21’ Century Advanced Concept for Waste-Fired Power Plants
# INTRODUCTION

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The growing waste problem

The world’s population produces around 2 billion tonnes of waste per year. The growing population and increasing consumption rates due to the increased standard of living mean that the world is facing a serious challenge.

People everywhere must realize that less waste should be generated, and that the produced waste must be treated in an environmentally safe manner.

The Asian scenario

The countries in Asia are undergoing remarkable development in respect of rapid socio economic changes and infrastructural, technological and industrial progress. Asian consumerism is increasing, and waste generated per capita per day is almost 2 kg in certain cities! In the near future more than 1 kg per day per person of waste in general will be generated and need disposal. The region has more than 25 large cities with 5 mill inhabitants or more. Cities are now surrounded by landfills and many places are short of landfills. New landfill sites are often located too far away. Much waste is burned in the open air although this creates serious air pollution.

The future challenge

The amount of municipal solid waste generated globally is estimated to increase by 7% over 2003 figures to 1.84 billion tonnes. Further it is estimated that between 2004 and 2008, global generation of municipal waste will increase by 31.1%[1].

The waste picture is dominated by the municipal waste output of the world’s wealthiest nations as shown below[2]. However it is also being fuelled by developing countries as they develop economically and socially and gradually adopt the characteristics of well-developed nations. The increase in tourism and modern life style is rapidly changing societies in Asia and generating waste at an alarming pace.

How shall we handle this challenge in the emerging economies?

The big questions

The questions arising from the challenge are numerous. How do we prioritize the waste management problem together with other environmental problems? How do we define a waste hierarchy, which prioritizes waste elimination at the source, reuse, recycling and composting to energy recovery, and landfilling?

What are the realistic options available today? Can we benefit from the situation and create something useful from our waste?

The answer

A part of the solution is to change our attitude towards our leftovers. Instead of only looking at the municipal solid waste as a problem, we have to start identifying the opportunities and possibilities. Then we can start looking at waste as a resource. At the same time the
Asian Waste Characteristics

The nature of Asian waste is wet and with a high content of organic matter. It is characterized by having a relatively low heating value that changes with seasonal precipitation. The waste is a moist, wet fuel, especially during the rainy seasons. In developing societies the heating value of the waste will typically increase as a consequence of the increasing standard of living. The use of packaging materials including paper, plastics and other combustible substances, increases.

Backyard trash burning

In many places backyard trash burning also known as open burning is practiced daily as a way of getting rid of the waste. Uncontrolled burning of waste holds great dangers. The US EPA[3] has conducted tests that show that 'backyard' burning of waste from one family generates pollutants (including dioxins and furans) equal to that of 7,500 similar families when burned in a modern waste fired power plant.

Waste hierarchy shall enforce us to reduce the amount of waste, separate the waste at the source for recycling and composting, landfilling, or possibly thermal treatment. These options are all part of the solution to the growing waste problem and together they form an integrated waste management concept with reliable environmentally friendly sound solutions.

Waste can be considered as a useful by-product from our daily life.

Waste - a problem or a resource?

In many countries waste is considered as a problem causing great difficulties, politically as well as environmentally. Local people are afraid of the possible pollution from the thermal treatment of waste. At the same time the consumption of energy is increasing steeply in Asia as seen below[4], and the need for new energy resources is urgent.
If this way of thinking is shared in a local community, then waste becomes a source of new energy and a valuable economic and environmental asset. We will then move from waste management to resource management.

The EU/Scandinavian scenario
Thermal treatment has been part of a sustainable waste management plan in all Scandinavian countries for decades. After collecting, recycling and reusing the various elements in the waste, the remaining combustible parts are incinerated in modern plants that fulfill the latest and most stringent EU requirements.

The present EU Directive 2000/76/EC on the incineration of waste was adopted in December 2000. In spite of its title it applies to all kinds of thermal treatment of waste. Open burning is prohibited.

