, a paragraph is dedicated to municipal waste incineration (pages 16 and 17) and a specific subsection is dedicated to health effects (page 17), which is reproduced in full below.

"*As stated above, emissions from incinerators have been much changing over time. This entails changing health impacts, and it is difficult to formulate overall considerations on the health effects. Available evidence is therefore specific to the period of investigation and to the different types of incinerator analysed (old generation versus new generation plants). On the other hand, the improvement in exposure assessment methods mentioned above can help summarize the health risks. Papers dealing with the health effects of incinerators active in the years* ***1969–1996*** *consistently report a detectable risk of some cancers in the populations living nearby, through high quality studies, as reported in different reviews. Quantitative estimates of excess risks of specific cancers in populations living near solid waste incinerator plants were provided for all cancers, stomach, colon, liver, and lung cancer. Other studies performed in Italy, France and the United Kingdom indicate some suggestive but not consistent results for non-Hodgkin lymphomas and soft tissue sarcomas.*
The majority of these studies concerned old generation incinerators, characterized by high emission levels. The emissions of modern incinerators which have been investigated are different in quantity and composition, as a result of modern abatements techniques. For this reason the results of all available studies cannot be compared, and consistency across studies is not expected.
Congenital anomalies were also investigated by several studies. Particular attention has been given to the excess risk for urinary tract defects by a well-designed study in France, which confirmed previous observations on an increased risk from exposure to solid waste incinerator emissions in early pregnancy. Results from other studies on the same outcomes are inconsistent.
Recent work in Italy found associations between birth outcomes (preterm birth and spontaneous abortion) in relation to increased level of exposure to incinerators. These findings are in line with work done in Taiwan.
Results on chronic or acute respiratory effects in children or adults, were inconclusive, although recent literature reports new evidence on this outcome".

The paper highlights how emissions from incinerators have changed a lot over time. This leads to a change in health impacts and it is difficult to make general considerations on health effects considering also the different reporting period of

the survey and the different types of incinerators analysed (old generation plants versus new generation plants).
Documents dealing with the health effects of **incinerators operating in the period 1969-1996**, therefore far removed from the technical standards regulated by BAT in terms of both technology and management, consistently report a detectable risk of certain cancers (stomach, colon, liver and lungs) in populations living in the vicinity. Studies showing the occurrence of non-Hodgkin's lymphomas and soft tissue sarcomas were inconsistent.
Most of these studies concerned older generation incinerators with high emission levels. The emissions from modern incinerators are quite different in both quantity and composition, thanks to modern techniques. For this reason, the results of all available studies cannot be compared and there is no consistency between the studies, especially with regard to regression on which it is impossible to intervene both in methodological terms and in terms of implementing the number of observations required.
For more recent plants, as potential criticalities that have emerged, but which need statistical confirmation of the data, the increased risk from exposure to emissions from solid waste incinerators in the early stages of pregnancy (study well conducted in France in 2010), the association between preterm birth and miscarriage, and the increased level of exposure to incinerators (studies conducted in Italy, 2013) are reported. Results on chronic or acute respiratory effects in children or adults were rated as insignificant (study conducted in Italy, 2014).

1.6 Article "REF 6"

In the article **(REF 6**) "Epidemiological study of residential cohort on mortality and hospitalizations in the area around the incinerator of San Zeno, Arezzo" **(year 2016**, Fabrizio Minichilli et al., Epidemiology and Prevention, DOI: 10.19191/EP16.1.P033.012) the authors evaluate the risks of mortality and hospitalization as a function of air pollution levels of a municipal waste incinerator active since 2000, located in an area of the Municipality of Arezzo characterized also by other sources of pollution.
As stated by the authors themselves:

- the incinerator uses the latest generation of BAT and is located in an area characterised by the presence of numerous sources of both point and linear pollution, with impacts that can also overlap, making the assessment of health effects complex;
- the definition of exposure has been based on the air matrix only (inhalation route) and has not taken into consideration the other contamination routes; in fact, it must be remembered that exposure can also occur through the water, soil and food matrices.
- methodological limitation of the study is the lack of individual data on potential confounders such as socioeconomic status, occupational exposure, subjects' lifestyle (smoking habit, alcohol consumption, physical activity) and diet.

