# ENERGY RECOVERY FROM WASTE THROUGH INDUSTRIAL CO-INCINERATION *

**APPLICATION OBJECTIVE**
- Thermal utilization of (usually processed) waste materials and mixtures of them in the form of refuse derived fuel (RDF) in industrial combustion processes to generate energy and substitute primary fuel materials
  
*) The cleaning of exhaust and flue gases as an integrated process and technology is covered by a separate description (see the fact sheet „Emission control – exhaust and flue gas cleaning“)

## OUTLINE ON APPLICATION FRAMEWORK

**PARTICULARLY APPLICABLE FOR WASTE TYPES**

<table>
<thead>
<tr>
<th>Glass</th>
<th>Light-weight packaging</th>
<th>Biowaste</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper / paperboard</td>
<td>Mixed household waste</td>
<td>Bulky waste</td>
</tr>
<tr>
<td>Lamps</td>
<td>Textiles</td>
<td>Electrical and electronic waste</td>
</tr>
<tr>
<td>Scrap metal</td>
<td>Waste wood</td>
<td>X</td>
</tr>
<tr>
<td>Waste oil</td>
<td>Old paint &amp; lacquer</td>
<td>Waste tyres</td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>partly, only materials with a medium to high calorific value, plants must have the adequate permissions</td>
<td></td>
</tr>
<tr>
<td>Branch specific waste</td>
<td>suitable components with a medium to high calorific value and which have low or no concentrations of chlorine and heavy metals</td>
<td></td>
</tr>
<tr>
<td>Other waste material</td>
<td>suitable components with a medium to high calorific value and which have low or no concentrations of chlorine and heavy metals, most especially sewage sludge, animal and bone meal, residues from commercial waste sorting</td>
<td></td>
</tr>
</tbody>
</table>

## SPECIAL CHARACTERISTICS AND REQUIREMENTS OF THE APPLICATION

### Pre-treatment of the input material:
The specific requirements/technical parameters of the co-incinerating facilities have to be observed and taken into account while preparing/processing the material for use as a fuel. Generally the waste must be processed in such a manner that certain specifications and chemo-physical properties are being attained, e.g. calorific value, moisture content, particle size, maximum chemical concentrations of certain elements—especially chlorine and heavy metals. The input material must also be freed from disturbing components such as large metal parts and should not contain any radioactive substances.

### Options for the utilisation of the generated output:
Depending on the input material and incineration process different residues and output products are generated. Waste components accepted for co-incineration in cement kilns for a large part get incorporated and fully bound in the clinker. By-products of an incineration in power stations (such as fly ash, bottom ash, boiler sand, wall cladding, granule from the melting chamber and gypsum) are to the most part of mineral composition and suit for use in road construction, landscaping operations and the production of certain constructional elements. Combustion slags and part of the ashes can be deposited but also be used in other applications after pre-treatment.

### Options for the disposal of process output and/or residues:
Most relevant are the residues from exhaust and flue gas cleaning, these must be safely deposited in facilities of the appropriate type (see the fact sheet „Exhaust and flue gas cleaning“)

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1. Recycling and the necessary sorting and mechanical processing this possibly requires shall be the preferred options for this waste. Industrial co-incineration is however a recommendable method for utilizing the high calorific residues and unsuitable components which remain after the sorting and processing, provided that an acceptable fuel quality and low heavy metal and chlorine concentrations can be ensured through additional conditioning and consistent control.

2. Any possibilities for this waste to be recycled should be examined and, whenever possible and economically feasible, applied first, in particular if amounts of wood in a natural or widely untreated state are involved. Energy generating facilities specialized on the combustion of woody biomass are also more suited for utilizing this waste in an energetically effective manner.

3. Any possibilities for this waste to be recycled or material used should be examined first and, whenever possible and economically feasible, preferred.
**Technical Details**

<table>
<thead>
<tr>
<th>General Overview</th>
<th>Industrial co-incineration means to utilize (mostly pre-processed) waste material of defined composition and properties (so-called refuse derived fuel-RDF) as an alternative or secondary fuel to generate energy and heat in an industrial combustion facility. The facilities most suited for an industrial co-incineration are coal-fed power stations, cement kilns and specially designed installations for the mono-combustion of special RDF fractions, less often these are also brick or lime kilns and blast furnaces of the steel industry. By using RDF in the industry, energy is recovered from parts of the waste and primary energy resources can be saved. An industrial co-incineration can be realized following some slight modifications of the standard technology which has previously been used by the industrial facility for the storage and feeding of the conventional fuel. Ordinary techniques such as grate combustion (see fact sheet on “Grate combustion”) or fluidized bed technology (see fact sheet on “Fluidized bed incineration”) are used for the actual incineration step. Rotary kiln systems are still most widely seen when waste material is co-incinerated by the cement industry. Existing installations for exhaust gas cleaning can be further used and/or must be upgraded/extended in dependence from the actual amount and composition of the RDF.</th>
</tr>
</thead>
</table>

**Aftercare requirements:**
Residues which have to be deposited on landfills of the appropriate categories must be subject of monitoring and become part of the usual aftercare procedures applying to these landfills.

