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# MECHATRONIC INCINERATOR FOR SOLID NON-RECYCLABLE WASTE, WITH ENERGY RECOVERY

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**Abstract**: Incineration is a non-recyclable waste heat treatment method taking place in furnaces. The incineration process generates thermal energy - steam, electric energy -if necessary, eliminating in the same time flue gas and residue-ashes are. The fumes resulting during burning are treated and recovered by filtering, so that **only fresh air** is discharged in the atmosphere. The incinerator is fully press buttoned, having many mechatronic systems capable to continuously monitoring the environment emissions, and so the incineration is one of maximum safety.

## 1. ARGUMENT

The lately technical and technological progress has led to new products, packed in various and **modern packages** made from different materials, mostly **non-biodegradable**. The resulted waste (W) behind these materials and also some special municipal waste resulted behind certain human activities, such as medical and veterinary ones – hospitals, polyclinics, surgeons or overdue medicines from drugstores, but also the municipal ones are part of the **non-recyclable waste** group.

These waste nature and characteristics, but also those of some other hazardous waste are imposing their elimination with the inside energy recovery through its use as thermal agent and electricity.

An important technology used in both non-recyclable and recyclable waste elimination is based on incineration seeing the advanced use of the waste calorific power and the performing cleaning of the resulting flue gas.

The waste incineration is done in some mechatronic equipment named as **specialized waste incinerator**.

The incineration operation is known as well as **Thermo-valorization**.

In the European standards, the incineration term is mentioned as “incineration process” with energy recovery.

## 2. SOLID UNRECYCLABLE WASTE NATURE AND CHARACTERISTICS

The first structural form of unrecoverable solid waste is based on two main groups, as it can be seen in figure 1.

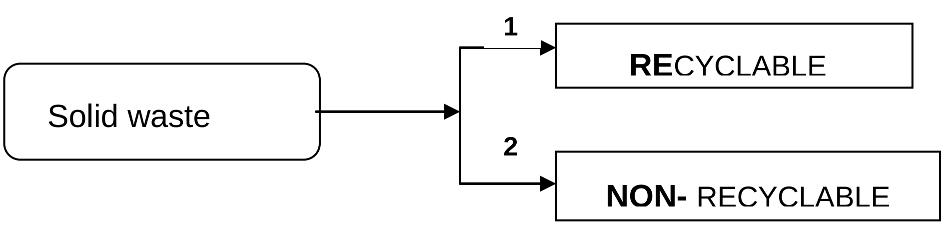


***Fig. 1. The solid waste structure***

Each group apart is divided in lots of subgroups.

The Unrecoverable Solid Waste treated through incineration is classified in some essentials subgroups (fig.2).