However, the authors reach the following conclusions, an extract of which is given below:

"Although the results of the present study do not outline any particular criticality for the population living in the areas around the incinerator, signs of criticality emerge regarding the causes of death and hospitalization for cardiovascular and respiratory diseases for which there is a high plausibility of etiological association with air pollution. Also in view of the presence of the other sources of pollution considered, a monitoring system that takes account of the results achieved is desirable.

In this consideration it must be taken into account that the atmospheric pollution is not attributed to the incinerator alone but to the whole area of high industrialisation and production in which the study in question was conducted and in which the possible contribution and/or effect of the incinerator with respect to the rest was not investigated and deepened. The same considerations apply to what follows.

"The signal of excess risk of leukemia mortality, although not significant, needs confirmation, also taking into account the heterogeneity between different etiopathogenetic types. The very small number of deaths and hospitalizations from non-Hodgkin's lymphoma discourages conjecture about the observed risks, as well as for the less than 1 risk observed for mortality from urinary tract disease. The excess of hospital admissions observed for diseases of the urinary tract for both genders is not supported by epidemiological evidence and should be investigated further, both by evaluating the distribution by specific cause and age, and by carrying out ad hoc studies able to estimate the associations with environmental and individual factors, although it must be taken into account the small number".

1.7 Article "REF 7"

In the paper **(REF 7**) "Adverse reproductive outcomes associated with exposure to a municipal solid waste incinerator" **(year 2016**, Santoro M. et al., Ann. Ist. Sup. Sanità 2016, Vol. 52, No. 4: 576-581, DOI: 10.4415/ANN_16_04_19) the authors investigate the association between exposure to a municipal waste incinerator and various reproductive outcomes (premature birth, low birth weight, small for gestational age and sex ratio), also considering the presence of other pollution sources (industrial plants, highways, main roads with high traffic flow) and also taking into account some maternal factors, including socioeconomic status.
The following evaluations and considerations expressed by the authors in the discussion and conclusions are particularly highlighted:

"*The study area presents an overall complex environmental framework and the overlap of the different sources of air pollution could lead to a misclassification of the individual exposure*".
"*The study detected a slight association between exposure at MSWI and preterm births. The results are in agreement with those of a previous multi-site study with*

similar design, and they strengthen the recommendation to consider gestational age in studies and surveillance in areas with MSWIs and similar sources of pollution".

Ultimately, the study found a non-significant association between exposure to municipal waste incineration and preterm births. The results are in agreement with those of previous multi-site studies with a similar study setting.

1.8 Article "REF 8"

In the article **(REF 8**) "Adverse pregnancy outcomes in women with changing patterns of exposure to the emissions of a municipal waste incinerator" **(year 2018**, Vinceti M. et. al., Environmental Research 164 444- 451, https://doi.org/10.1016/j.envres.2018.03.024), the rates of miscarriage and birth defects among women who resided or were employed near the municipal solid waste incinerator plant located in the city of Modena were examined in the years 2003 to 2013. In 2009, a gradual shutdown of the old incineration lines and the operation of a new line resulted in higher atmospheric releases of polycyclic aromatic HC's, and dioxins, due to temporary irregular operating conditions.
Excerpts from the work are given below:

"*In the present study, we examined rates of miscarriage and birth defects among women who resided or were employed in the vicinity of a municipal solid waste incinerator plant in the town of Modena, from 2003 to 2013. In 2009, a progressive shutdown of the old incineration lines and operation of a new line caused considerably higher atmospheric release of polycyclic aromatic hydrocarbons, particularly of dioxins, due to these irregular operating conditions, technological renovation, and increased capacity*".
"*Concerning birth defects in the offspring of women residing in the exposed area, no evidence of increased risk emerged, since the prevalence ratio at birth was 0.64 (95% CI 0.29–1.26), with comparable results in the 2003–2008 and 2010–2013 period. Corresponding analyses carried out in municipal residents who worked in the exposed area confirmed these findings. We also did not detect abnormally high rates of miscarriage and birth defects in the exposed cohorts in the single year 2009*".
"*Overall, these results do not suggest an effect of exposure to the emissions of the municipal solid waste incinerator we investigated on two indicators of reproductive health. However, the limited statistical stability of the estimates and the absence of individual-based information on some potential confounders suggest caution in the interpretation of study findings*"

