



**EUROPEAN COMMISSION**  
DIRECTORATE-GENERAL  
ENVIRONMENT

**GUIDELINES**  
**ON THE INTERPRETATION OF THE R1 ENERGY EFFICIENCY FORMULA FOR**  
**INCINERATION FACILITIES DEDICATED TO THE PROCESSING OF**  
**MUNICIPAL SOLID WASTE ACCORDING TO ANNEX II OF**  
**DIRECTIVE 2008/98/EC ON WASTE<sup>1</sup>**

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<sup>1</sup> Directive 2008/98/EC on waste and repealing certain Directives – OJ L 312, 22.11.2008, p. 3.

## Foreword

The new Waste Framework Directive, which since 12 December 2010 has to be applied by all Member States, marks a shift away from thinking about waste as an unwanted burden to seeing it as a valued resource. The Directive establishes a straightforward five-step waste hierarchy as a priority order for Member States decisions on waste policies and legislation. Waste prevention is regarded as the most desirable option, followed by preparing waste for re-use, recycling and other recovery, including energy recovery, with disposal (such as landfill) as the last resort. When applying the waste hierarchy, EU Member States shall encourage those options that deliver the best overall environmental outcome over the whole life-cycle of products and services.

Recycling of waste by reprocessing it into new products can make the most efficient use of the resources contained in waste. Where waste recycling is not the environmentally preferable option, technically not feasible or economically not viable, waste should be used to generate energy. The new Waste Framework Directive promotes production of energy from waste. With the so-called R1 Formula<sup>2</sup>, it has introduced an incentive for municipal waste incinerators to contribute to the energy supply for industries and households. Municipal waste incinerators meeting or exceeding the energy efficiency thresholds of this formula can be classified as facilities for the recovery of energy from waste according to the waste hierarchy.

This guidance is intended to help the authorities in the Member States to interpret and apply the R1 Formula. It could also be used as a reference by economic operators, as they will have to comply with the national laws transposing the Directive. The guidance has been developed together with experts from Member States, industry and NGOs. It reflects the views of the Commission, and as such is not legally binding; binding interpretation of EU legislation is the exclusive competence of the Court of Justice of the European Union. The guidance is a living document and as such may be revised according to experience with the implementation in the Member States and further development of European waste management policy.

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<sup>2</sup> Annex II, footnote (\*) of Directive 2008/98/EC

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The following abbreviations for pertinent legislation are used in this document:

Legislation/Guidance	Abbreviation
Waste Framework Directive 2008/98/EC	WFD
Directive on the incineration of waste 2000/76/EC <sup>3</sup>	WID
Directive concerning integrated pollution prevention and control 2008/1/EC <sup>4</sup>	IPPC Directive
Directive 2010/75/EU on industrial emissions <sup>5</sup>	IED
Waste Shipment Regulation (EC) No 1013/2006 <sup>6</sup>	WSR
Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration, from August 2006 <sup>7</sup>	BREF WI

<sup>3</sup> OJ L 332, 28.12.2000, p. 91; repealed by 7 January 2014 by Directive 2010/75/EU.

<sup>4</sup> OJ L 24, 29.1.2008, p. 8; repealed by 7 January 2014 by Directive 2010/75/EU.

<sup>5</sup> OJ L 334, 17.12.2010, p. 17.

<sup>6</sup> OJ L 190, 12.7.2006, p. 1.

<sup>7</sup> [ftp://ftp.jrc.es/pub/eippcb/doc/wi\\_bref\\_0806.pdf](http://ftp.jrc.es/pub/eippcb/doc/wi_bref_0806.pdf).

## 1 Introduction

These guidelines are destined to provide legal certainty and a level playing field in the application of the energy efficiency thresholds for municipal waste incinerators in Annex II of Directive 2008/98/EC on waste (Waste Framework Directive - WFD).

The new WFD has introduced a **five-step waste hierarchy as a priority order** with waste prevention at the top followed by preparing for re-use, recycling, other recovery including energy recovery and waste disposal as the last resort. The Directive allows municipal waste incinerators to be classified as recovery operations provided they contribute to the generation of energy with high efficiency to promote the use of waste to produce energy in energy efficient municipal waste incinerators and encourage innovation in waste incineration.

In this context, it is important to note that “recovery” means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy (Art 3 (15) of the WFD).

The non-exhaustive list of recovery operations presented in Annex II of the WFD defines R1 as a recovery operation which is understood as “*Use principally as a fuel or other means to generate energy*”. It is clarified in footnote (8) that this includes incineration facilities dedicated to the processing of municipal solid waste (MSW) only where their energy efficiency is equal to or above:

- 0.60 for installations in operation and permitted in accordance with applicable Community legislation before 1 January 2009,
- 0.65 for installations permitted after 31 December 2008,

using the following formula:

$$\text{Energy efficiency} = \frac{E_p - (E_f + E_i)}{0.97 * (E_w + E_f)}$$

In which:

$E_p$  means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2.6 and heat produced for commercial use multiplied by 1.1 (GJ/year)

$E_f$  means annual energy input to the system from fuels contributing to the production of steam (GJ/year)

$E_w$  means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)

$E_i$  means annual energy imported excluding  $E_w$  and  $E_f$  (GJ/year)

0.97 is a factor accounting for energy losses due to bottom ash and radiation

In addition, Annex II of the WFD highlights that this formula shall be applied in accordance with the Reference Document on Best Available Techniques for Waste Incineration (BREF WI).

The “R1-formula” is not strictly speaking an expression of efficiency in physics, but a performance indicator for the level of recovery of energy from waste in a plant dedicated to the incineration of municipal solid waste (MSWI). The practical impact of this provision will have to be monitored in future and the R1 formula may be revised in 2014 in accordance with the provisions of article 37(4) of the WFD, and if necessary to keep it up to date with technological progress.

For historical development of the formula and its link to the Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration from August 2006 (BREF WI) see Annex 1.

For better readability, this document specifies major topics in specific thematic areas in shaded boxes and summarises the major elements of guidance in boxes at the end of each chapter.

It should be noted that this guidance only reflects the opinion of the Commission services and is not legally binding. A final binding legal interpretation of EU legislation can only be provided by the Court of Justice of the European Union. This guidance is without prejudice to the position the Commission might take should related issues arise in a procedure before the Court of Justice.

## **1.1 Scope of the Energy Efficiency Formula**

Annex II, footnote (\*) of the WFD clearly restricts the scope of the formula to “incineration facilities dedicated to the processing of municipal solid waste” (MSWI). The WFD should, pursuant to its recital 20, clarify when incineration of (MSW) is energy-efficient and may be considered as recovery operation.

*Waste incinerators dedicated to the incineration of municipal waste are waste incinerators which have the permit and are technically designed in a way so that they are capable to incinerate mixed municipal solid waste.*

*The R1 formula does not apply to co-incineration plants and facilities dedicated to the incineration of hazardous waste, hospital waste, sewage sludge or industrial waste.*

Installations shall correspond to the IPPC activity 5.2. “Installations for the incineration of municipal waste (household waste and similar commercial, industrial and institutional wastes) with a capacity exceeding 3 tonnes per hour” (it should be noted that the capacity limit in this context is not applicable in the context of the R1 formula). However, this activity description will change under the IED, Annex I, as indicated below:

- 5.2 Disposal or recovery of waste in waste incineration plants or in waste co-incineration plans:
  - (a) for non-hazardous waste with a capacity exceeding 3 tonnes per hour;
  - (b) for hazardous waste with a capacity exceeding 10 tonnes per day.

In the context of IED, installations dedicated to the incineration of municipal waste shall correspond to a sub-sector of activity 5.2 recognizing that: (1) only if the facility is dedicated to the incineration of municipal solid waste will it fall within the R1 energy efficiency thresholds of the WFD and (2) that the R1-formula does not apply to co-incinerators.

Municipal waste is classified in chapter 20 of Commission Decision 2000/532/EC on the list of waste. Usually, MSWI are installations permitted for the incineration of 'mixed municipal waste'. Mixed municipal waste is defined in Art 3(3) WID as waste from households as well as commercial, industrial and institutional waste, which because of its nature and composition is similar to waste from households, excluding separately collected fractions of recyclable waste.

In addition, other waste streams can be accepted by MSWI if listed in the permit for the IPPC category 5.2, if applicable, or the permit according to WID. Authorization of any waste input, except for mixed municipal solid waste, shall be in line with the BREF on waste incineration and with the waste hierarchy (Art 4 WFD).

In practice, the waste input into a MSWI is made of different mixed and heterogeneous fractions which are blended before feeding the hopper in order to optimize the combustion process.

The calculation of the R1 formula shall be done on the waste composition which is actually incinerated in a facility, not only on the part of the waste which is classified as municipal waste or mixed municipal waste.

In case an incineration plant has two separate lines (one for hazardous waste and one for MSW), only the line for MSW can apply for the R1 status according to the formula.