Waste management has been refined over decades and thermal treatment is now part of the backbone infrastructure in many countries\(^\text{[5]}\),

The European Union's approach to waste management is based on three principles:
- Waste prevention
- Reuse
- Recycling

Further improving final disposal and monitoring with five major targets to aim for:
- Limiting the amount of waste generated
- Reducing the content of hazardous substances and emissions from waste by means other than recycling, such as thermal and other treatments.
- Increasing reuse and recycling – separation and collection systems
- Recovering energy from the waste
- Reducing the volume of the waste

Mass-burning versus pre-treated waste streams
Pre-treatment is a process during which waste is prepared before it can be used as a fuel i.e.: sorted, dried, shredded, mixed, separated etc.

Mass-burning systems takes raw MSW refuse including different other streams including bulky waste without any pre-treatment. Oversize items may however be shredded.

When deciding on a solution for generating energy from waste, the energy efficiency is the most important issue.

Eco-efficient systems extract maximum energy from the fuel at lowest cost. Pre-treatment processes require energy and reduce the net energy extracted from the waste.

Eco-efficient solutions minimize the internal energy consumption and makes maximum use of resources. In other words producing more with less!
Fluidized bed combustion (as well as most pyrolysis and gasification processes) requires that the waste be shredded to a small particle size before being introduced in the combustion (pyrolysis/gasification) chamber. Grate combustion; on the other hand, can accept bigger items and only oversized materials has to be crushed. For that reason grate combustion is often referred to as mass burning.

Mass burn combustion is by far the preferred option, and the only one which has shown its reliability during prolonged 24 hour a day operation. In other words mass burn combustion is the only proven technology available today. Most of the waste is combustible and burns away during the combustion process forming a flue gas, which – after treatment – is discharged through a chimney to the atmosphere.

But the waste does also contain incombustibles. These leave the process as bottom ash, but at a much-reduced rate both by volume and by weight. Most often, the bottom ash is utilized as a synthetic gravel-like material, but under certain conditions it may be taken to a landfill.

**Waste as a fuel**

The diverse nature of MSW demands that the Waste Fired Power Plant (WFPP) must be carefully designed to handle and to operate efficiently over a wide range of waste input conditions.

The energy recovery from MSW is a function of the heating value of a given material composition. The energy content in the various waste components ranges from inert to 20 MJ/kg or more. The total energy content in Scandinavia and Japan is up to 3 MWh per ton of waste.

In Asia heating values down to 3.3 MJ/kg are seen. On the other hand, the system needs to be able to adjust to higher heating values and different waste streams. Co-firing of biomass, sewerage sludge and non-pathological hospital waste could be possible scenarios. This requires a flexible firing scheme with possibility of air preheating and addition of auxiliary fuel.

**Waste in Asia vs. Europe**

The composition of waste in Asia and Europe differs in a number of ways. The above table is a comparison between the capital of Denmark, Copenhagen and the cities of Hangzhou, China and Seoul, Korea.

It can be seen from the table that the values differ substantially, mainly in accordance with the organic content.

<table>
<thead>
<tr>
<th>Population (mill.)</th>
<th>Total amount of waste (t/d)</th>
<th>Food &amp; garden waste</th>
<th>Textiles &amp; others</th>
<th>Paper</th>
<th>Plastics</th>
<th>Glass</th>
<th>Metals</th>
<th>Density</th>
<th>Humidity</th>
<th>Calorific value (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copenhagen</td>
<td>1.2</td>
<td>2740</td>
<td>63</td>
<td>16.8</td>
<td>3.5</td>
<td>21.1</td>
<td>0.36</td>
<td>50-60</td>
<td>3.5-12</td>
<td>10.5</td>
</tr>
<tr>
<td>Bangkok</td>
<td>9.0</td>
<td>8,340</td>
<td>55</td>
<td>14</td>
<td>4</td>
<td>1</td>
<td>0.36</td>
<td>53</td>
<td>4-8</td>
<td>2.5-12</td>
</tr>
<tr>
<td>Hangzhou</td>
<td>4.0</td>
<td>11,339</td>
<td>28</td>
<td>7</td>
<td>5</td>
<td>9</td>
<td>0.36</td>
<td>40</td>
<td>4-12</td>
<td>2.5-12</td>
</tr>
<tr>
<td>Seoul</td>
<td>10.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Typical waste characteristics in four cities**

- Population: mill.
- Total amount of waste: t/d
- Food & garden waste:%, dry
- Textiles & others:%, dry
- Paper:%, dry
- Plastics:%, dry
- Glass:%, dry
- Metals:%, dry
- Density: t/m³
- Humidity:%
- Calorific value: MJ/kg

Did you know that...