The authors, therefore note the following. With regard to birth defects in the offspring of women residing in the exposed area, there was no evidence of increased risk, with comparable results in the periods 2003-2008 and 2010-2013. Corresponding analyses conducted on both residents at the exposed area and workers at the plant confirmed these results. In addition, abnormally high rates of miscarriage and birth defects were not found in the cohorts exposed in the single year 2009. In conclusion, the published results, based on the two reproductive health indicators studied, do not show an effect of exposure to municipal solid waste incinerator emissions. However, the authors highlight the limited statistical stability of the estimates and the absence of individual information on some potential confounding factors found in the data collected.

1.9 Article "REF 9"

The final Report **(REF 9**) "Studio epidemiologico per valutare gli effetti sulla salute dei soggetti residenti intorno all'inceneritore di Valmadrera" **(year 2018**, University of Turin1, Health Protection Agency (ATS) of Brianza2, Tecno habitat - Società di ingegneria3, by Cristiano Piccinelli1, Paolo Carnà1, Emanuele Amodio2, Magda Rognoni2, Marco Vuono3, Luca Cavalieri d'Oro2), contains the epidemiological study to assess the state of health of its citizens that was commissioned by the Municipality of Valmadrera and that involved also the municipalities (Annone Brianza, Civate, Galbiate, Lecco, Malgrate, Suello and Valmadrera) closest to the incineration plant of Municipal Solid Waste of Valmadrera managed by Silea Spa, in responding to the requests put forward by the population and associations on the perception of worrying effects of such a plant on health. The study was carried out in collaboration with the Health Protection Agency (ATS) of Brianza, the Centre for Epidemiology of the University of Turin and the company Tecno habitat, which produced the dispersion model of the plant's emissions in the area under study.
The study is based on the residential history of the population residing in the area and the health data of this population from 1/01/2003 to 31/12/2015.
In order to assess potential health effects, information from the ATS della Brianza, which is responsible for information on the state of health of the population in its area, was used. The ATS della Brianza has provided, suitably anonymized, the following information on the living status and health status of the historical cohort, by processing the following information flows: - Living status of the population in the cohort (NAR) - Causes of death (Registro Nominativo delle Cause di Morte dell'ATS della Brianza) - Morbidity by cause (Schede di Dimissione Ospedaliera - SDO) - Incidence of cancer pathologies (Registro Tumori dell'ATS della Brianza) - Certificates of delivery assistance (Cedap).
The study results show no health effects for diseases associated with exposure to incinerator emissions, such as non-Hodgkin's lymphomas, soft tissue sarcomas, cardiovascular and respiratory diseases. Some excesses have been found in the population living in the area, but these concern diseases for which the plausibility of an etiological association with pollution from the incineration plant is very limited, as in the case of liver tumours, or non-existent, as in the case of pleural tumours. Furthermore, with regard to neonatal health, which is considered to be of great importance because it involves a moment in the life cycle that has an enormous impact on the health and development of the individual, no differences were found between residents in areas with different levels of exposure.
In conclusion, the results show the absence of a clear and well-characterizable relationship between residence in areas with different fallout of pollutants emitted

by the incineration plant located in the municipality of Valmadrera and the onset of diseases related to it. In these territories, the exception found concerned liver and biliary tract tumours, the excess of which in residents in the areas with the highest fallout from emissions deserves further investigation with regard to the possible causes, given the very limited scientific plausibility of an aetiological association of these diseases with pollution from the incineration plant.