*Non-municipal wastes can be accepted as long as specified in the permit in accordance with the IPPC and WID and the BREF document, although primarily other treatment options might be preferred. Separately collected waste fractions should be managed in line with the waste hierarchy.*

*The calculation of the  $E_w$  as a parameter for the R1 efficiency is based on the actual waste mix incinerated.*

## **1.2 Principles of self-sufficiency and proximity and the waste hierarchy**

Together with the introduction of the R1 formula, the principles of self-sufficiency and proximity have been extended from waste disposal installations to the recovery of mixed municipal waste collected from private households, including where such collection also covers such waste from other producers.

The fact that municipal waste treated in an R1-facility is to be regarded as recovered has to be distinguished from the question of whether the recovery of a certain waste in such a facility is to be seen as a waste management option with the best environmental outcome considering the waste hierarchy and taking into account life-cycle thinking (Art 4 WFD). Certain waste streams like paper, glass, plastic, and metals can be used with higher resource efficiency when they are separately collected from other municipal wastes and recycled.

According to Art 4(2) WFD, Member States should encourage those waste management options that deliver the best overall environmental outcome. For waste streams where recycling is the preferable option, this should include appropriate measures such as introduction of separate collection schemes and other measures supporting recycling, implementing recycling targets and avoiding overcapacities for waste incinerators in waste management plans. National legislation on recycling of certain waste streams might be another option.

Hazardous waste is usually treated in the most appropriate way in incinerators specifically dedicated to the treatment of hazardous waste which are not under the scope of the R1 formula.

*The principle of self-sufficiency and proximity (Art 16(1) WFD) is applies to mixed municipal waste from private households destined to incinerators that are classified as recovery. Similar waste from other producers is included when is has been collected together with mixed municipal wastes from households.*

*The waste hierarchy principle (Art 4 WFD) establishes a 5-step priority order with waste prevention as the most preferable solution, followed by preparation for re-use, recycling, other recovery (including energy recovery) and waste disposal as the last resort. According to Art 4(2) WFD, Member States should encourage those waste management options that deliver the best overall environmental outcome taking into account life-cycle thinking.*

## **2 System Boundaries for application of the R1-formula**

### **2.1 Definition of system boundaries**

The definition of system boundaries has considerable implications for the calculation of the energy efficiency, because it affects the energy streams which are to be calculated as  $E_i$ ,  $E_f$  and  $E_w$ , thus influencing the R1 factor.

WFD does not contain a definition of the compounds of an “incineration facility”, hence definitions in other relevant laws and guidance shall apply. In this context it is important to differentiate between “waste incineration installation” according the IPPC Directive and “incineration facility” according to WID.

The boundaries of a “**waste incineration installation**” according the IPPC Directive are defined by the limits of the operator’s permit. “Installation” according to Art 2(3) of the consolidated IPPC Directive means a stationary technical unit where one or more activities listed in Annex I of this Directive are carried out, and any other directly associated activities which have a technical connection with the activities carried out on that site and which could have an effect on emissions and pollution. Depending on local conditions, the “waste incineration installation” according to the IPPC Directive may simply include an “incineration facility” according to WID and its offices or other additional processes/activities, such as:

- ash processing, recovery of metals from ash, on site manufacture of products from those recovered materials,
- other waste treatment processes, such as a sorting facility, aerobic and/or anaerobic digestion facility, station for waste collection vehicles maintenance, etc.
- other activities such as sewage sludge treatment,
- classic boiler (fired with classic fuels), a complex process such as a combined cycle with gas turbine, an industrial complex.

It should be noted, however, that the IED introduces new activity descriptions for which a permit will be required. According to IED, permits issued to incinerators under IED, Annex I, activity 5.2, may also contain provisions for the other waste treatment activities listed in IED, such as Annex I, activity 5.3, given that an installation can contain more than one Annex I activity and be subject to a single permit. However, such pre and post-treatments are not included within the R1 system boundary (see section 2.2).

The “**incineration plant**” according to the WID includes the site and the entire incineration plant with all incineration lines, waste reception area, storage, on-site pre-treatment facilities, waste fuel and air supply systems, waste incineration furnace/combustion chamber(s), boiler(s), a cleaning system for incineration flue gas, and on-site facilities for treatment or storage of residues and water as well as the stack. This definition is generally the same in the IED.

In line with the description in the related BREF Document (Annex 10.4.1, figure 10.14), **the R1 system boundaries** shall comprise only the essential parts of the incineration and energy recovery process. This includes the combustion chamber(s) and boiler(s), the flue gas treatment system, energy transformation and recovery equipment such as heat exchangers and turbine generator set, as well as all electrical systems (e.g. pumps, motors, fans, compressors, trace heating, control systems, etc.) and heat consuming systems needed for their proper functioning.

The inclusion of the turbine into the R1 system boundaries is underpinned by the WID requesting combined heat and power recovery from waste to the extent possible (for more details see BREF document).

The inclusion of the flue gas cleaning system gives the incentive to use also lower temperature heat, which otherwise would be wasted.

*The system boundaries for the calculation of the R1-formula are the incineration facility as defined above including incineration furnace/combustion chamber(s), the boiler(s), the incineration flue gas cleaning system and, often, energy transformation and recovery equipments such as heat exchangers feeding a District Heating (DH) or cooling network and/or a Turbine Generator (TG), see Annex 2 to this document.*

In order to ensure a correct calculation of the R1-formula, measurement points have to be established at the system boundaries. A basic illustration of system boundaries and energy flows is provided in Annex 2 to this document.

## 2.2 Pre-treatment, post-treatment, conventional boiler and combined processes

Pre-treatment, post-treatment, conventional boiler, and combined processes shall not be included in the R1-formula system boundaries.

This is justified by the fact that pre-treatment is typically not included in the permit of the installation and is not an essential part of the incineration process. It is also not included in the plant efficiency (Pl ef) calculation formula BREF document, and apart from mixing the waste and crushing or shredding bulky wastes, in general is not essential for the incineration process in MSWI. Furthermore, it is listed as separate recovery operation (R 12) in Annex II to the WFD. R 12 operation can include preliminary waste treatment operations prior to recovery including pre-processing such as, *inter alia*, dismantling, sorting, crushing, compacting, pelletising, drying, shredding, conditioning, repackaging, separating, blending or mixing.

A similar approach applies to bottom ash (post)treatment, which also is not considered in the WI BREF Document and is classified in Annex II to the WFD as R 4/R 5 operation.

Classic boilers or combined processes (e.g. if the incinerator is coupled with a gas turbine) using conventional fuels included in the installation, if any, are also not included in the R1 system boundaries, even if they are connected to the incineration facility.

## **2.3 Processes outside the scope of the incineration facility permit**

It is important to note that the R1-formula system cannot be extended outside the “incineration facility” nor the “installation” as defined by the permit; and that installations outside the responsibility of the operator are to be excluded from the R1 system boundaries, in particular because the operator has no authority there.

The technical unit used in the definition of the “incineration plant” (according to Art 3(4) WID) dedicated to the thermal treatment of wastes with recovery of the generated combustion heat, as specified in the corresponding WID permit, shall be the decisive factor as regards inclusion or exclusion of scope of a turbine for generation of electricity and their consideration in the calculation of the R1 efficiency.

Therefore, turbine generators set outside the boundary limits of the permit are excluded from the “R1-formula system”, so as are classic boilers or combined processes (e.g. if the incinerator is coupled with a gas turbine) using conventional fuels even if installed on the same site.

Existing plant permits may not be changed to include/exclude electricity production in order to reach R1 classification without corresponding plant modification.

## **3 Energy Flows and Single Factors of the Energy Efficiency Formula**

$E_w$ ,  $E_f$ ,  $E_i$  and  $E_{exp}$  must always be defined as energy flow at the system boundaries. In this context,  $E_w$ ,  $E_f$  and  $E_i$  constitute the input to the system, whereas the output from the system to third parties and/or the grid is  $E_{exp}$ .

$E_p$  as another important factor of the R1 formula is not related to system boundaries but is clearly defined by means of the formula itself.

It is important to emphasise that the R1 formula does not cover all energy flows that have to be counted for a full energy balance for the system and that the R1 formula is not calculating the boiler efficiency but is considering the part recovered and utilized from the energy generated at the boiler.

A compilation of examples of energy flows allocated to the different parameters is provided in Annex 3a to this document.

### **3.1 Equivalence factors**

Equivalence factors as specified in the calculation formula apply to electricity and heat irrespective whether produced, imported, self-consumed or taken back into the system as

return flow or backflow. No equivalence factor applies for fuels (fuel-oil, gas ...), i.e. the factor is 1.

Electricity is to be multiplied with the equivalence factor of 2.6. The equivalence factor for heat (steam or hot water) is 1.1.

