WASTE-TO-ENERGY POWER PLANTS

Preface

With this document ***MGM Engineering & Contracting*** wishes to provide a brief overview on the advantages that waste-to-energy solutions can offer.

What is Waste-to-Energy

Waste-to-Energy (WTE) is the sum of processes that produce electric energy from controlled waste incineration. Nowadays it has also become a safe and favourable form of energy recovery from the environmental point of view.

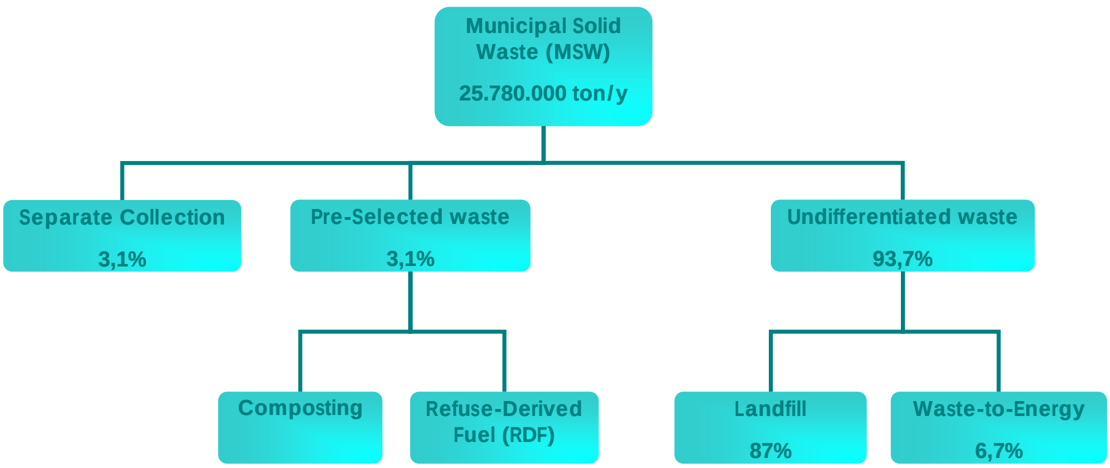
As such, it is currently regarded as an essential element in the mechanism of integrated waste management, in all industrialized Countries. In Italy too, after some 10 years of stasis, this energy recovery method is reporting a strong revival.

The new trend is supported by the safety granted by modern WTE technologies in terms of environmental impact, and so also in terms of effects on the population living in the surroundings.

Waste management in Italy

Every year in Italy, 25 million tons of Municipal Solid Waste (MSW) are produced. The resulting yearly average waste production of an Italian citizen is about 450 kg, more than one kilogram per day.

Such waste is almost completely disposed of in landfills: the percentage of waste separation aimed at recycling, composting or energy recovery is still totally negligible.



This situation definitely sets aside Italy from the rest of Europe, where percentages are reversed, as a matter of fact: the majority of waste is sent to WTE plants, while the rest is stored in landfills.

If Italy were to level up to other European countries, where about 30% of waste is used in WTE plants (Denmark 65%, France 42,3%, Germany 40%, Sweden 55%), recovered energy would be enough to make for 10% of the consumption of Italian families.

The role of WTE

The Waste-to-Energy philosophy, when correctly inserted into an integrated management strategy, aimed at maximizing the worth of waste, can achieve significant environmental and economical advantages.

First, it allows huge savings at the landfill: ashes and slag are a mere 10% in comparison to the original waste volume.

In WTE plants the entire energy contents of waste is recovered, save the unavoidable fraction that is lost through the flue gas, cooling devices, boiler walls and ashes.

Thanks to energy recovery, MSW can be considered a renewable energy source (as stated in law 9/1991 and 10/1991 on energy saving). Energy recovered from the waste is partially used for operating the plant itself (covering for about 50-60% of operating costs) and partially introduced in the national power grid or used in the whereabouts of the power station (for example, to heat schools or public buildings).

Energetic contents of MSW

During the last 30 years new life and consumption styles have remarkably modified the composition of MSW. The quantity of organic waste has decreased, while packaging-related waste has increased (as of now it is about 40% of the total).

Such a massive presence of packaging material, like plastic, paper, cardboard – all of which have high energy contents – has progressively raised the overall Heating Value of MSW.