1.10 Article "REF 10"

In the article **(REF 10**) "Environmental and health risks related to waste incineration" **(year 2019**, de Titto E. and Savino A., Waste Management & Research, DOI: 10.1177/0734242X19859700) the authors present a mini "review" of published research findings focused on understanding the environmental impacts and human health effects of waste incineration plants.
Excerpts from the work are given below:

"*We found no studies indicating that modern-technology waste incineration plants, which comply with the legislation on emissions, are a cancer risk factor or have adverse effects on reproduction or development*".
"*There are several factors in favor of this affirmation: (a) the emission levels of the plants currently built in the developed countries are several orders of magnitude lower than those of the plants in whose environments epidemiological studies have been carried out and which have found some kind of negative association in terms of health; (b) risk assessment studies indicate that most of the exposure is produced through the diet and not by a direct route; and (c) monitoring dioxin level studies in the population resident in the environment of incineration plants did not reveal increases of these levels when compared with a population living in reference areas*". "*A necessary condition for the development of a waste incineration plant is to generate the conditions to prevent any impact that activates or potentially carries damage or risks to the environment and, in particular, to health. This makes it imperative to use a preventive strategy through the implementation of a previous environmental impact assessment and the establishment of emissions standards and an emissions monitoring program in order to ensure the prevention of environmental damage*".

In the presented work, the authors point out that for waste incineration plants with modern technology that comply with emissions legislation, they found no studies that identify waste incinerators as risk factors for cancer or adverse effects on human reproduction or development.
In support of these conclusions, they point to the following factors:

- the emission levels of the latest generation of plants in developed countries are many orders of magnitude lower than those of plants operating in territories where epidemiological studies have identified negative associations in terms of health;
- risk assessment studies indicate that most of the exposure is via the diet and not via a direct route such as emission;

- the measurement of dioxin levels in the population living in areas close to incineration plants did not show higher levels than those found in a population living in areas not affected by these plants.

1.11 Article "REF 11"

In the document **(REF 11**) *"DOES THE THERMOVALORISATION OF TURIN HAVE AN IMPACT ON HEALTH?* The *results of the SPOTT Programme three years after the start-up of the plant",* (2020, https://www.dors.it/alleg/spott/202002/200217%20Report%20Spott.pdf) highlights the role and the activity carried out within the SPoTT programme (Surveillance of the Health of the Population near the Turin Waste to Energy Plant) launched in 2013 and aimed at creating a surveillance system to assess the adverse health effects of environmental pollution in the areas surrounding the Turin waste to energy plant. The working group set up for this programme is made up of the most important competent public institutions with the commitment of dozens of qualified technicians and specialists, also supported by research centres and universities. SPoTT, has developed and implemented one of the largest and most comprehensive surveillance programs on the possible health effects of municipal solid waste incinerators, combining *"epidemiological monitoring lines to a biomonitoring study, involving multiple categories of subjects (residents, farmers, plant operators), comparing data in space and time. The protocols of investigation, the feasibility of the various actions, the adequacy of resources and technologies involved, have been continuously discussed and shared in methodology, procedures and outcomes by the Scientific Technical Committee. The results have been validated by the scientific community through the peer review process activated prior to the* ***publication of the 8 articles available to date in national and international scientific journals****. SPoTT provides important information for the citizens and institutions of Turin and its surroundings but, thanks to the scientific rigour with which it was conducted, it contributes more generally to improving knowledge on the subject of incinerators and health".* SPoTT has *"paid great attention to promptly informing all those interested in learning more, using multiple communication tools: a regularly updated website (www.dors.it/spott) reports and summaries of results as soon as they are available; videos, conferences and press releases; public presentations and at institutional tables. In this document SPoTT provides a summary of all the results produced in seven years of activity".*
At present, the following activities have been activated:

- *"biomonitoring to verify how the amounts of certain pollutants varied over time on a group of inhabitants in an area most affected by the fallout from the emissions (those closest to the plant)".*
- "*monitoring of short-term effects on health*" with "*the objective of assessing any short-term effects that the Turin municipal solid waste incinerator has on the health of the population living in the municipalities bordering the plant and potentially most affected by its emissions*;
- *"monitoring of long-term health effects. The populations living in areas close to*

municipal solid waste incineration plants", according to literature, *"have been the subject of numerous studies" … "To date, the international scientific community agrees that old generation plants have been the cause of some cancers (liver, stomach, colorectal, lung, non-Hodgkin's lymphomas, soft tissue sarcomas), births of babies with congenital anomalies (in particular urinary tract malformations) and preterm births. In light of this information, SPoTT decided to address this type of diseases characterized by long latency times between exposure and disease onset. The long-term effects study, therefore, will look at hospitalisations and mortality from 2003 to 2022 (10 years before and 10 years after the plant was turned on)";*

- *"monitoring of the plant's workers"… "through a continuous collection of work and health information (tasks and shifts performed, reports from the competent doctor, occupational injuries and illnesses) that made it possible to know and follow the cohort of workers over time. Similar to what was done on the residents, the employees of the plant operator were also invited to participate in the biomonitoring study. Biomonitoring was repeated over time by taking the first sample at the time of recruitment and subsequent samples after 1 and 3 years of employment. In parallel with biomonitoring (in 2013, 2014, 2016, 2017), a number of environmental monitoring campaigns were carried out in different premises where workers work";*
- *"monitoring of farmers near the plant. The biomonitoring activities planned for residents have been proposed to all farmers operating farms located within an area of 5 km from the incinerator.*

With regard to the conclusions of the results finished so far, it is found as:

- the latest biomonitoring survey of the resident population, conducted in 2016, showed the following. *"The metal values detected are comparable to, or lower than, those found in other similar national and international studies. Over time, there has been an overall reduction in the values of metals"* found in the blood. *"This decrease is greater among people living near the plant. The results suggest that the changes in blood and urine metals found in the sampled resident population are not associated with plant activity. Residents closest to the facility and residents farthest from the pollutant fallout area have similar PCDD, PCDF, and PCB values in 2016. A general decrease in PCDD, PCDF, and PCB levels was measured three years after the plant was turned on. The significant reduction of these pollutants in the resident population is in line with the documented decrease in the levels of dioxins and PCBs in the environment and in food over the years, probably the result of European policies aimed at setting increasingly restrictive limits, especially on the use of dioxins and furans. After three years of operation of the waste-to-energy plant, OH-PAHs are lower than those measured before the plant started up. Thus, the observed OH-PAHs changes do not appear to be related to plant activity.*
- the latest biomonitoring survey of workers at the plant, with regard to the concentration of metals in the blood, showed that *"the values found are lower than the exposure limit values. Concentrations of most metals decreased over time … Values for manganese, platinum, and antimony, metals for which a slight increase*

over time was measured, were similar to or lower than those found in other similar international studies ... Differences found in 2016 OH-PAH values between workers on the lines and workers performing "office" activities do not appear to be work-related. After three years of operation at the plant, the levels of OH-PAHs found in workers are stable or decreasing ... Environmental monitoring inside the plant has shown, in most of the rooms, the presence of metals below the limits measured by the instruments, confirming the absence of occupational exposure to these pollutants ... Thanks to some improvements, the concentrations of PAHs, initially higher in some areas of the plant, have also decreased after three years of operation ... The levels of dioxins, furans and PCBs, after three years of operation, are similar or lower than those measured at the start-up of the plant.

- the last biomonitoring survey, with regard to the concentration of potential hazardous substances in the blood, showed that *"the results of metal detection in the group of farmers are in line with those obtained in the group of residents, for all types of pollutants monitored, despite the limited number of subjects*. *PAHs, while showing the same trend as in the general population, show generally higher values in farmers, probably due to a higher smoking habit in this group. Dioxins and PCBs, as already highlighted in the sampling carried out before the start-up of the plant, although in general decrease, have higher values than the resident population.*