The equivalence factors for electricity and heat generation which are taken directly from the BREF WI can be explained as follows:

The factor 2.6 for electricity is based on an average European coefficient of coal plants with 38%, which means an energy demand of 2.6 kWh for the production of one kWh of electricity.

The factor 1.1 for generated heat is based on an average European coefficient of heat plants of 91%.

*The factors of 1.1 and 2.6 are to be applied independently whether the energy is used outside or inside the R1 system boundary.*

### **3.2 Energy produced - $E_p$**

#### **3.2.1 Definition of $E_p$**

Annex II to the WFD defines  $E_p$  as “annual energy produced as heat or electricity”. It is calculated with energy in the form of electricity [...] and heat produced for commercial use [...].

“Produced” in this context is to be interpreted as “produced and utilized” in the meaning of the generated energy that is recovered and effectively used<sup>8</sup> or the “part of the energy generated (...) reclaimed and used”<sup>9</sup> (see) or “recovery of energy from waste” as stipulated in chapter 3.5.4, page 194 ff of the WI BREF document or BREF document (page 597). This is not restricted to the exported energy as in the “plant efficiency potential” or “output from the incineration facility” (Pl ef)<sup>10</sup> described in chapter 3.5.6 of the BREF, titled “data comparing energy required by, and output from, the installation”.

<sup>8</sup> ECJ C-228/00, para 42.

<sup>9</sup> ECJ C-458/00, para 34.

<sup>10</sup> 
$$Pl\ ef = \left( \frac{Oexp - (Ef + Eimp)}{(Ef + Eimp + Ecirc)} \right)$$

In the BREF document (page 597) the formula is given for the total specific electricity produced in correlation to the quantity of waste incinerated:  $Ne_{sp\ prod} = (Oe_{exp} + Ee_{circ})/m$ <sup>11</sup>.

This means that per quantity of waste the produced electricity is the sum of the total exported electricity and the circulated electricity divided by the quantity of waste. When this formula is applied for the total waste incinerated, it transforms to:  $Oe_{sp\ prod} = Oe_{exp} + Ee_{circ}$ .

The same sort of a formula is given in the BREF document for produced heat. By combining the electricity and heat produced, the total energy produced can be calculated. This can be written as:  $O_{prod} = O_{exp} + E_{circ}$  or  $E_p = \text{exported} + \text{circulated energy}$ .

This interpretation is confirmed by the Commission non-paper on the energy efficiency draft, issued during the negotiations of the WFD in the European Parliament and the Council, stating that “some operators suggest changing the meaning of  $E_p$  from gross amount of energy from the turbine/generator (the actual meaning in COM(2005)667) to the amount of energy actually exported to the grid”.

$E_p$  thus includes the energy (heat and electricity) recovered from waste which is exported outside the R1 system boundary to third parties or to other uses within the installation, as well as the energy which is used inside the R1 system boundary, e.g. for heating up the flue gas before the chimney, but not including energy uses influencing the steam/heat production. This distinction is necessary to avoid double-counting of energy flows and is in accordance with table 10.98 of the BREF-WI (footnote 2-4) which is reflected in Annex 3a of this guidance. In order to be counted in  $E_p$ , operators shall prove that uses within the system boundary and within the installation are state-of-the-art and technically designed and operated in line with BAT (where relevant).

Note: To be counted in  $E_p$ , a commercial use needs to be given for heat. Exported heat shall only be counted in  $E_p$  if the operator can prove commercial use by means of valid contracts with third parties. Internal heat consumption (within the permit boundaries) shall also be regarded as commercial use, as it directly replaces primary energy which otherwise would have to be purchased (opportunity cost principle). All internal uses have to be documented in the calculation form as proof of utilisation.

*In order to avoid double counting:*

- The energy of the steam which is converted into electricity in the incineration facility to generate electricity which is counted as produced electricity cannot be counted as produced heat.*
- The electricity generated by a third party using the steam from the incineration facility is not to be counted as electricity but only as produced heat.*

<sup>11</sup>  $E_{circ}$  is circulated energy, energy that is produced and then circulated so that it is used in the installation.

### 3.2.2 Transport losses, inefficient use by third parties and transformation of heat into electricity by third parties

$E_p$  is the energy produced by the incineration facility. The fact that energy is used inefficiently by third parties shall not be taken into account and shall have no effect on the R1 energy efficiency formula. The same applies in the case of energy losses due to transport of heat energy.

### 3.2.3 Backflows and return flows of generated energies

Backflows and return flows are energy flows (e.g. steam or warm water) that come back from the air- or water-cooled condensers as condensation water, from internal heat exchangers or from external customers in a closed circuit, e.g. from district heating or a power plant. Although strictly speaking not a “backflow”, fresh feed water added as make-up to compensate the blow down and water losses shall be counted with backflows.

Backflows from internal or external sources shall be deducted from  $E_p$  as they directly lower the rate of energy recovery from waste.

## 3.3 Fuel inputs - $E_f$

$E_f$  is defined as annual energy input to the system from fuels contributing to the production of steam (GJ/year).

$E_f$  includes only fuels. Fuels are “combustible non waste substances” (e.g. diesel, natural gas) compliant with the Fuel Quality Directive 2009/30/EC, used for start-up and shutdown of the incineration process, including fuels to maintain required temperatures  $> 850^\circ\text{C}$  by using auxiliary burners.

Note that the energy of all waste, including RDF/SRF (Refuse Derived Fuel) or waste (exhaust) gas, is to be counted within  $E_w$  and not within  $E_f$ . This shall apply also to waste oil, although exclusively used in a burner, due to its definition as waste and the fact that it can only be used when the legally required incineration temperature has been reached.

*During start-up, the period where fuel contributes to the production of steam (counting as  $E_f$ ) starts when the steam generator is connected to the steam grid and lasts until the legal minimum flue gas temperature (required by the legislation and/or the permit) is reached. During shut down, it lasts until the steam generator is disconnected from the grid.*

## 3.4 Other energy imported - $E_i$

$E_i$  means annual energy imported excluding  $E_w$  and  $E_f$  (GJ/year).

$E_i$  consists of electricity, other kinds of imported non fuel energy such as steam and hot water, and of the amounts of fuel used during start-up and shut down processes before connecting and after disconnecting to steam grid (i.e. that part which is not counted as  $E_f$ ), the energy for re-heating of the flue-gas for catalysts or after the flue gas cleaning systems (e.g. with gas or

oil), as well as other energies imported for the use in the “incineration facility” plant which are not used for steam production are to be counted in  $E_i$ .

Avoid double counting: The condensate (or cold water) from the condensers or backflows returned from the export of steam (or hot water) are not counted in  $E_i$ , but are to be deducted from  $E_p$ .

*Circulating heat and electricity for own uses of the incineration plant are part of  $E_p$  and are not to be counted in  $E_i$ .*

This aspect gives an incentive to incineration facilities to make use of the energy they produce (namely heat) and avoids that sophisticated flue gas treatment used to minimize air emissions (e.g. NO<sub>x</sub>) would have a negative impact on the ability to reach the R1 efficiency.

In this context it has to be underlined that own energy consumption of an incineration facilities is limited by process design and that own energy consumption as well as minimum annual energy exports are clearly specified in the Waste Incineration BREF document in BAT No. 61, 62, 63, 66b and 68 which shall be taken into consideration and reflected in the corresponding plant permits (limitations for internal use and minimum export requirements set in the BATs are listed in Annex 3b).

### **3.5 Distinction between $E_f$ and $E_i$**

Distinction between  $E_f$  and  $E_i$  has to be made for fuel used by the burner for start-up and shut down. The consumption at the burner during start-up and shut down periods is roughly 50% without steam being produced ( $E_i$ ) and 50 % with steam production ( $E_f$ ).

*Although specified separately in the calculation formula, in practice there is no need to make a distinction in imported fuel consumption between  $E_f$  and  $E_i$  because the numerator of the R1-formula requests the sum  $E_f + E_i$ . This corresponds to the totally imported energy for which data are readily available for operators.*

*The routine measurements performed by operators give direct access on the one hand to  $E_w + E_f$  and on the other to  $E_f + E_i$  which are the elements addressed by the R1-formula.*

### **3.6 Energy contained in waste - $E_w$**

Annex II of the WFD defines  $E_w$  as: “...annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)”.

This comprises all types of waste acceptable at the MSWI plant as defined in IPPC and WID (see scope of the formula). This includes secondary fuels derived from waste as long as they have not reached their end-of-waste status (Art 6 WFD).

$E_w$  has to be calculated for waste entering the R1 system boundary, which means after pre-treatment, if in place.

Analysis of individual waste samples is not a feasible determination method because the amount of waste to be sampled and the frequency of sampling for a reliable outcome would be too high.

The best method for the determination of the energy content of the waste or the net calorific value (NCV) is a calculation with proven process data over longer time periods (energy balance).