The following table shows the typical composition of Municipal Solid Waste:

COMPONENT	WEIGHT %	LHV (kcal/kg)	MOISTURE %
Organic matter	31	1.000	75
Plastic and rubber	13	7.300	6
Paper and cardboard	24	2.900	30
Textile and wood	7	1.300	42
Glass and inert	8	-	-
Metal	4	-	-
Sieve scraps	13	1.200	45
TOTAL	100	2.200	40

The Lower Heating Value is nowadays close to 2.000 – 2.200 kcal/kg. When waste is being pre-selected, that is, when organic matter is subtracted and sent to composting, the lower heating value of the remaining material raises to about 3.000 kcal/kg.

Contribution of waste energetic content

The energetic content of waste is extremely important both for energetic and management efficiency in a WTE plant.

When the Lower Heating Value of waste is lower than 1.200 kcal/kg, combustion gets troublesome and it becomes necessary to take some countermeasures. One is the increase of combustion air, which has the significant disadvantage of lowering the combustion temperature and raising the volume of flue gas to be cooled, treated and evacuated in the atmosphere with all subsequent efficiency losses.

From the combustion of 1.000 kg of MSW with a mean Lower Heating Value it is possible to produce about 2.500 - 3.000 kg of steam and thus about 500 - 600 kWh of electric energy.

Chemical characteristics of waste and pollutants production

The chemical composition of waste sent to WTE plants directly effects the composition of the flue gas stream, although not with a linear correlation and depending on the way the plant is run. The following tables show the mean chemical composition of MSW and the mean concentrations of the major macro-pollutants contained.

Mean chemical composition of Italian MSW:

Water	Inerts	Carbon	Oxygen	Hydrogen	Sulphur	Nitrogen	Chlorine
25,5%	25,0%	24,2%	20,8%	3,4%	0,15%	0,50%	0,45%

Mean contents of major macro-pollutants:

Pollutant	**Concentration** (mg/kg of MSW)	**Pollutant**	**Concentration** (mg/kg of MSW)
Arsenic	0,6	Chlorobenzene	12,6
Cadmium	7,4	Chlorophenol (CP)	521,3
Chrome	215,6	Polychlorobiphenil (PCB)	79,8
Manganese	0,07	Dioxins	19,8
Mercury	247,6	Furans	2,3
Lead	161,8		
Copper	1558,3		
Zinc			

Dioxins

The generic term “dioxins” refers to a whole family of organic chlorinated compounds, namly “polychlorinated dibenzodioxins” (PCDD). 75 different compounds belong to this family, each with a different degree of toxicity depending on its chemical structure.

Dioxins are ubiquitously present in the environment. Global human exposition to dioxins has been evaluated in a daily assumption of about 120 picograms. In recent years, however, a significant reduction in the levels of environmental dioxins has been noticed, and the trend is destined to continue afterwards.

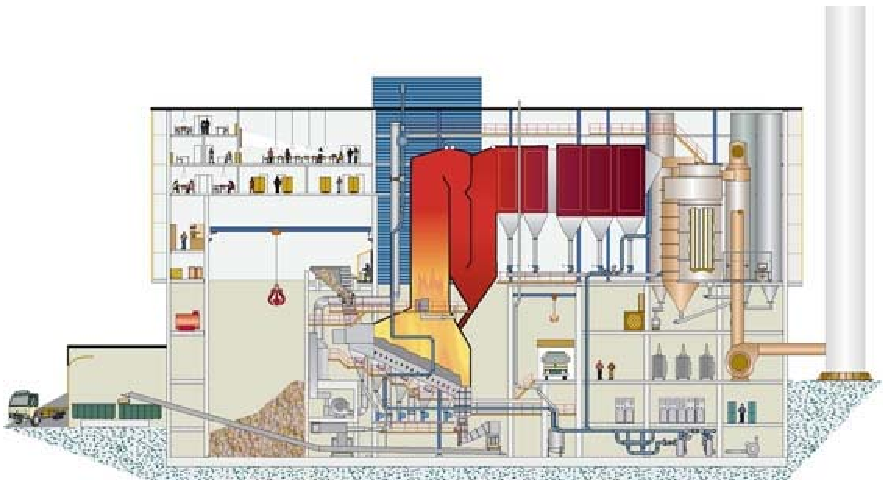
Dioxin formation from MSW combustion

Dioxins, like many harmful substances, are formed during the incomplete combustion of organic matter in presence of chlorine, either organic or inorganic.