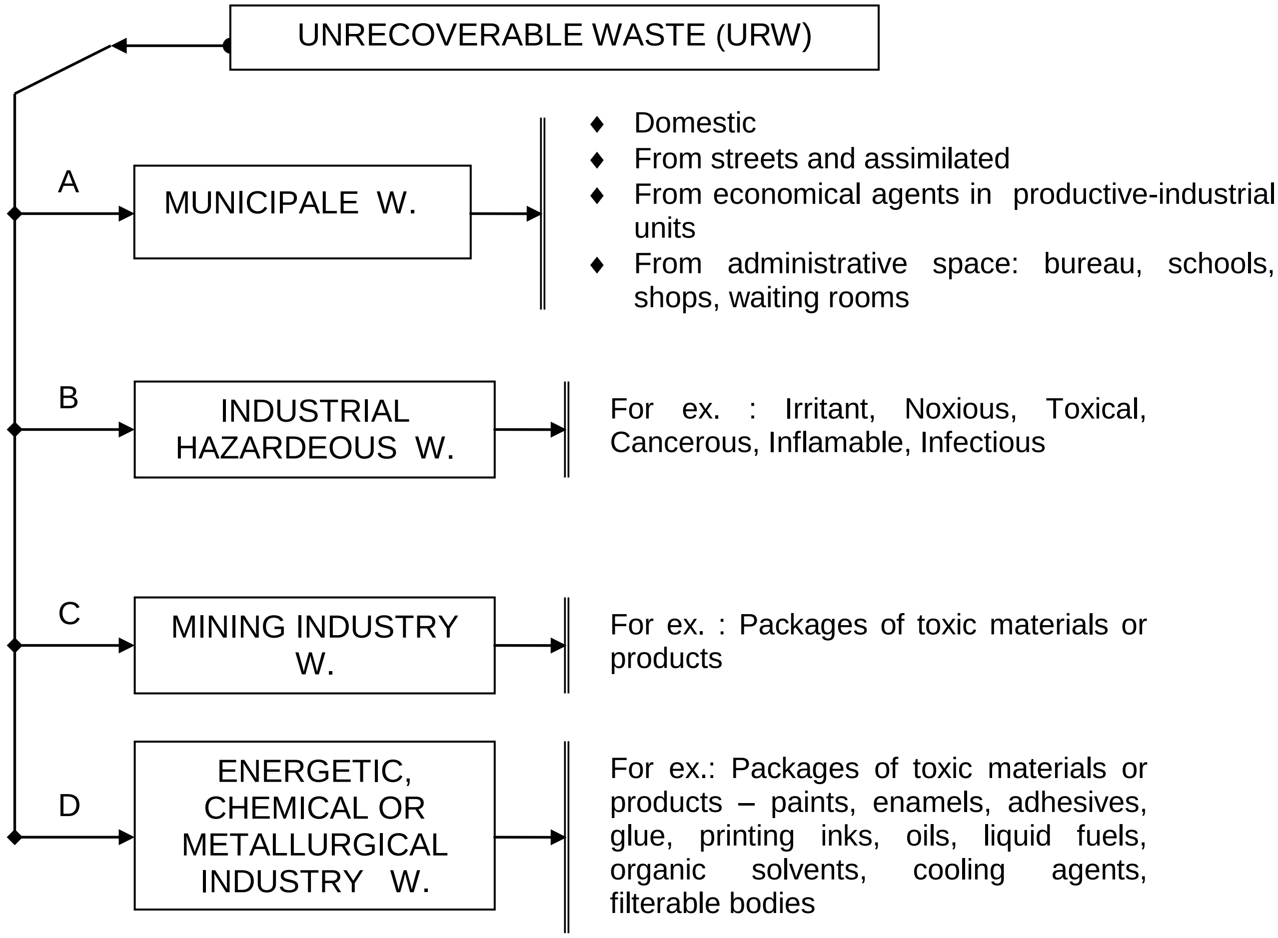


***Fig. 2. Unrecoverable waste (URW)- examples***

## 2. THE INCINERATION TECHNOLOGICAL PROCESS

The main purpose of the **unrecoverable solid waste incineration** is to recover the energy inside waste and to use it as “**alternative energy**” unlike “regenerable energy”.

The non-recyclable waste that can’t be processed or treated through burning is the **final waste**. Both in this waste case and in the **residues** resulted after burning (ashes) case the **controlled storage** solution is applied.

Due to the **technical and technological** solutions applied on the incineration equipment, this one could be placed in habitable zones also, because of the following matters:

- Keeps the Environment Rules
- Avoids the medium pollution through silenced working and lack discharging
- Assures the population’s safety and health
- The incinerator is well bordered in the environment landscape having a pleasant architectural aspect, peculiar to that emplacement zone apart

The following essential technological processes are taking place inside of the incinerator:

- **burning of waste** fed into the oven through different circuits- non-toxic and toxic waste;
- **thermal energy** generation, partially used in heating or in **electric energy** production;
- retention and treatment of **toxic substances**, **solid particles** and **acids**;
- **fumes** retention and treatment **in two steps**- dry filtering and fine filtering;
- fumes continuous **monitoring**;
- **releasing fresh air** in the atmosphere.