The method relies on a European standard developed for the specific case of Waste-to-Energy incinerators in relevant reference documents<sup>12</sup>. These documents describe the detailed procedure for the Acceptance Test which is performed according to the methodology and principles of the European standard EN 12952-15 once in the course of the tests on completion of the plant and during which the efficiency of the boiler is determined.

The principle of the methods is to use energy balance on the furnace and the boiler considered together as a calorimeter<sup>13</sup>. Energy inputs equal energy outputs plus energy losses (in flue gas, in bottom ash, by convection and radiation). The main energy outputs are measured during the comprehensive “acceptance test” at the beginning of the life of the incineration facility (e.g. steam flow) and the small ones are assessed. Boiler efficiency gives the ratio between the energy output and the overall energy input.

For calculation and measurement details see annex 4 to this document.

The energy coming from the waste ( $E_w$ ) is then obtained by deducting from the total energy input the energy of fuels contributing to the production of steam/hot water ( $E_f$ ) used over the same period of time.

The average NCV of the waste is obtained by dividing this waste energy input by the waste flow entering the incineration furnace/combustion chamber over the corresponding period of time.  $E_w$  is equal to the NCV by the waste flow.

Alternatively, the NCV formula given in the BREF document (chapter 2.4.2.1 and Annex 10.4.2) can be used in justified cases if the formula has been adapted to the specific installation via an initial energy balance and if recalculated to standard oxygen. According to the BREF NCV is to be measured as follows:  $NCV = (1.133 * (\text{mst waste/m waste}) * \text{cst x} + 0.008 * \text{Tb})/1.085$  [GJ/Mg(tonne) waste].

*Although specified separately in the calculation formula, in practice there is in general no need to specifically determine  $E_w$  and NCV, because the denominator of the R1-formula requests the sum of  $E_w + E_f$ , which corresponds to the total energy input to the boiler that is directly calculated by the method using the boiler as a calorimeter (see above).*

<sup>12</sup> Acceptance Testing of Waste Incineration Plants with Grate Firing System' Guideline Edition 04/2000 by FDBR. Available from FDBR in German and in English. Cahier des clauses techniques générales (CCTG) applicables aux marchés publics de travaux, Fascicule.' approved by "Arrêté du 6 mars 2008" of "Ministère de l'économie, de l'industrie et de l'emploi. Available in French from Mininstry of ecology:

<sup>13</sup> The boundary limits of the system here (furnace and boiler) are different (narrower) than the R1 boundary limits considered in the other parts of the R1 guideline document.

## **4 Qualification Procedure and Monitoring of Compliance**

Statements in this chapter are recommendations for an appropriate and harmonized procedure resulting from the discussion in the expert working group which accompanied the preparation of this guidance. Implementation and enforcement of monitoring remains the full responsibility of Member States.

The procedures for classification of municipal waste incineration facilities as either a 'Recovery operation' or a 'Disposal operation' have to ensure sufficient legal and planning security for operators.

In this context, it has to be taken into consideration that energy efficiency is largely dependent on the technical design of the facility and will only change to a limited extent during operation.

The status of a facility should be known before the waste is treated, well in advance before the treatment begins, in order to comply with the stipulations of waste management contracts.

### **4.1 Applicable factor for the classification as R1 operation**

According to Annex II of the WFD, incineration facilities dedicated to the processing of MSW can be classified as R1 recovery operations where their energy efficiency is equal to or above:

- 0.60 for installations in operation and permitted in accordance with applicable Community legislation before 1 January 2009,
- 0.65 for installations permitted after 31 December 2008,

In this context the meaning of "installations in operation and permitted" as mentioned above shall include installations that had a permit and were in operation before January 2009.

The factor of 0.65 applies exclusively for installations permitted after 31 December 2008. It does not apply for existing plants with a modification in a part of the installation, e.g. in the combustion chamber/furnace, boiler, turbine generator set or flue gas cleaning carried out after 31 December 2008. Existing plants shall have the possibility to reach the threshold by adjusting their efficiency.

Modification is understood as any measure to increase the recovery of energy from the incinerated waste by improving the process conditions or by establishing additional uses. An increase in capacity shall not be regarded as modification in the abovementioned meaning.

### **4.2 Existing plants**

For existing plants ("installations in operation"), the R1-formula shall be determined on the basis of practical annual performance data of the plant (see R1 calculation procedures below).

A plant having undergone constructive or contractual adjustments concerning the energy efficiency will follow the same procedures as a new facility.

#### **4.3 New plants**

For new plants, the R1 status shall initially be granted on the basis of the planning or construction specifications, considering the energy supply contracts and by determination of the general efficiency of the facility from an energetic view. This shall be achieved by means of a comprehensive “acceptance test”, determining the boiler efficiency made after commissioning, followed by a calculation on operational data made after one year in normal operation conditions on the basis of annual data.

#### **4.4 R1 calculation procedures**

According to Annex II WFD, the energy efficiency of the incineration facility is to be based on annual figures for energy production and energy consumption of the plant. This shall be understood as real practical performance and not as a theoretical maximized value which would not take into consideration periods of lower efficiency.

The calculation therefore shall be based on regular operation (including revisions) of the whole facility. The regular operation shall also include imperfect supply of electricity and heat because of lower demand.

The acquisition of data is made over a complete year. This is not necessarily a calendar year (i.e. the measuring period does not necessarily start on the 1st of January). The instruments and control equipment of the plant are maintained and controlled by the operator. Some data can be directly read from a counter as a sum, for instance fuel consumption and electricity produced. Some data require continuous computation and integration, for instance the energy of steam flows.

Calculation of plant performance data and therewith of the R1-formula is associated with uncertainties which, if necessary, shall be calculated following the methodology to determine the uncertainty of measured efficiency for guaranteed performance<sup>14</sup>. Therefore, when applying for R1 classification, plant operators are recommended to ensure that a sufficient safety margin is maintained between the plant efficiency and the R1 threshold.

The R1 threshold shall be regarded as satisfied on the condition that:

- R1 calculated (with measured, assessed and corrected data) minus overall uncertainty;
- R1 threshold where ‘R1 threshold’ value is 0.6 for existing plants and 0.65 for new plants.

Calculation of the R1-formula on the basis of annual input and output data shall follow the exemplary calculation format provided in Annex 5 to this document.

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<sup>14</sup> In EN 12952-15 standard, Section 10.5.1 and 10.5.2, In FDBR guideline, § 7.3.1, formulas 7.3.1-1, 7.3.1-2 and 7.3.1-3, pp. 32-33/50, English version.

#### **4.5 R1 calculation procedures for multiple incineration lines**

Multiple incineration lines are multiple facilities, and they can apply separately for the R1 status when the line(s) operate independently or the flows of each part of the plant can be clearly distinguished and calculated separately.

#### **4.6 Approval of R1 calculation and allocation of R1 status**

There are two different possibilities for initial calculation of the R1-formula.

- Calculation by the plant operator (with external control),
- Calculation by an external certified expert or an expert from competent authorities.

The R1-formula shall be either calculated or verified by an independent third person before it is presented to the competent authority of the EU Member State by the operator of the respective facility. In a normal operating year, the formula is calculated by the operator and submitted to the competent authority together with the details of the calculation. The competent authority shall receive the calculation sheet and, if needed, can carry out controls to verify whether the R1 formula is properly used. The competent authority can also request further information or verification by an independent expert, if needed. If the performance of an existing plant at initial application for R1 status is close to the threshold, the plant operator shall demonstrate to its competent authority that the R1 threshold was met over the past three years, using the mean value over the whole period (“gliding average” using two decimal places).

The R1 status of the plant shall be formally confirmed by the competent authority on the basis of the data required to calculate the R1 value and the R1 value calculated provided by the plant operators. When the calculated R1 value is above or equal to the threshold, the competent authority issues a certificate within three months attesting that the plant complies with the R1-formula condition.

#### **4.7 Revision of monitoring results/ verification of R1 status**

The calculation of the R1-formula and the statement of maintaining the energy efficiency level have to be presented on the basis of data of the preceding year (annual performance data as indicated above). The R1 classification of a municipal waste incinerator shall be confirmed by the competent authority to the operator for the running year in writing and in due time.

In order to guarantee smooth procedures and legal security, it is recommended that the confirmation is issued within 3 months from the date of the presentation of the operator's report. It shall be valid for the period of one year following the period for which the data has been provided. The operator shall annually report on the performance of the plant by means of a reporting form similar to the one presented in annex 5 to this document. This calculation shall be based on routine operator's monitoring results and cover the quantities of waste incinerated, quantities of fuel and imported electricity/heat consumed, electricity generated, heat used outside the incinerator facility. For the additional energy flows, lump sum data based on the previous R1-formula calculation of the plant might be used. The reporting shall

be integrated into the reporting under Art 12(2)<sup>15</sup> of the WID. The report shall be made available to the competent authority not later than one month after the calculation period agreed during the initial classification or any new classification.