The SPoTT Programme has contributed, through its results, to an increase in knowledge about the health effects of a waste incineration plant. Its results, however, have not only had a local resonance as evidenced by several scientific articles published in international journals in the field, which are listed below:

a) Bena A, Orengia M, Farina E, Chiusolo M, Alimonti A, Bocca B, Cadum E, De Felip E, Iamiceli AL, Pino A, Procopio E, Salamina G per il gruppo di lavoro SPoTT. **Biomonitoring and exposure assessment of the general population living near an Italian incinerator: methodology of SPoTT study.** Environmental Monitoring and Assessment (2016) 188(11), 1-11. DOI 10.1007/s10661-016-5624-5;

b) Bena A, Chiusolo M, Orengia M, Cadum E, Farina E, Musmeci L, Procopio E, Salamina G e il gruppo di lavoro SPoTT. **Sorveglianza sulla Salute della popolazione nei pressi del termovalorizzatore di Torino (SPoTT): presentazione del programma di sorveglianza.** Epidemiologia e Prevenzione (2016) 40(5):366-73;

c) Bocca B, Bena A, Pino A, D'Aversa J, Orengia M, Farina E, Salamina G, Procopio E, Chiusolo M, Gandini M, Cadum E, Musmeci L, Alimonti A. **Human biomonitoring of metals in adults living near a waste-to-energy incinerator in ante-operam phase: focus on reference values and health-based assessments.** Environ Res 148(2016)338–350;

d) Bena A, Gandini M, Cadum E. Procopio E, Salamina G, Orengia M, Farina E **Percezione del rischio nella popolazione residente nei pressi del termovalorizzatore di Torino: risultati ante-operam e strategie comunicative.** BMC Public Health (2019) 19:483 https://doi.org/10.1186/s12889-019-6808-

e) Ruggeri F, Alimonti A, Bena A, Pino A, Orengia M, Farina E, Salamina G, Procopio E, Gandini M, Cadum E, Bocca B. **Human biomonitoring health surveillance for**

metals near a waste-to-energy incinerator: the 1-year post-operam study. Chemosphere (2019) 225: 839-48. doi: 10.1016/j.chemosphere.2019.03.041

f) Bena A, Orengia M, Farina E. 2019. **Inceneritore di Torino: storia in 5 atti di un rapporto difficile.** Epidemiol Prev (2019); 43 (5-6):322-327.

g) Iamiceli AL, Abate V, Abballe A, Bena A, De Filippia S. P, Silvia De Luca, Fulgenzi R, Iacovella N, Ingelido A.M, Marra V, Miniero R, Farina E, Gandini M, Orengia M, De Felip E. **Biomonitoring of the adult population in the area of Turin waste incinerator: baseline levels of polycyclic aromatic hydrocarbon metabolites.** Environmental Research 181 (2020) 108903

h) Bena A, Orengia M, Gandini M, Bocca B, Ruggeri F, Pino A, Alimonti A, Ghione F, Farina E, **Human biomonitoring of metals in workers at the waste-to-energy incinerator of Turin: an Italian longitudinal study** International Journal of Hygiene and Environmental Health 225(2020) 113454 https://doi.org/10.1016/j.ijheh.2020.113454

The SPoTT Working Group, in agreement with the Technical Scientific Committee, has decided to invite the citizens, already involved in the biomonitoring study, to a further sampling, scheduled in 2020, to measure again all the pollutants already monitored in the past.

In January 2020, SPoTT-2, the second phase of the SPoTT Programme - Population Health Surveillance near the Turin Incinerator, was launched. The activities foreseen by SPoTT-2 will take place in the period 2020 - 2023 and will be divided into 10 project lines.

The SPoTT-2 Programme foresees to promptly inform all those who are interested in knowing more, making available to the population, the local health network, the world of associations, local, provincial and regional public bodies all the material produced (results as soon as available, reports of the meetings of the Technical Scientific Committee, operational protocols of the different project lines, bibliography used for the methodological choices, etc.)

1.12 Conclusions

The due and correct assessment of the health status of the population exposed to risk factors arising from incineration plants must also be made taking into account the historical evolution of the techniques, understood as available and adopted technologies and management methods implemented and/or regulated, to which this treatment is linked and therefore the reference period of the studies and assessments conducted.