... 230 million tons of municipal solid waste or garbage is generated each year in the United States of America. This means that on average each person generates about 800 kg of waste per year.

... each person in the United Kingdom, throws away seven times their body weight (about 500kg) in waste every year, on average.
The Kyoto Protocol and greenhouse gases

The Kyoto Protocol was adopted in December 1997. It contains legally binding obligations for 38 industrialized countries, including 11 countries in Central and Eastern Europe, to reduce their emissions of GHGs to an average of 5.2 percent below the 1990 levels over the period 2008-2012.

The targets cover the six main greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFC), hydrofluorocarbons (HFCs, CFC alternatives), and sulfur hexafluoride (SF₆). The Protocol also allows these countries the option of deciding which of the six gases will form a part of their national emissions reduction strategy. Some activities in the land-use change and forestry sector, such as deforestation and reforestation, that emit or absorb carbon dioxide from the atmosphere, are also covered by the Protocol. Landfilling of waste creates methane, a violent greenhouse gas, and other greenhouse gases are released to the atmosphere when the waste decomposes and composts.

Thermal treatment also creates CO₂, but in general it is only a minor part (10-30%) of the CO₂ emitted from a WFP that comes from fossil material. Thermal waste treatment consequently reduces CO₂ emissions to the atmosphere and can contribute to the targets set by the Kyoto protocol.

Best Available Technique (BAT)

Best Available Technique is a guideline to selecting the most appropriate system from an environmental point of view with due consideration to obtaining a reasonable economy. With the adoption of the so-called IPPC directive, the term ‘best available technique’, BAT, was introduced into the European legislation. The directive contains specific definitions of the term, including a requirement that it must be possible to apply the technique under economically and technically viable conditions as well as an annex listing 12 considerations to be taken into account when determining BAT. The twelfth and last of these considerations is to acknowledge the BAT Reference Documents (BREFs) published by the European Commission. What is the best available technique for treatment of waste? The directive does not answer this question. Instead it lists a number of industrial activities covered by the directive, including landfilling and installations for the thermal treatment of municipal waste with a capacity exceeding 3 tonnes per hour[9].

Thermal treatment of waste is usually effected by mass burning.

A finalized BREF[10] on waste incineration was published in July 2005. It contains a general description of the techniques applied in the waste to energy sector and establishes 63 numbered recommendations concerning BAT for design and operation of waste to energy plants.

What are the benefits of thermal waste treatment?

Compared to other methods of treating waste which cannot be reused or safely treated by other means, thermal treatment provides a safe and optimal way of extracting the energy and eliminating the harmful substances. Organic pollutants, toxins and infectious substances are effectively destroyed at high temperatures. Thermal treatment of waste can generate electricity and thermal energy which can be substituted for other scarce fossil energy resources. The energy from thermal treatment of waste is considered renewable energy (electricity and thermal energy) and can supply “base load” electricity 365-days-a-year, 24-hours a day to the community. This is why thermal treatment is now part of sustainable environmental policies in developed countries.

Ecological footprint

The German company BASF has sponsored a study comparing the environmental impacts of three waste management solutions: mechanical-biological treatment (MBT) (aerobic digestion), waste-to-energy and landfilling[11].

The main conclusions are summarized in the illustration below that shows the ecological footprint of these three management solutions. The larger the footprint becomes the less preferable is the solution.

The ecological footprint

The carbon dioxide emissions from landfills per ton MSW are at least 1.2 tons CO₂. Landfills contribution to greenhouse gas emissions are much higher than WTE plants[12,13]. Landfilling has the lowest cost of the three with mechanical-biological treatment being 8% more expensive and WTE 54% more expensive than landfilling. However, considering all of the environmental performance criteria (energy, material, and land consumption, air and water emissions, risks) WTE is the favorable solution.

Reduction of volume and weight

A main objective of thermal treatment is to minimize the volume of waste to deposit at landfills. Municipal solid waste collected at the kerb side has a typical density of 100-150 kg/m³ but is compacted on collection so the density changes to 225 to 300 kg/m³.