Due to the fact that major features of an incineration plant do not change over time, the operator's report including annual monitoring results completed by information on any structural changes that occurred in the plant during the past year (e.g. technical modification, change of customers, etc.) allows the competent authority to conduct a routine validation and check if a new acceptance test (see procedures for new installations) is necessary. If a new acceptance test is not necessary, the installation can keep its R1/D10 status.

A new comprehensive recalculation<sup>16</sup> with external control or external expert is to be repeated after a maximum of 5 years, or in case of a substantial change of the basic conditions (modification of boiler, turbine generator, heat supply contract, the flue gas cleaning system) on which the first verification was based. If necessary, or in case of doubts, the authorities have the right to send inspectors or ask for any additional calculations/measurements they need.

#### **4.8       Transitional periods, new application**

It is the responsibility of the operator of the plant to provide sufficient certainty concerning a consistent achievement of the R1 threshold, even in case of modified circumstances for the plant's operation. Thus, an operator should aim at maintaining the energy efficiency well above the R1 threshold in order to be able to compensate for a modification in the conditions of operation. However, in case where an E-parameter changes due to circumstances which cannot be influenced by the plant operator (*force majeure*, e.g. loss of industrial heat consumer, unexpected climatic conditions, breakdowns or other outage periods) and the R1 threshold cannot be met in the annual reporting, the status of the plant will not be withdrawn immediately.

In such cases, the plant operator may – on the basis of the annual performance over the past three years – provide a justified statement why the threshold could not have been met. The plant operator will then be authorized to adjust/remediate in such a manner that the efficiency ratio complies with the thresholds again until the following year. If this result is achieved, the R1 status is maintained.

In case of a long-lasting breakdown or disturbance with significant impact on the efficiency (e.g. turbine breakdown or customer's failure), after expertise and assessment of the duration of the unavailability, the operator may: (i) give up the R1 status (and inform the competent authority thereof) and recover it as soon as the breakdown or failure is fixed (and calculate the R1 value over a year starting when the incineration facility is back to normal operation conditions); (ii) continue to try to achieve the R1 threshold.

When a plant cannot reach the R1 status or loses it due to not being able to meet the threshold in two subsequent reporting years, the operator can try again to obtain the R1 status by

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<sup>15</sup> An annual report to be provided by the operator to the competent authority on the functioning and monitoring of the plant shall be made available to the public. This report shall, as a minimum requirement, give account of the running of the process and the emissions into air and water compared with the emission standards in the WID.

<sup>16</sup> Similar to an acceptance test (see chapter 4 -  $E_w$ ).

applying for a new test, after documentation of procedural changes or changed energy supply contracts.

#### **4.9 Communication on R1 status in the context of transboundary shipment**

The operator of a MSWI plant with R1 classification has to communicate the status of his plant to his clients by means of appropriate documentation (official certificate). In case of doubts, the competent authority can be asked for confirmation by other involved authorities and potential economic partners. A valid permit is a prerequisite for transboundary movement. The procedural requirements of the Waste Shipment Regulation should apply for MSWI with R1 classification as for any other facility.

## **ANNEX 1: The R1 calculation formula**

The formula in the WFD is related to the plant efficiency formula (Pl ef) in the "Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration", from August 2006 (hereinafter referred to as BREF document), Annex 10.4.5, as described hereinafter.

$$\text{Pl ef} = (O_{\text{exp}} - (E_f + E_{\text{imp}})) / (E_f + E_{\text{imp}} + E_{\text{circ}})$$

*all figures as equivalents in accordance to BREF, Chapter 3.5.6*

*E<sub>f</sub> = annual energy input to the system by fuels with steam production (GJ/y)*

*E<sub>imp</sub> = annual imported energy (Note: energy from the treated waste (E<sub>w</sub>) is not included)*

*E<sub>circ</sub> = annual energy circulated*

*O<sub>exp</sub> = annual exported energy (combined total of heat plus electricity as equivalents)*

"If the result is higher than 1: This shows that the plant minus imported energy with steam production is exporting (BREF) or producing (ECJ C-228/00) more energy than that which is required to operate the total waste incineration process"

According to the BREF document, all amounts of energy (E<sub>p</sub>, E<sub>f</sub>, E<sub>i</sub>, and E<sub>w</sub>) are declared in GJ/a or MWh/a and equivalent values are used for heat and electricity in accordance to BREF, Chapter 3.5.6. Primary fuels are taken into account without equivalent value (i.e. with a factor of 1) because no conversion of energy is connected with it.

The R1-formula can be deduced from the energy calculation formulas presented in BREF WI (Annex 10.4.4) as follows:

The denominator of the boiler efficiency by heat/steam production in correlation to the total heat/steam producing energy input, taking into account energy losses due to bottom ash and radiation or to remaining carbon content in the residues which can technically not be avoided (factor 0.97). (BREF WI Annexes 10.4.4, page 599),

$$\eta_b(97\%) = \left( \frac{E_h \text{ st boiler}}{0.97 * (E_f + E_w)} \right) * 100\%$$

was used to derive the denominator of the R1-formula "0.97 \* (E<sub>f</sub> + E<sub>w</sub>)".

The numerator of the R1 energy efficiency formula is related to the numerator of the boiler efficiency (E<sub>h</sub> st boiler). However, instead of the total thermal energy (E<sub>h</sub>/st boiler) generated by the boiler, only the energy (heat and or electricity) factually recovered - or in other words produced and utilized -from the waste, as the sum of the energy exported to third parties and the energy used within the installation forms the calculation basis for E<sub>p</sub>. The numerator of the R1 energy efficiency formula can also be deduced from the numerator of the plant efficiency (Pl ef) formula Pl ef = O<sub>exp</sub> - (E<sub>f</sub> + E<sub>imp</sub>). In contrast to Pl ef however, the recovery efficiency of an incineration plant according to the Formula in Annex II to the new WFD is based on the

energy in terms of heat and electricity factually utilized from the energy generated at the boiler ( $O_{prod}$ ) and on the energy exported from the plant ( $O_{exp}$ ). (For standardization purpose  $O_{prod}$  was changed to  $E_p$  and  $E_{imp}$  to  $E_i$ ).

*Energy efficiency =  $O_{prod} - (E_f + E_{imp}) \Rightarrow E_p - (E_f + E_i)$ . That means that the energy efficiency formula in the new WFD corresponds to the “recovery of energy from waste” as stipulated in chapter 3.5.4.1 and 3.5.4.2 (Tables 3.40 to 3.43) p. 195/196 of the WI BREF and not to the plant efficiency potential as described in chapter 3.5.6 titled “data comparing energy required by, and output from, the installation”.*

*The calculated R1-factor gives the relation between:*

- (a) the energy recovered from waste (exported energy plus internally used energy) minus the imported energy, and*
- (b) the energy from waste plus other imported energy used for steam production.*

## ANNEX 2: System Boundaries of R1-formula

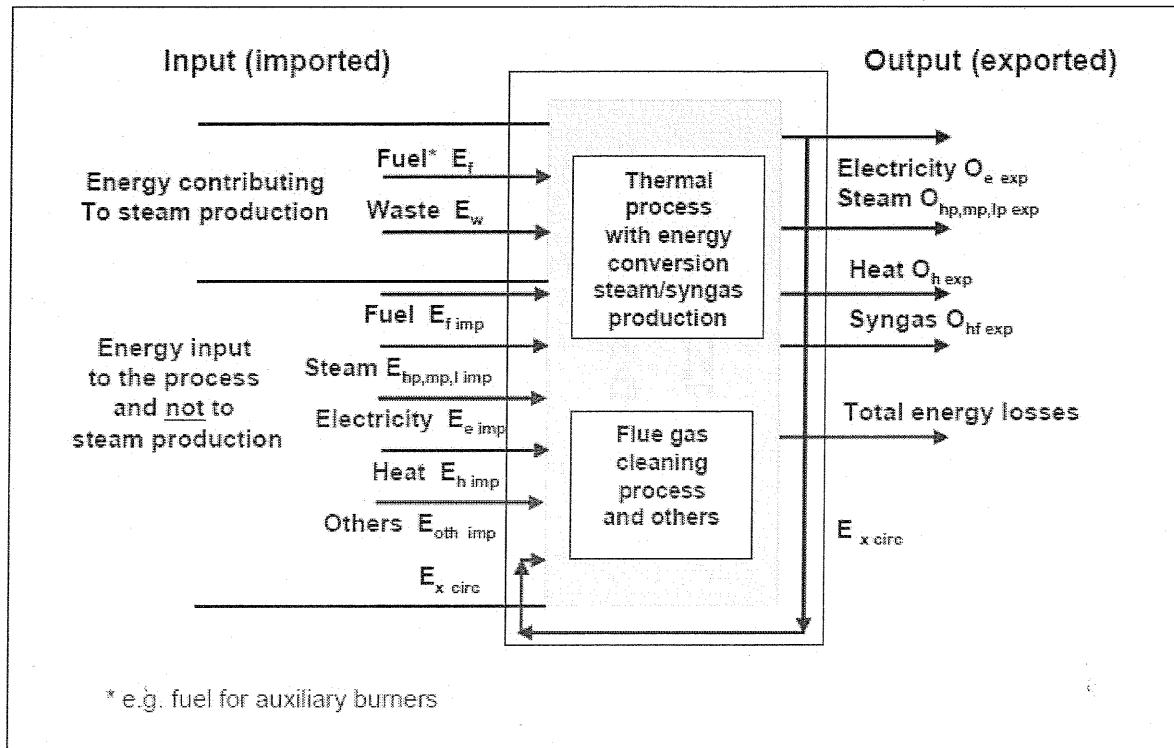


Figure 1: Energy efficiency system boundary according to BREF WI (Figure 10.14)