MSW combustion leads to the formation of dioxins when temperatures are below 850°C. Dioxins are originated both from chlorinated compounds found in many types of waste (CPs, PCBs) and from carbon particles in presence of chlorine, steam, oxygen and inorganic chlorides that act as catalysers in the 200°C – 400°C temperature range.

Dioxins are already present in waste in higher quantities that those found in flue gas after combustion. This means that MSW combustion using the most recent technologies allows, as a matter of fact, to reduce the emission of dioxins into the environment.

Recent studies, based on accurate matter balances, have proved that dioxins entering the WTE plant are 40 to 100 times those released by the flue gas into the environment.



How does a WTE plant work.

Scientific studies called for by growing worries about the safety of waste combustion processes and the definition of strict emission standards have led to advanced WTE technologies, capable of ensuring adequate environmental performances.

The following paragraphs will briefly describe the operation of a typical MWS-fired, WTE power plant, built following law prescriptions for safety and emission control.

The plant is made up of the following main items: a furnace, an afterburning chamber, a heat recovery steam generator and the emission control equipment.

Combustion

Inside the furnace the combustion of MSW takes place at about 1.100 °C in modern plants. Italian laws require a minimum temperature of 950°C when chlorine content is lower than 2%. If chlorine content exceeds 2% the required minimum temperature is 1200°C.

The process itself takes place in three distinct steps:

- Waste drying and precombustion.
- Combustion of volatile substances.
- Combustion of solid remnants and final conversion into ashes.

When combustion is carried on this way, it allows the destruction of toxic substances released during the process, with an efficiency which is more than or equal to 99,9%, as Italian laws decree.

Post-combustion

Combustion flue gas produced in the furnace flows to the post-combustion chamber, where combustion processes complete, resulting in the complete destruction of organic compounds.

Italian laws set the maximum levels for various process parameters which are to be monitored and recorded in continuous. For MSW with chlorine content less than 2%:

- Free oxygen, higher than 6% in volume
- Gas temperature, higher than 950°C
- Gas speed, not less than 10 m/s
- Mean stay in the post-combustion chamber, at least 2 seconds

Energy recovery

Once through the post-combustion chamber, the flue gas enters the heat recovery boiler, where steam is produced.

Steam can be used for industrial usage (process steam), for district heating or for energy production in a steam turbine. State-of-the-art technologies can achieve net electric efficiencies up to about 25%.

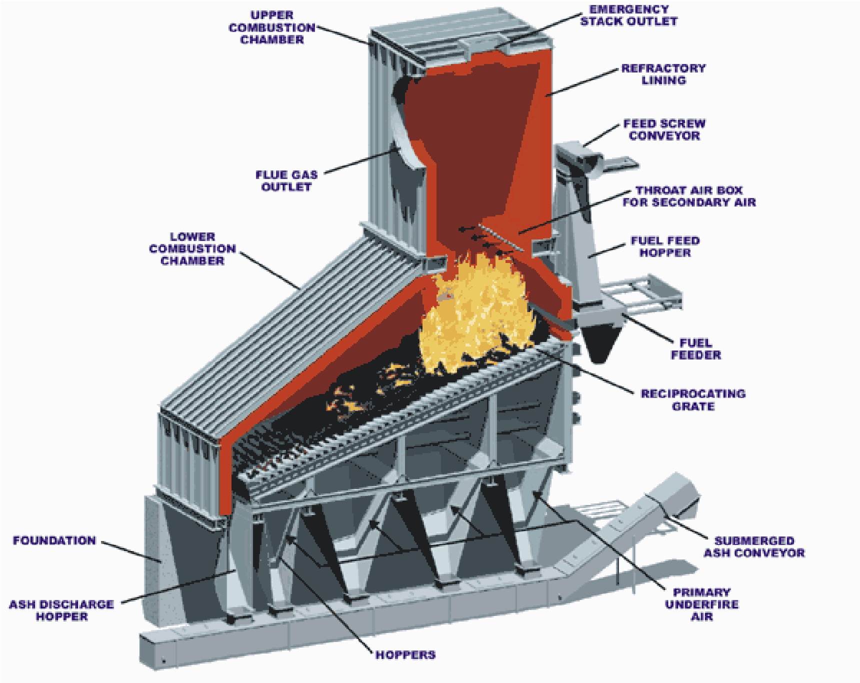
Flue gas treatment

Cold flue gas outside the recovery boiler is processed through various treatment systems, each dealing with a particular pollutant genre.