During thermal treatment the energy content is released and the volume and weight reduced by up to 95% and 80%, respectively.

The final disposal volume is reduced by more than 95% after thermal treatment.
Energy generation & co-generation

The WFPP can create various forms of energy by means of thermal treatment:

- Electricity
- Heat for district heating purposes
- Steam for process use
- Cooling for air-conditioning
- Energy for desalination of seawater

By extracting all of the energy from the plant and utilizing the heat it is possible to achieve >90% thermal efficiency: In traditional plants with electricity production only, the efficiency is approximately 20% and the excess heat has to be cooled away.

Co-generation or combined heat and power generation is a way of increasing the overall thermal efficiency from the 20% to more than 85% by utilizing the waste heat from the electricity production. By also extracting energy from the flue gas by condensation and heat pumps it is possible to achieve more than 100% energy efficiency (based on the net calorific value).

Reduction in emissions of greenhouse gas (GHG)

The increased emission of greenhouse gases, most noteworthy carbon dioxide (CO₂), during the 20th Century is believed to cause a global warming and illustrated below\[14\]. In an attempt to prevent this effect the Kyoto Protocol has been agreed. Combusting the waste instead of taking it to landfill contributes to the objectives of the Kyoto Protocol by preventing the methane formation associated with the anaerobic degradation of waste under landfill conditions.
What comes out of the chimney?
The combustion process should be operated in such a way that secures maximum burnout of both the bottom ash and the flue gas. Consequently, EU legislation sets limits to the content of Total Organic Carbon (TOC) in bottom ash and flue gases. Any dioxin present in the waste should be completely destroyed.

In addition, there are limits as to the formation of carbon monoxide (CO), and the combustion conditions should also minimize the formation of nitrogen oxides ($NO + NO_2 = NO_x$).

But the flue gas must also be treated to remove other air pollutants such as particles (fly ash), hydrochloric acid (HCl), hydrogen fluoride (HF), sulphur dioxide ($SO_2$) and heavy metals like mercury (Hg), cadmium (Cd) and lead (Pb).

Some of these processes also remove other potential air pollutants like dioxins, hydrogen bromide (HBr), brominated dioxins, polynuclear aromatic hydrocarbons (PAH) and additional heavy metals.

Standards for emission to air
In the EU, Korea, Japan and China emissions are controlled by law. The below table is a comparison between the different standards. The last column indicates BAT.

Consequently, a modern waste fired power plant emits hardly any toxic effluents from the chimney. The treated flue gas that is seen coming out consists primarily of carbon dioxide, oxygen, nitrogen, and water vapor.

Dioxins and heavy metals
Modern waste plants actually contribute to the net reduction of dioxins and furans$^{15,17}$! In popular terms you can say that in certain areas and cities the air that comes out of a plant is cleaner than the air that goes into it.

Household waste and other waste generated by modern society reflect production
and consumption. These kinds of waste will therefore contain all the types of materials and chemicals used in society and the pollutants that they form. In particular, this applies to household waste which consists of heterogeneous material containing small amounts of mercury, cadmium, dioxins or other pollutants. Household and other waste must therefore be treated carefully and dealt with safely to prevent the pollutants from spreading and causing harm to humans and to the environment.

One very important aim of thermal treatment is to break the harmful ecocycle of heavy metals, dioxins etc\(^{[10]}\). The incoming waste contains varying amounts of dioxins, depending on the origin and composition. By far the largest part of these dioxins is broken down into carbon dioxide, water and hydrogen chloride during the thermal process, which takes place at temperatures above 700°C. The small quantities of dioxins that have not been broken down are collected in the flue gas treatment system.

When released into the air, dioxins may be transported over long distances and are found in most places in the world. Today most of the daily dioxin pollution in Scandinavia is ‘imported’ from other countries by the wind and originates from other sources than thermal treatment of waste\(^{[16]}\).

Compared to 1990 dioxin from waste to energy plants has has dropped to approx. one thousandth in 2005\(^{[17]}\).