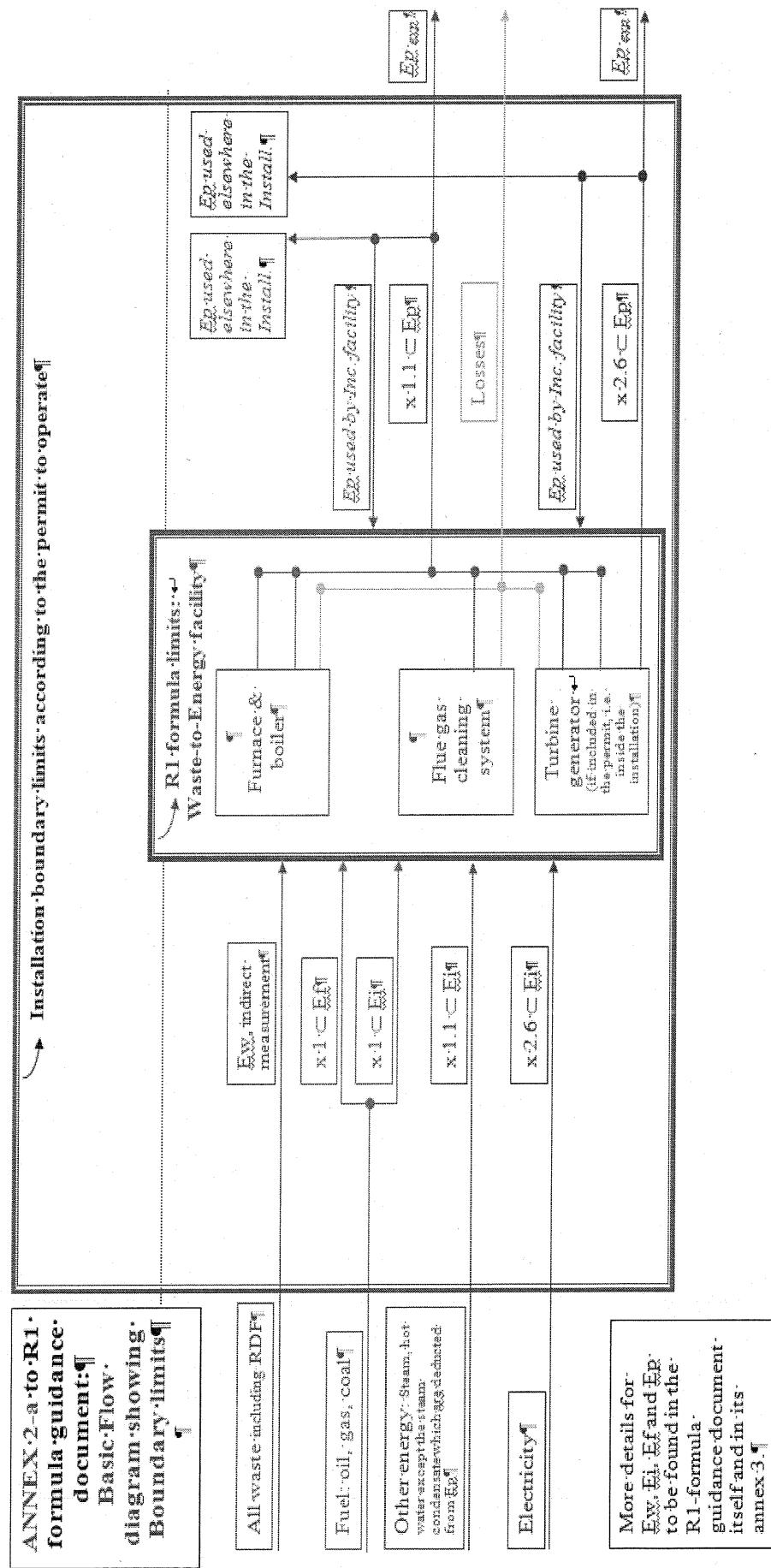


Figure 2: Distinction between R1 system boundary and permit boundary for MSWI (Source: CEWEP-ESWET-FEAD Proposal for a Guideline for the use of the R1 energy efficiency formula for incineration facilities dedicated to the processing of Municipal Solid Waste (Waste Framework Directive 2008/98/EC, Annex II, R1-formula), 30 Nov 2009.