All this is fully taken into account by the current regulations, both at Community and national level, through the binding and guiding regulation on waste incineration, which is particularly reflected in the introduction of best available techniques (BAT). The sector BREF documents explain, in a continuous update with technical developments, how these techniques respond to the "*most efficient and advanced stage of development of activities and their methods of operation that indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values and other permit conditions designed to prevent or, where that is not practicable, generally to reduce emissions and the impact on the environment* as a whole". It is considered a BAT because, inter alia, as recognised in the BAT reference document or 'BREF' published by the European Commission, it adopts "*the most effective techniques for achieving a high level of protection of the environment as a whole*".

The pressure and contamination factors affecting all environmental matrices come from a wide variety of activities and have multiple consequences on the environment and the populations living and working in these areas. Health consequences are also mediated by social and economic factors, which add complexity and make it difficult to know and describe how health and quality of life are affected, positively and negatively, by the concomitance of these activities. All of these factors can lead, to widely varying degrees, to strong environmental pressures and important risk factors with multiple residential, occupational and para-occupational exposures.

Very often it happens that, in such contexts in which among the activities in question may be present also that of a waste incinerator, there is a tendency to attribute to the waste incineration the predominant negative role on the health of the population living there.

It is scientifically recognised that concerns about the potential health effects of incinerators due to pollutants potentially present in emissions such as heavy metals, dioxins and furans are due to **older generation plants and management techniques in place before the second half of the 1990s**. Most of the studies carried out in reporting periods **prior to 1996** also concern older generation incinerators, some of which were poorly operated and therefore in some cases had high emission levels.

As pointed out by the WHO, documents dealing with the health effects of active incinerators in the period **1969-1996** consistently report a detectable risk of certain cancers (stomach, colon, liver and lung) in populations living in the vicinity. Studies showing the occurrence of non-Hodgkin's lymphomas and soft tissue sarcomas were inconsistent.

Also according to the WHO, emissions from incinerators have changed a lot over time. This has led to a change in health impacts, and it is difficult to make general considerations on health effects without taking into account the different reporting periods of the survey and the different types of incinerators analysed (old generation plants versus new generation plants). The emissions from modern incinerators are quite different in both quantity and composition, thanks to modern techniques.

According to available studies, in general, a well-designed and well-managed incineration plant, especially one of recent design (from the 2000s onwards) emits relatively small amounts of pollutants and contributes little to environmental concentrations and, therefore, there is no evidence that it poses a real and substantial health risk.

Another issue that emerged from the evaluation of the accredited studies conducted, especially prior to 2010 and referring to plants built and operated before the end of the 1990s, is that there are doubts about the effectiveness in assessing the epidemiological side effects in relation to the number of studies conducted, the time of investigation and the methods used. This evidence has made the scientific and health world aware of the fundamental need to identify a methodological approach that would then allow the various studies to be correctly evaluated and compared with each other, which has mostly been adopted in subsequent studies characterising the investigative work on new generation incinerators.

Consideration should also be given to the role and activity of several new-generation plants currently operating in Europe (e.g. the Copenhill plant in Copenhagen, DK) and in Italy (e.g. the Gerdibo plant in Turin), the aim of which was to set up a surveillance system to assess the adverse health effects of environmental pollution in the areas surrounding the waste-to-energy plant, which does not play the same role in other plants.

In conclusion, the most recent studies are the most appropriate to provide evidence of the actual impact of currently operating waste incinerators on human health and the environment and therefore support the conclusions that for BAT-compliant waste incineration plants, which comply with the waste incineration legislation and consequently also with the established emission limits, there are no waste incinerators that should be considered as risk factors for cancer or adverse effects on human reproduction or development, as also testified and confirmed by a recent study published in Great Britain in 2019 (REF 12). The following factors contribute to support these conclusions:

- the emission levels of the latest generation of plants in developed countries are many orders of magnitude lower than those of plants operating in territories where epidemiological studies have identified negative associations in terms of health;
- risk assessment studies indicate that most of the exposure is via the diet and not via a direct route such as emission;
- the measurement of dioxin levels in the population living in areas close to incineration plants did not show higher levels than those found in a population living in areas not affected by these plants.

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