**Protective needs:**
Industrial facilities active in the co-incineration of waste materials and RDF must take special precautions for fire protection, especially in the areas for the storage and feeding of these fuels. Exhaust and flue gases from the incineration must be appropriately treated and cleaned. Protective measures must ensure that no health risks or any negative impacts on sensitive media such as the soil, ground water or sites of special value do occur. Guidance what measures and limits may apply is provided in other documents and fact sheets (see fact sheet on “Exhaust and flue gas cleaning“ and the document on "Technology-related EU regulations" in particular the “Directive on industrial emissions”)

**Potential health risks:**
A release of untreated flue gases pose a health risk which can be avoided if contemporary cleaning techniques and protective measures as indicated in this fact sheet and in the fact sheet on “Exhaust and flue gas cleaning“ are employed and properly followed. Waste incinerators using state-of-the-art cleaning technologies are nowadays considered as not threatening human health any longer.

**Restrictions or Influence of Externalities on the Application**

**Infrastructural conditions:**
The co-incineration of waste materials in an industrial combustion process is usually implemented in an established facility which implies that the necessary infrastructural conditions, like a good accessibility by road, railway or waterways already exist. However, extensions of the site might be necessary due to the need of space for the reception and storage for the additional fuel material. Erecting an incineration facility in or close to dwelling areas requires that minimum distances to the nearest buildings and other precautionary/protective measures need to be observed.

**Climatic conditions:**
No restrictions apply. To avail of industrial co-incineration as a way to produce energy and heat in regions with colder climates is highly advisable.

**Suitable financing mechanism:**
The additional investments and organizational measures that must be undertaken to realize the co-incineration of waste in an industrial combustion process can be recovered by way of a special fee that is charged on/collected from those who supply the waste-derived fuel and therefore 'request' the service of a thermal (waste) treatment. Additional financing can come from savings made by substituting a higher priced regular/conventional fuel or by selling surplus energy.

**Abstract**

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**October 2015**
BASIC REQUIREMENTS

- waste material which is going to be used as refuse-derived fuel has to conform with certain, pre-defined physical and chemical properties, mainly mechanical treatment and separation techniques are applied to ensure this. The properties are determined by the special co-incineration process, the type of installation and the RDF quantities used or added in the process. The processing shall also make sure that the RDF produced from larger quantities of waste is of stable composition and quality. Some parameters for RDF standard qualities are shown in the following table.

Table 1: Common standards and requirements on RDF quality

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Power stations</th>
<th>Cement industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle size</td>
<td>mm</td>
<td>10–25</td>
<td>approx. 30</td>
</tr>
<tr>
<td>Unwanted matter</td>
<td>-</td>
<td>stones, metals, wooden pieces, hard plastics, large sized items</td>
<td></td>
</tr>
<tr>
<td>Ash content</td>
<td>% by weight (dry matter)</td>
<td>10–25</td>
<td>10–25</td>
</tr>
<tr>
<td>Moisture content</td>
<td>% by weight (dry matter)</td>
<td>10–25</td>
<td>10–25</td>
</tr>
<tr>
<td>Calorific value</td>
<td>MJ/kg</td>
<td>&gt;18</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Chlorine</td>
<td>g/kg dry matter</td>
<td>5–15</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Heavy metal content</td>
<td>mg/kg dry matter</td>
<td>individual regulations (see RAL-GZ 724)</td>
<td></td>
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</tbody>
</table>

EXPECTED RESULTS

- Reduced need of conventional primary fuel
- Output power stations:
  - energy from waste
  - usable inert by-products in the form of slags, ashes, boiler sand, gypsum
  - exhaust/flue gases
- Output cement kilns:
  - with the persistent components and ashes from combustion being fixed in the material matrix of the cement, there are almost no residues left from the process

SPECIFIC ADVANTAGES

- substitutes primary energy sources (in connection with cost savings or even proceeds that can be made from using RDF)
- reduces the amount of waste for which other treatment and/or disposal options would otherwise have to be found, saves landfill space
- harmful content and reactivity of the waste is drastically lowered, partly a waste utilization without residues takes place
- costs less than the operation of a standard waste incinerator