Remnants

After the combustion of undifferentiated waste, about 10-12% of the original volume (which accounts for 20-25% in weight) remains on the bottom of the furnace in the form of slag. This quantity can be lowered to 15% in weight if the dry fraction is pre-selected. Another 5% in weight is left as ashes.

All such remnants are collected and sent to landfills. However, studies are underway to make use them as road beds after detoxification.



Emission quality

Substances found in the flue gas of WTE plants (before treatment) can be classified into three groups:

Dust – Dust is made of solid-state particles (metal oxides, carbon-based particles, etc.) often referred to as "soot", upon which dioxins and other condensable micro-pollutants tend to fix.

Macro-pollutants – They are all substances present in gaseous form, like carbon dioxide and monoxide, sulphurous anhydride and hydrochloric acid.

Micro-pollutants – They are substances present in very low concentrations, such as heavy metals, organic chlorinated compounds like chlorophenols, polychlorobiphenils, dioxins, furans and aromatic polycyclic hydrocarbons (PAH).

A fraction of the stated pollutants, life for example carbon monoxide, carbon-based particles and traces of organic particles, is the result of incomplete combustion.

Another fraction is made of heavy metals (mercury) and their chlorides (like lead, cadmium).

Therefore, besides a proper management of the plant, it's necessary to resort to multi-staged flue gas treatment, depending on the physical-chemical characteristics of pollutants.

Emission reduction

One first partial step in reduction of the polluting potential is taken in the heat recovery boiler, thanks to the cooling processes that impede the formation of dioxins.

Afterwards, before being released in the atmosphere, the flue gas is treated to bring all pollutants levels below those set by environmental laws. This treatment consists of several cleaning chemical-physical operations:

Dust removal – Dusting equipment, installed on tail-end after the recovery boiler, can be of the cyclone or electrostatic kind. In the latter case flue gas temperature has to be kept under 250°C to avoid dioxin forming, which is fostered by sparks.

Once ashes are removed, the flue gas is stripped of acid components before being released in the atmosphere.

Macro- and Micro-pollutants removal – Different technologies for macro- and micro-pollutants are available: wet, semi-dry and dry.

In *dry processes*, the flue gas flows through bubblers with a solution of caustic soda. This way, hydrochloric and hydrofluoric acids, sulphur dioxide, heavy metals chlorides are all removed, while nitrogen oxides and most mercury are not. Dioxins usually condensate on soot particles and are concentrated in the sludge from the ash removal system.

After the bubblers, equipment can be installed for reducing nitrogen oxides to gaseous nitrogen by injecting ammonia or urea. Mercury is removed with a process involving sodium sulphide, while remaining dioxins are absorbed in active carbon filters.

In *semi-dry processes* an aqueous suspension of calcium hydrate is used to neutralize the acid potential in the flue gas. Calcium hydrate is effective on all gases but nitrogen oxides.

In *dry processes* the neutralizing agent is ventilated calcium oxide or sodium bicarbonate.

Emission control

Most recent technologies allow modern WTE plants to achieve emission levels that not only satisfy all current regulations on the matter of environmental performance, but also exceed them by far.

MGM experience and services

WTE plants, also combined with district heating networks, are a part of the know-how of ***MGM Engineering & Contracting***. Our experience in the field allows us perfectly tailoring investments on the customer's needs.

MGM Engineering & Contracting can offer the customers complete projects and engineering services, thanks to managers and technicians with long time proven experience in the energy area.

Consulting, engineering and expert services can be provided to energy and utility companies, municipalities and power plant investors. Fields of expertise include, integrated or separately, the following:

- Technical and economical feasibility studies
- Investment cost definition
- Owner engineering
- Conceptual and basic design
- Front-end engineering
- Detail engineering, including all related technical disciplines
- Design review
- Procurement, including purchasing, sub-contracting, expediting, inspection and logistics
- Tender evaluation, negotiation and contract preparation
- Construction management, including field supervision and testing
- Plant commissioning and start-up, including personnel training
- Project management, planning and cost control
- Proposal management and bid document preparation
- Energy audit and services
- Permits, authorizations and certifications