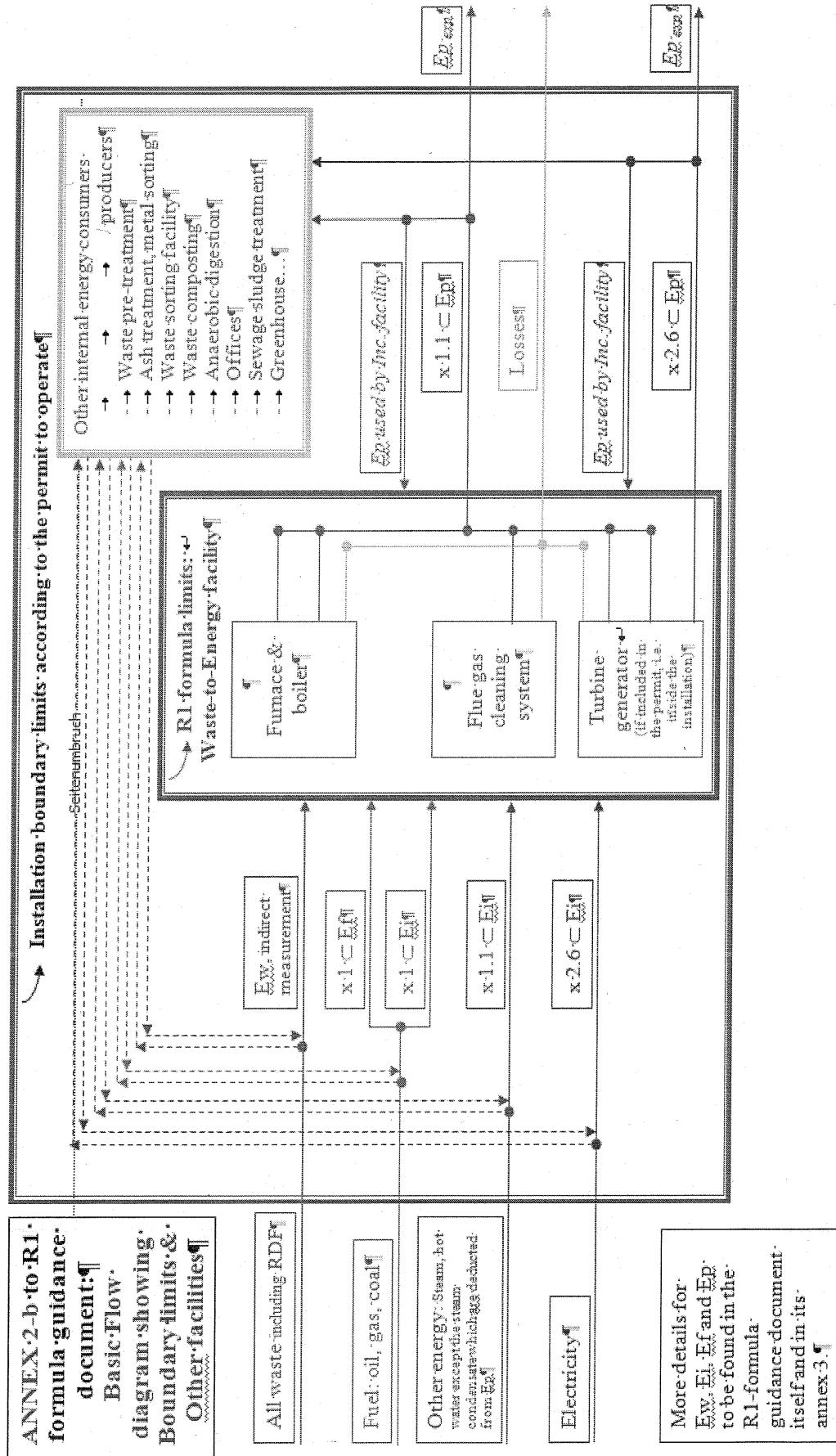


Figure 3: Other internal uses excluded from the R1 system boundary

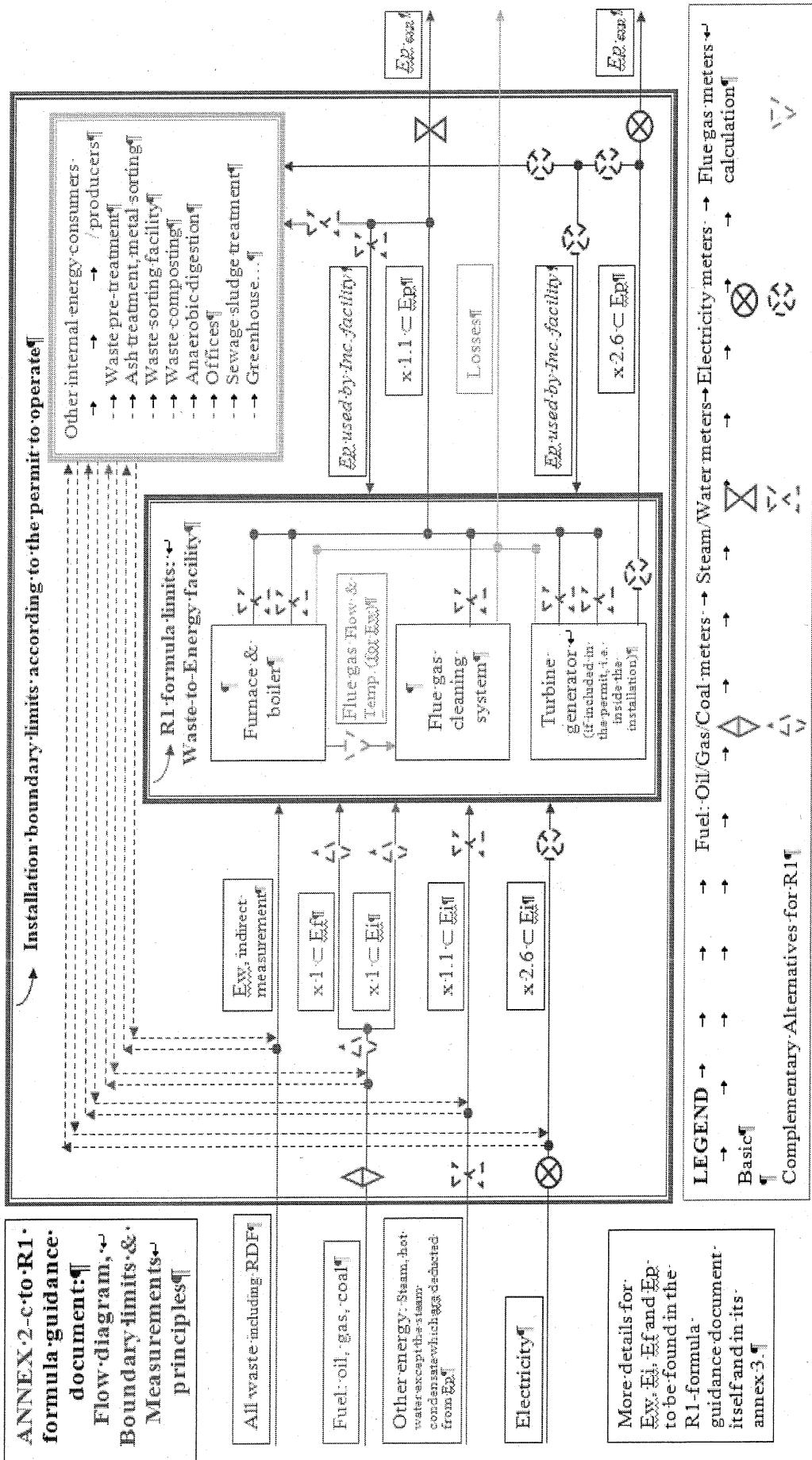


Figure 4: Position of measurement devices to determine energy flows relevant for the R1 calculation

**ANNEX 3a: Energy to be counted in  $E_p$ ,  $E_f$  and  $E_i$**

$E_p$	$E_f$	$E_i$
<ul style="list-style-type: none"> <li>• Electricity produced (self use and delivery*)</li> <li>• District heating produced (self use and delivery*)</li> <li>• Process steam produced (self use and delivery*)</li> <li>• Other types of heating (local heat, mobile heat accumulator)</li> <li>• Incineration facility self use as electricity, steam/heat are e.g. <ul style="list-style-type: none"> <li>- Energy used for evaporation or injection e.g. NH<sub>4</sub>OH injection with steam, water for cleaning purpose or waste water from wet scrubbing</li> <li>- Energy used for soot blowers</li> <li>- Steam driven devices such as pumps, compressors, vacuum pumps</li> <li>- Energy used for steam trace heating</li> <li>- Electricity used for all electrical systems (pumps, motors, fans, compressors, trace heating, control systems etc.), buildings and infrastructure (e.g. illumination, air conditioning etc.)</li> <li>- Energy used for re-heating of flue-gas (before catalytic reactor, after scrubber, before fabric filter)</li> <li>- Use of condensing energy from the steam in the flue gas</li> <li>- Heat for concentration process (salt concentration, spray drier)</li> <li>- Energy used for Apparatus, silos and buildings heating incl. warm water feed (administration, social buildings, other constructions)</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Support combustion with fuels for maintaining the minimal temperature/ incineration conditions</li> <li>• Start-up process with fuels starting when the steam generator is connected to the grid (usage of steam)</li> <li>• Shut-down process with fuels until decoupling of the steam generator with the grid (usage of steam)</li> </ul>	<ul style="list-style-type: none"> <li>• Support combustion with fuels in the start-up- and shut-down processes without connection of steam generator with the grid.</li> <li>• Imported energy for re-heating of the flue gases, e.g. with in duct burner (oil, gas) before catalytic reactor (SCR) or scrubber</li> <li>• Import of electricity (e.g. plants without turbine)</li> </ul>

\* Energy “self use and delivery” means the energy used by the incineration facility and the energy delivered inside the installation to other users as well as the energy delivered outside of the installation.

## **ANNEX 3b: Relevant BAT to limit self demand and determine export minimums**

Extract from: *Integrated Pollution Prevention and Control, Reference Document on the Best Available Techniques for Waste Incineration, August 2006*

### **Reference: 5.2 Specific BAT for municipal waste incineration**

In addition to the generic measures given in Section 5.1, for municipal waste incineration BAT is in general considered to be:

61. the location of new installations so that the use of CHP and/or the heat and/or steam utilisation can be maximised, so as to generally exceed an overall total energy export level of 1.9 MWh/tonne of MSW (ref. Table 3.42), based on an average NCV of 2.9 MWh/tonne (ref. Table 2.11) 62. in situations where less than 1.9 MWh/tonne of MSW (based on an average NCV of 2.9 MWh /tonne) can be exported, the greater of:
  - a. the generation of an annual average of 0.4 – 0.65 MWh electricity/tonne of MSW (based on an average NCV of 2.9 MWh/tonne (ref. Table 2.11) processed (ref. Table 3.40), with additional heat/steam supply as far as practicable in the local circumstances, or
  - b. the generation of at least the same amount of electricity from the waste as the annual average electricity demand of the entire installation, including (where used) on-site waste pretreatment and on-site residue treatment operations (ref. Table 3.48).
63. to reduce average installation electrical demand (excluding pretreatment or residue treatment) to be generally below 0.15 MWh/tonne of MSW processed (ref. Table 3.47 and section 4.3.6) based on an average NCV of 2.9 MWh/tonne of MSW (ref. Table 2.11).

### **Reference: 5.3 Specific BAT for pretreated or selected municipal waste incineration**

For pre-treated or selected municipal waste (including municipal refuse derived fuels) incineration BAT is in general considered to be:

66. at new and existing installations, the generation of the greater of:
  - a. an annual average of generally at least 0.6 – 1.0 MWh electricity/tonne of waste (based on an average NCV of 4.2 MWh/tonne), or
  - b. the annual average electricity demand of the entire installation, including (where used) on-site waste pretreatment and on-site residue treatment operations.
67. the location of new installations so that:
  - a. as well as the 0.6 – 1.0 MWhe/ tonne of electricity generated, the heat and/or steam can also be utilised for CHP, so that in general an additional thermal export level of 0.5 – 1.25 MWh/tonne of waste (ref. section 3.5.4.3) can be achieved (based on an average NCV of 4.2 MWh/tonne), or

b. where electricity is not generated, a thermal export level of 3 MWh/tonne of waste can be achieved (based on an average NCV of 4.2 MWh/tonne).