SPECIFIC DISADVANTAGES

- may possibly alter product qualities (cement, bricks, steel slag)
- causes higher thermal stress and wear to industrial boiler and passages for exhaust gases
- faster deterioration of the installations in the result of rather aggressive corrosion, increased maintenance and risk of breakdowns for repair
- exhaust gas is partly of worse quality than that dedicated facilities for the mono incineration of waste produce, hence the installation of a bypass for critical heavy metals (such as mercury) will in future be needed in the cement industry
- produces reactive bottom ashes and slags
- requires additional investment + more complex management and control
- increased risk of production standstill due to problems caused from waste feed

APPLICATION DETAILS

Prominent procedures for the processing of different waste materials and the options they incorporate to generate RDF are the subject of a number of separate fact sheets (see fact sheet on “Sorting and processing of bulky waste” and fact sheet on “Mechanical-biological waste treatment”). For the incineration process itself the technologies described in the separate fact sheets on grate combustion (see fact sheet on “Grate combustion”) and fluidized bed combustion (see fact sheet on “Fluidized bed combustion”) are of main interest.

Usually, the following arrangements can be found for industrial co-incineration:
In coal-fed power stations:
- **Option #1**: Utilization of the existing installations and their optimization for a predominant co-incineration of RDF
- **Option #2**: Thermal treatment of the RDF using gasification or pyrolysis as a preceding step before the incineration of the generated pyrolysis coke or gases in the existing boiler  
  *Important additional note:* so far no such application ever had a confirmed full functionality at larger long-term technical scale
- **Option #3**: Utilization of the RDF in a fluidized bed incinerator
- **Option #4**: Utilization of the RDF in an external fluidized bed incinerator with its own flue gas treatment, use of the energy to heat the steam boiler (composite circuit).

Figure 1: Exemplary scheme for industrial co-incineration in a conventional (fossil-fueled) power station.

In the cement industry:
RDF is co-incinerated in cement production at the stage of clinker production and cement making. Rotary kilns play a predominant role here. The kiln is a cylindrical vessel, inclined slightly to the horizontal, which is rotated slowly about its axis. The material to be processed including the RDF is fed into the upper end of the cylinder. As the kiln rotates, the material gradually moves down towards the lower end, and may undergo a certain amount of stirring and mixing. The addition of RDF to the material mix influences the overall amount of fossil fuel added as well as its distribution onto rotary kiln and calcinator unit. This distribution must be known at the beginning of the process in order to ensure stable conditions and uniform quality of the end product.

An essential role in the co-incineration in cement kilns plays the element ratio and the ratio of the calorific values between conventional (fossil) and secondary (RDF) fuel. With the incineration of the latter taking place at temperatures of 2000 °C no toxic gases can form. Nitrous gases are eliminated through the DeNOx-process. The clinker reactions at 1450°C allow incorporation of ashes and in particular the chemical binding of metals to the clinker. Drying, heating and the degassing of the volatile waste components occurs near the upper feeding slot already. The hot gases pass along the kiln, sometimes in the same direction as the process material (co-current), but usually in the opposite direction (counter-current). The ignition and incineration of these gases takes place in the calcinator. The gasification and incineration of the solid waste parts takes place near the lower exit.

The counter example is an upstream gasification unit for RDF with the subsequent use of the combustible gas in the process. This kind arrangement is used in the German cement plant in Rüdersdorf near Berlin.

<table>
<thead>
<tr>
<th>QUANTITY ASPECTS / SCALE OF APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depending on the kind of process and facility used, a partial or full substitution of conventional fuel with RDF is achieved in a co-incineration process. Incineration technology, product requirements and RDF composition determine how large this share can be. Whereas industrial power stations substitute only 5–25% of their total rated thermal input with the help of RDF, this can be up to 75% (2014) or in single cases even more in cement kilns.</td>
</tr>
</tbody>
</table>
**INTEROPERABILITY**

Industrial co-incineration in principle is an option that can be adopted for any kind of production, energy or heat generating processes based on the combustion of medium and high calorific materials. Special installations designed to supply industrial parks or large production facilities (like paper mills) with energy from a dedicated mono-combustion of RDF fractions however become more and more popular. These installations use conventional incineration technologies like grate combustion (see fact sheet on “Grate combustion”) and fluidized bed combustion (see fact sheet on “Fluidized bed combustion”) but with modifications purposefully made in order to achieve high energy efficiency and cope with RDF-related specificities like aggressive flue gases and varying emission values.