▪ ***Advantages*** of incineration

☞ **Reduces the waste volume,** stocked in the nowadays way, to 5% (max.10%), this one being turned into **residual materials** – ashes or slag;
☞ **Recovers the energy inside** the waste, transforming it into thermal or electric energy;
☞ The solid municipal and industrial waste can be **directly fed**, without a preliminary preselection;
☞ The slag and other materials also (such as the ashes) are **sterile** and can be recycled as filling materials in road construction
☞ Has an economic implication

▪ ***Disadvantages*** of incineration

☞ Uses spare energies when placing in operation
☞ Great investments
☞ High operating and maintenance costs

These disadvantages are specific for those incinerators having the potential waste feeding capacity **up to 100 t/day**. In case of those having higher capacity, the equipment's eco-efficiency is insured.

## 4. STRUCTURING THE CONSTRUCTIVE TYPES AND THE ESSENTIAL PARAMETERS FOR INCINERATORS

From the constructive and functional point of view, an incinerator can be characterized using a number of six defining elements which are presented in the structural scheme in figure 3.

For the two constructive groups of incinerators – the vertical and horizontal ones - some average values for the essential considered parameters are presented in table 1 here below.

NB. The great capacities are realized using two or more incinerators operating in parallel.

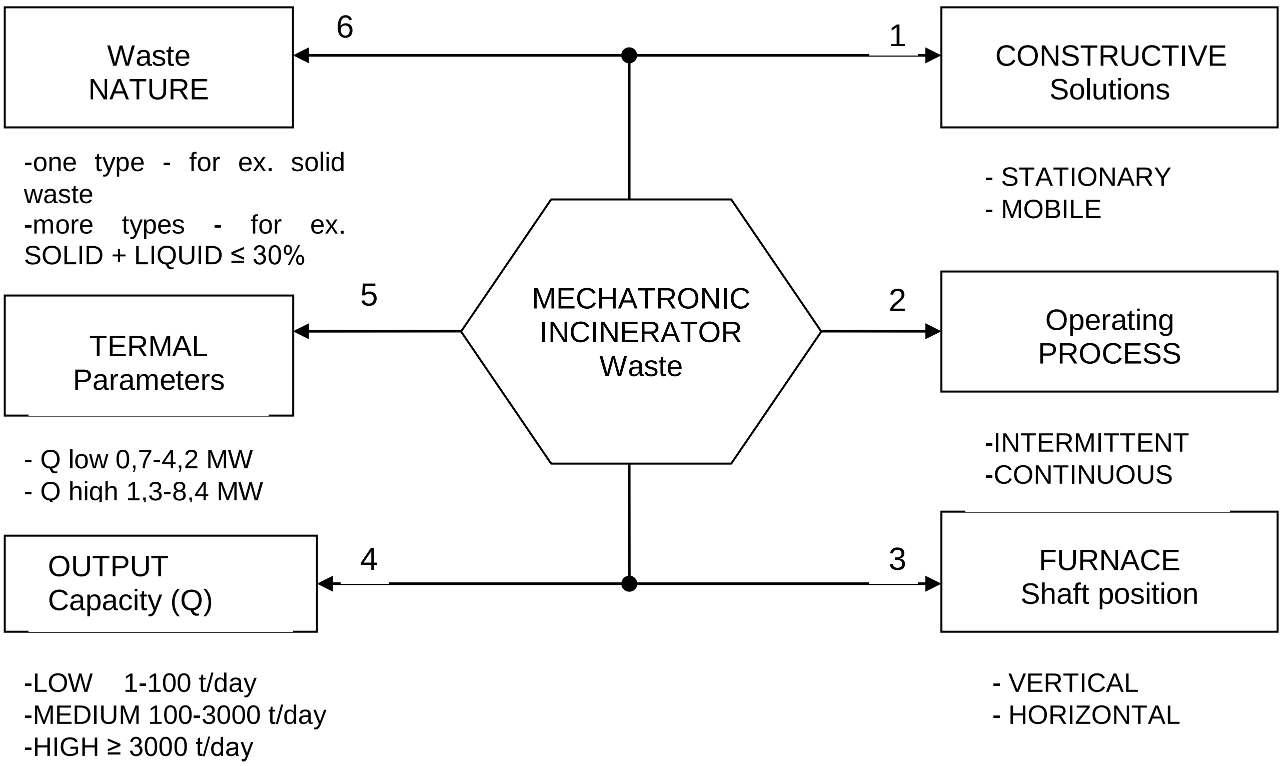


***Fig. 3. Six composing and operating characteristics of some INCINERATOR treating unrecoverable waste***

**Tab.1 Essential parameters for two types of waste incinerators**

| No. | Parameters | MU | Waste incinerators constructive type | |
|---|---|---|---|---|
| | | | VERTICAL | HORIZONTAL |
| 1 | Constructive solution: operation | - | intermittent | continuous |
| 2 | Waste type: normal and contagious | - | solid | solid, paste, sludge, liquid |
| 3 | The oven shaft | - | vertical | horizontal |
| 4 | Capacity of waste output | t/day | 1,2…10 | 7,2…24 |
| 5 | Thermal parameters | MW | 0,7…4,2 | 1,27…8,4 |
| 6 | Waste density | Kg/m$^3$ | 50…200 | |
| 7 | Heating value | MJ/kg waste | 5…40 | 1,0…45 |
| 8 | Waste moisture | % | < 30 | < 86 |
| 9 | Combustion temperatures | $^0$C | 1000…1200 | 1200…1400 |
| 10 | Operating system | h/day | 8-10; 16-20 | 24 |

## 5. INCINERATOR: CONSTRUCTIVE COMPONENTS AND TECHNOLOGIC FLOW

The waste is transported using special auto vehicles and, if possible, using the railway; it is weighted and registered and the non-toxic one is discharged in the receiving-storage hopper, and the toxic being directly discharged in the burning oven (fig.4).

Special technologic lines are used for sanitary contagious waste, lines including some belt-conveyers (3-fig.4) assuring the direct feeding of waste into the feeding device of the burning oven's burner.