68. to reduce installation energy demand and to achieve an average installation electrical demand (excluding pretreatment or residue treatment) to generally below 0.2 MWh/tonne of waste processed (ref. Table 3.47 and section 4.3.6) based on an average NCV of 4.2 MWh/tonne of waste.

## **ANNEX 4: Determination of the Energy input ( $E_w + E_f$ ) and of NCV**

The ratio between the energy output and the energy input is the boiler efficiency and therefore:

$E_w + E_f = [(Energy\ of\ steam\ or\ hot\ water - Energy\ of\ feedwater) / boiler\ efficiency] - Energy\ of\ combustion\ air,$

Physical quantities required and related instruments:

- Steam or hot water flow and enthalpy (Flow meter, Pressure, Temperature) at boiler outlet (usual location; can be adapted if more favourable location elsewhere).
- Steam flows and enthalpy (F, P, T) extracted before the main steam flow meter if any, e.g. from the drum if the unit consuming it is external to the 'calorimetric system' boundary limits and if these flows cannot be calculated from design data parameters or lump sum values be agreed.
- Feedwater flow and enthalpy (Flowmeter if flow not calculated, Temperature), usually at economizer inlet.
- Sensible heat of primary and secondary combustion air. This can be taken from the Acceptance Test or a lump sum value agreed, typically 7 to 8% of  $(E_w + E_f)$  if primary and secondary air is pre-heated and 5 % if only primary air is pre-heated. If not possible: Flow meter, Temperature after pre-heating.

Physical quantities measurement:

- The physical quantities which are not re-calculated from other data nor taken as lump sum values are usually measured continuously.
- The corresponding energy flows can be calculated continuously by local counters or the plant CS (Control System) and averaged over the period of testing.

**ANNEX 5: Example and calculation form for the determination of the RI energy efficiency factor**

Type of energy		unit	amount [Mg(tonne)]	NCV [kJ/kg]	Reporting year [MWh]
1.1	amount of incinerated waste (without 1.2 and 1.3)		701,182	10,264	1,999,148
1.2	e.g. amount of incinerated sewage sludge		0	0	0
1.3	e.g. amount used activated carbon incinerated		0	0	0
<b>2</b>	<b><math>E_w</math>: energy input to the system by waste</b>	<b>MWh</b>			<b>1,999,148</b>
2.1	$E_{f1}$ : amount of light fuel oil for start up (after connection with the steam grid)	litre	335,834	42,000	3,370
2.2	$E_{f2}$ : amount of light fuel oil for keeping the incineration temperature	litre	323,193	42,000	3,243
2.3	$E_{f3}$ : amount of natural gas for start up and keeping incineration temperature	Nm <sup>3</sup>			0
<b>3</b>	<b><math>\sum E_f</math>: energy input by imported energy with steam production</b>	<b>MWh</b>			<b>6,612</b>
3.1	$E_{i1}$ : amount of light fuel oil for start up/shut down (no connection with the steam grid)	litre	111,945	42,000	1,123
3.2	$E_{i2}$ : e.g. natural gas for heating up of flue gas temperature for SCR and start up/shut down	Nm <sup>3</sup>	0	0	0
3.3	$E_{i3}$ : imported electricity (multiplied with the equivalence factor 2.6)		0	0	0
3.4	$E_{i4}$ : imported heat (multiplied with the equivalence factor 1.1)		0	0	0
<b>4</b>	<b><math>\sum E_i</math>: energy input by imported energy <u>without</u> steam production</b>	<b>MWh</b>			<b>1,123</b>
4.1	$E_{pel\ internal\ used}$ : electricity produced and internally used for the incineration process	MWh	-		82,807
4.2	$E_{pel\ exported}$ : electricity delivered to a third party	MWh	-		339,982
<b>5</b>	<b><math>\sum E_{pel\ produced} = E_{pel\ internal\ used} + E_{pel\ exported}</math></b>	<b>MWh</b>			<b>422,789</b>
5.1	$E_{heat\ exp.1}$ : steam delivered to a third party without backflow as condensate		11,750	3,023	9,867
5.2	$E_{heat\ exp.2}$ : district heat delivered to a third party with backflow as condensate (hot water)				71,445
<b>6</b>	<b><math>\sum E_{heat\ exported} = E_{heat\ exp.1} + E_{heat\ exp.2}</math></b>	<b>MWh</b>			<b>81,312</b>
6.1	$E_{heat\ int\ used}$ : for steam driven turbo pumps for boiler water, backflow as steam		42,831	397	4,723

Type of energy		Reporting year		
	unit	amount [Mg(tonne)]	NCV [kJ/kg]	energy E <sub>x</sub> [MWh]
6.2	E <sub>pheat int,used2</sub> ; for heating up of flue gas with steam, backflow as condensate	120,404	2,225	74,416
6.3	E <sub>pheat int,used3</sub> ; for concentration of liquid APC residues with steam, backflow as condensate	23,863	2,730	18,097
6.4	E <sub>pheat int,used4</sub> ; for soot blowing without backflow as steam or condensate	38,026	2,918	30,822
6.5	E <sub>pheat int,used5</sub> ; for heating purposes of buildings/instruments/silos, backflow as condensate	23,638	2,490	16,351
6.6	E <sub>pheat int,used6</sub> ; for deaeration-deminerallization with condensate as boiler water input	21,972	2,699	16,475
6.7	E <sub>pheat int,used7</sub> ; for NH <sub>4</sub> OH (water) injection without backflow as steam or condensate	10,517	2,918	8,525
<b>6</b>	<b>S E<sub>pheat int,used</sub> = S E<sub>pheat int,used6-9</sub></b>	<b>MWh</b>		<b>169,409</b>
	R1 = (E <sub>p</sub> - (E <sub>f</sub> + E <sub>i</sub> )) / (0.97 * (E <sub>w</sub> + E <sub>f</sub> ))	[-]		
	$E_p = 2,6 * (S E_{pheat,int,used} + S E_{pheat,exported}) + 1,1 * (S E_{pheat,int,used} + S E_{pheat,exported})$	MWh	1,375,044,5	
	R1=((2,6*(422,789)+1,1*(250,721)-(6,612+1,123)))(0,97*(1,999,148+6,612))		0,703	

#### Remarks:

- to 2.1 Amount of light fuel oil ( $\rho_{oil} = 0,86$  kg/litre) during start up/shut down with steam production, determined from the light fuel oil demand during the relevant time period: connected to the steam grid but yet without release of waste into the furnace.
- to 2.2 Amount of light fuel oil ( $\rho_{oil} = 0,86$  kg/litre) with steam production, during the relevant time period: keeping incineration temperature.
- to 3.1 Determined as difference out of total light fuel oil demand minus demand by 2.1 and 2.2.
- to 5.1 In this example there is no backflow of condensate, therefore difference of enthalpy equal to the enthalpy of middle pressure (mp) steam (advice: in case of backflow of condensate Dc is the difference out of enthalpy from delivered steam minus enthalpy of condensate).
- to 5.2 Amount of district heat determined from the quantity of transported hot water (deviation concerning the steam quantity about 3%).
- to 6.1 Steam driven turbo pumps for boiler water using high pressure (hp) steam, decompressing to low pressure (lp) steam;  $\Delta c = 397$  kJ/kg.

to 6.2 Heat exchangers for heating up flue gas are operated with middle (mp) pressure steam (13 bar). Depending on the fouling of the heat exchangers and throughput, so that the steam pressure is in the range of 9-12 bar. Only the difference of enthalpy, that means the enthalpy of mp steam (as average 10 bar) with backflow of the condensate into the condensate collecting tank (3.2 bar) and therefore on energy losses are taken into account (in the condensate collecting tank decompression to lp steam, which goes into the lp steam net).

to 6.3 Liquid APC residues are treated with mp steam, condensate at 70°C flows back into the boiler (feed) water tank.

to 6.4 Hp steam used for soot blowing with an energy demand of  $\Delta c = 3,211 - 293 = 2,918 \text{ kJ/kg}$ . Amount of energy used for soot blowing taking part in the hp steam production was neglected.

to 6.5 Heating of buildings e.g. administration, boiler houses and other sectors of the WtE plant as well as preparation of warm water for sanitary demand is processed by heat exchangers with lp steam. Backflow of condensate at about 70°C.

to 6.6 Temperature of fresh water from the demineralization installation about 20°C.

to 6.7  $\text{NH}_4\text{OH}$  injection with hp steam.

(Source: Based on Draft Guidance for the determination of the energy efficiency factor R1 (Waste Framework Directive 2000/98/EC, Annex II, R1-formula elaborated by ITAD in coordination with the German Environment Ministry and the Environment Agency, May 2009).