**OPERATIONAL BENCHMARKS: RESOURCE CONSUMPTION**

| ENERGY BALANCE | • A positive balance can be obtained through the saving of primary fossil fuels and the utilization of the renewable waste components as an energy source |
| CO2-BALANCE | • Reduction of CO2-emissions up to 35 % through the partial substitution of primary fossil fuels  
• A complete substitution would prevent all climate damaging emissions from the combustion of the respective amount of conventional fuels and those generated during the disposal of the waste converted into RDF |
| AIDS/ADDITIVES NEEDED | • No additives are required to generate a suitable RDF product out of combustible waste material. However, there is a need for mechanical processing and possibly some biological treatment (drying) for which certain technical means have to be employed |
| HUMAN RESOURCES | • The demand on personnel in the co-incineration facility may slightly increase in order to ensure the proper handling (storage, feeding) and quality assurance procedures for the RDF material and do some additional maintenance and repair works. |
| SPATIAL NEEDS | • an additional storage of the RDF-material corresponding to the capacity/RDF-throughput of the facility is needed; for example silo storage is needed for animal and bone meal used in co-incineration  
• additional space for the reception and feeding installations of the fuel material |

**OPERATIONAL BENCHMARKS: COST DIMENSIONS**

| INVESTMENT COSTS | To allow for the co-incineration in an industrial facility, certain additional investments are necessary. For the most part they are in relation to:  
• the planning and erection of the RDF reception and storage area and installations for dosage and feeding  
• necessary extensions on the flue gas cleaning and emission detection and measurement  
The additional investments may take a range of EUR 1.3–6 million per incineration facility or EUR 25–45 per Mg of RDF used (price quotations from the year 2008). These amounts also include the costs for maintaining an adequate storage capacity and for fire protection measures. |
| OPERATING COSTS | The overall operating costs of the industrial plant are likely to increase in the result of a slightly increased personnel demand, additional repair/maintenance and enhanced requirements for emission treatment (e.g. bypass regulation). Possible changes with regard to the utilization potentials for certain byproducts of power stations (especially fly ashes) may lead to lower proceeds from their sale and an increase of disposal costs. |
### POSSIBLE PROCEEDS

Accepting waste-derived fuels for co-incineration to a certain extent can be regarded as a thermal treatment service for waste materials and also goes hand in hand with some additional risks and investments. Industrial plant operators for these reasons use to charge a fee to the suppliers of RDF, depending also on how much conventional fuel they can substitute and what the treatment of byproducts and process residues inclusive the emissions costs them. An indicative price range for the fees (established for the year 2011) collectable at the market is shown hereafter:

- lignite fired power plants using the method of dust firing: 5–15 EUR/Mg RDF input
- hard-coal fired power plants using the method of dust firing: partly no fees due to the higher requirements imposed on the conditioning of the RDF products
- hard-coal fired power plants using fluidized bed combustion: 0 to ≤ 10 EUR/Mg RDF input

For less intensively processed RDF incinerated in dedicated incinerators with higher flexibility in terms of quality and other parameters, fees might be set at much higher levels, across Europe price quotations currently reach up to 50 EUR/Mg.

### MASS SPECIFIC OVERALL COSTS

can vary greatly

### OTHER RELEVANT ASPECTS

### MISCELLANEOUS

### MARKET INFORMATION

#### REFERENCE FACILITIES

(Nota: the list of sites and/or firms does not constitute a complete compilation)

The industrial co-incineration of waste material is widely applied in Germany to date and is becoming a common practice also in other countries of Europe and elsewhere in the world. Industrial facilities which are using co-incineration in Germany are for example:

**Cement industry**
- Cemex Zementwerke Rüdersdorf [www.cemex.de](http://www.cemex.de)
- Dyckerhoff Zementwerke Deuna [www.dyckerhoff.de](http://www.dyckerhoff.de)

**Power stations**
- Kraftwerk Jänschwalde [www.vattenfall.com](http://www.vattenfall.com)
- Kraftwerk Werne [www.rwe.com](http://www.rwe.com)

**Steel production**
- DK Recycling und Roheisen GmbH, Duisburg [www.dk-duisburg.de](http://www.dk-duisburg.de)

#### RECOGNIZED PRODUCER AND PROVIDER FIRMS

(Nota: the list of firms does not constitute a complete compilation of companies)

Provider of installations for an industrial co-incineration and/or of the necessary components in Germany are for example:

- Oschatz GmbH [www.oschatz.com](http://www.oschatz.com)

#### ADDITIONAL REMARKS AND REFERENCE DOCUMENTS

A relevant organization and contact point for further information concerning RDF-production and use by the industry is for example: Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz e.V. (BGS). [www.bgs-ev.de](http://www.bgs-ev.de)