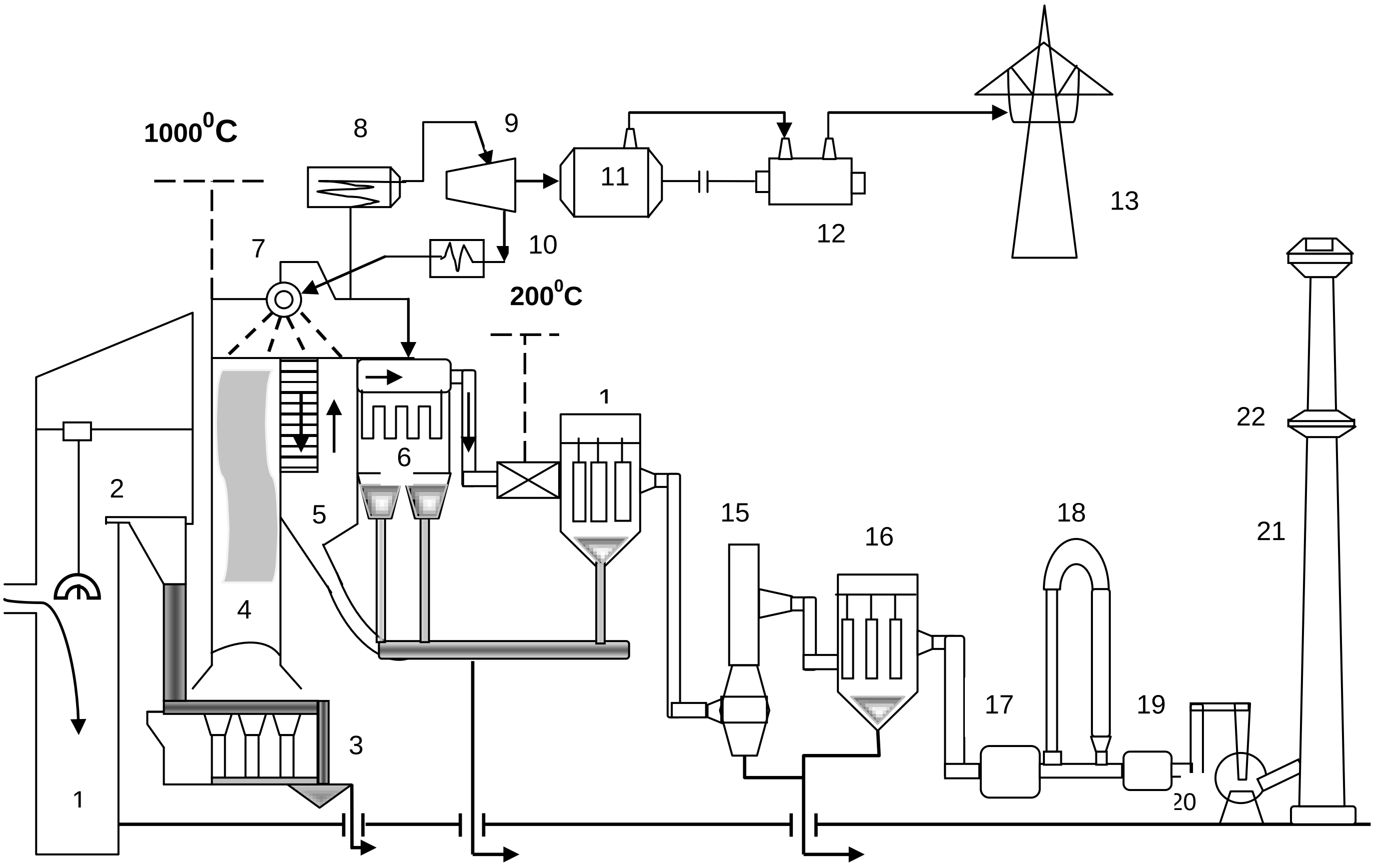


*Fig. 4. Static incinerator for continuous batch operation, vertical shaft of oven, medium capacity, solid waste. Constructive components and technological flow*

## 5.1 THERMAL AND ELECTRIC ENERGY OUTPUT

Burning the waste in the burning furnace, at temperatures around 1000…1200$^0$C, some fume-gas-steam is exhausted. In the burning oven, the waste is spayed with water recirculated from the steam-turbine condenser (10). The produced steam is distributed in two directions: one for the necessary steam for heating the spaces in the area (6), the other- through which the steam follows the changing circuit- heat accumulator (8)-steam-turbine (9), driving off the electric current generator in a rotary motion (11) at **0,4 kV** stress, value necessary to feed the area of supply consumers . If it is necessary, a stress lifting-transformer is able to raise the stress value to 6 kV (LEC) or even 20 kV (LEA).

## 5.2 FUMES CLEANING

The fumes resulted after waste burning are completing **oxidation process** in the post-combustion chamber (5) and are **treated with urea** in order to diminish **nitrogen oxides**. This way we can assure the **polluting organic micro particles destruction**.

The fume and a part of the steam quantity that are released in the waste burning process, goes through two groups of dry filters –one for **primary filtering** (14), and the other for **fine filtering** (16). One group has vertical plug-filters, in a cylindrical shape, bag type, the texture being from Teflon alloy, extremely resistant. Such group is made of more than 1000 of plug-filters, ranged in several lines. Between the two groups of filters, the fume passes through a vessel of wet filtering (15). The plug-filters filtering medium is mainly made of hydrated gypsum and active carbon. The plug-filters **capture the powder compounds** which, after cleaning the plug-filters using a vibratory process, are collected on belt-conveyers and conducted in reaping pools; here, the powder compounds are treated for **destroying the polluting acids** through a deposition and elimination process.

Between the two filter batteries, the fume passes through some wet treatment recipient (15), in two stages: inferior acid stage and superior basic stage. The **acid gas residues** and **the heavy metals** are destroyed at this level- mainly the mercury and the plumb, purpose for which the **sodium tetrasulfide** is added.

♦ Getting out from the washing towers, the fumes are entering in the area of dry treatment using electro filters. This system contains baking soda and active carbon to eliminate the hydrochloric and hydrofluoric acids, having high efficiency on sulphur compounds. The filter is periodically shacked to permit the powders to fall into a funnel, wherefrom they are transported on a belt conveyor to a collecting basin.

♦ Then, the fumes are passing through the primary heat exchanger (17) where a certain step of heat is attained.

♦ After, the fumes are passing through a scrubber – catalytic denitrification (18), where some ammonia is injected in a aqueous solution for cooling.

♦ In order to avoid the condensing, the fumes are passing forwards through another heat exchanger (19) where their temperature is raised.

♦ The air fan (20) ventilates and evacuates the fumes at temperatures up to 120-140$^{0}$C through the stack for fresh air discharging which is around 60*m* high (21), the fumes being monitoring all the time (21).

♦ The residual waters resulted in during the technological process are purified.

♦ The residue-ashes are transported into a controlled deposit of final waste.

## 6. MECHATRONIC SYSTEMES CONTROLLING THE INCINERATOR

The construction of the ecological waste incinerator is completely press buttoned. The equipment's board panel is automatically and continuous monitoring a great number of quantitative and qualitative parameters.

Essential mechatronic components.

- ♦ The metals magnetic separator used for removing the eventual different metal pieces in waste
- ♦ Automatic weighing machines used for quantitative waste reception
- ♦ Automatic systems for temperature measurement- some functioning at long-range order:
  - burning oven; - combustion chamber ; - heat exchanger-accumulator; - battery of primary filtering; - wet treatment equipment; - battery of fine filtering; - heat exchanger; - stack for fresh air discharging
- ♦ Systems for pressure measurements at:
  - air turbine
  - tubes feeding the area with thermal energy
  - air fan
- ♦ Batching system for chemical and physical addition components: baking soda, active carbon, hydrochloric and hydrofluoric acids, nitrates a.s.o.

♦ Systems for electric parameters measurements –stress, power, intensity- at:
- electric generator
- electro filters

♦ Systems for measuring carbon dioxide ($CO_2$)
♦ Apparatus system for continuous monitoring of air dropped out from the incinerator's tower (22, fig.4).

## 7. CALCULUS ELEMENTS

In order to define the definitive elements regarding the operation and efficiency of the waste incinerator, a temperature diagram is presented below and also two formulae determining the waste incineration energetic efficiency.

### 7.1. THE PROCESS DIAGRAM FOR INTERMITTENT BURNING

The process diagram is referring to vertical burning furnaces operating in stand fast position. Four main temperature zones are focused: combustion, post-combustion, fume-gas cooling - after using their heat in the steam generation process, filtering-disposal gas (fig.5) [5].

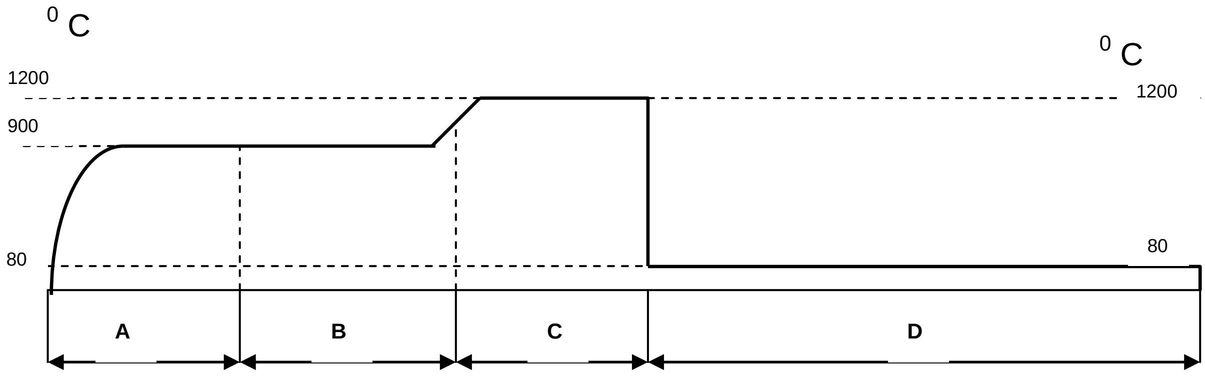


***Fig. 5. Process diagram: intermittent burning; burning oven in stand fast; A - combustion zone 80-1000$^0$C; B - post-combustion zone 1200$^0$C; C - fume-gas cooling zone 1200-200$^0$C; D - gas filtering-disposal zone 200-140$^0$C***

### 7.2 THE ENERGY EFFICIENCY OF WASTE BURNING

The energy efficiency is calculated using an expression, for simplicity referred to as the **R1-formula** (**MSWI**=Municipal Solid Waste Incinerator), scheduled in the Directive 2008/98/EC**, WFD** (Waste Framework Directive) [3].

- The energy efficiency ($\varepsilon_c$) for the annual energy produced ($E_p$) as heat ($E_{pc}$)

$$\varepsilon_c = \frac{\lfloor \kappa_2 \cdot E_p - (E_f + E_i) \rfloor}{\lfloor \kappa_1 \cdot (E_w + E_f) \rfloor} \quad (1)$$

- The energy efficiency ($\varepsilon_e$)for the annual energy produced ($E_p$) as electricity ($E_{pe}$)

$$\varepsilon_e = \frac{\lfloor \kappa_3 \cdot E_p - (E_f + E_i) \rfloor}{\lfloor \kappa_1 \cdot (E_w + E_f) \rfloor} \quad (2)$$

where: $E_p$ is for the annual energy produced as heat or electricity, in *GJ/year*

$E_f$ -the annual energy input to the system from fuel contributing to the production of steam, in *GJ/year*

$E_i$ - the annual energy imported excluding $E_w$ and $E_f$ , in *GJ/year*

$E_w$ - the annual energy contained in the treated waste, calculated using the net caloric value of the waste, in *GJ/year*

$\kappa_1$ - multiplication coefficient accounting the energy losses due to bottom ash and radiation; $\kappa_1 = 0{,}97$

$\kappa_2$ - coefficient multiplication $E_p$ for heating

$\kappa_3$ - coefficient multiplication $E_p$ for electricity

The revised WFD now specifies that the incineration facilities dedicated to the MSW can be classified as R1 only where their energy efficiency is equal or above:

- 0,60 - for installations in operation and permitted in accordance with applicable Community legislation before the 1st January 2009;
- 0,65 – for installation permitted after the 31st December 2008.

## 8. THE SITUATION IN ROMÂNIA

- In **Slobozia,** an **Ecological waste incinerator** is in train to be built, authorized to finally eliminate the hazardous and non-hazardous waste – PROAIR CLEAN [2]
- At **Glina-Bucharest**, the waste water purification station, the construction of an **incinerator for sludge remained after waste water purification** is foreseen.

## 9. CONCLUSIONS

- The incinerator is fully press buttoned
- The garrison is specially qualified in the equipment's and hazardous material's operating, being periodically verified and certified.
- The technological process and the environment emissions are continuously monitoring (the gas performance cleaning)
- The incineration is realized in maximum safety conditions
- The even application of legislation and specific working procedures, proper to the European Community
- The waste volume minimization
- The destroying of hazardous bio-degradable components

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