**Residues**

As mentioned previously, the burning process itself produces bottom ash, which is either utilized or landfilled. In some countries the bottom ash must fulfill certain criteria regardless of whether it is utilized or landfilled. The criteria are intended to prevent the bottom ash from polluting the aquatic environment due to leaching of harmful substances. In the EU a distinction is made between inert, non-hazardous and hazardous waste and acceptance criteria have been adopted for wastes to go on landfills for these three categories of waste. See scheme on next page.

The flue gas treatment processes also generates solid residues and in some cases also a wastewater, which – of course – must be treated before being discharged. These residues are normally landfilled or brought to an underground storage facility.

**What are dioxins and furans?**

Chlorinated dioxins and other substances within the group known as persistent (stable) organic pollutants (POPs) occur and are formed in many different activities and processes and in many different places within the industrialized countries. Due to emissions and other activities, these substances, which are stable by nature and are enriched in the food chains, have built up in the ecosystems where they cause serious disturbances. Dioxins include the most toxic substances known to mankind. 'Dioxins' is a collective name for 210 different chlorinated dibenzo-p-dioxins and dibenzofurans. Some of these compounds are extremely toxic, whereas others are practically harmless. In total, 17 of these dioxins are toxic to some degree, and the one called 2,3,7,8-TCDD is the most toxic. The toxicity of the dioxins is stated in TCDD equivalents, which are a measure of how the 17 toxic dioxins are distributed in a sample from a flue gas, an ash or another material. The most commonly applied and generally accepted method is the international I-TEQ system, in which the 17 toxic dioxins are assigned a factor indicating their relative toxicity.

Brominated dioxins and furans form a group of substances with similar properties to the chlorinated analogues (equivalents). The composition, structure and toxicity of both groups are comparable. One crucial difference, however, is that the brominated dioxins and dibenzofurans are not as stable in sunlight as their chlorinated counterparts. Tests have also shown that the rate of degradation of the brominated compounds in nature is significantly faster\(^{[18]}\).

**Formation of dioxins**

Dioxins have never been produced commercially in the same way as polychlorinated biphenyls (PCBs) and polychlorinated naphthalenes (PCNs). Dispersion in the environment has only taken place via products which have been contaminated with dioxins or through emissions from thermal and chemical/ biological processes. Dioxins can be formed in a number of different ways. A distinction is usually drawn between two main types of formation: formation in thermal processes and formation in chemical/biological processes.

It has emerged that conditions for dioxin formation can be found in many different activities and processes in society, and even in nature under both natural and influenced conditions. For example, dioxins can be formed during all types of combustion based on organic waste materials. This is a result of chlorine and catalytically active substances such as copper commonly occurring in all forms of organic material. Precursors can also be found in many materials, which mean that the conditions for dioxin formation are present. Other known sources of dioxin emission are related to:

- traffic
- industry (forest industries, iron and steelworks, aluminum and copperworks, foundries, the cement industry and lime-burning etc.)
- energy production - (excluding thermal waste treatment plants) - is a major source
- small boilers, wood-fuelled furnaces etc.
- fires at landfill sites, forest and land fires
- fires in buildings, cars and other objects that contain PVC and other chlorine-containing materials, are major sources of dioxins.

**Biological/chemical processes:**

- composting processes (Household waste contains dioxins to a varying degree, depending on the origin and composition of the waste. Surveys indicate that no degradation of dioxins takes place during composting. The dioxin content in the waste remains and is transferred to and included in the resulting product – compost\(^{[16]}\).
Critical aspects of waste combustion

Objectives of combustion

The prime objective of a waste combustion plant is to burn the waste in an environmentally safe manner. This means that the burnout of the flue gas and bottom ash shall be maximized and the formation of air, water and soil polluting substances shall be prevented as far as possible.

A secondary – but equally important – objective is to maximize the energy recovery. The incinerator shown on next page is equipped with a steam boiler, and the energy recovery takes places by raising steam, which is passed to a turbine/generator set (not shown) for electricity and possibly heat production. In such a plant the steam production rate (kg/s) should be as constant as possible to secure a smooth operation of the turbine and a uniform electricity production. This again calls for a constant thermal conversion rate in the furnace/boiler system.

On the technical side

Process monitoring and control

However, waste is an inhomogeneous fuel with widely varying properties. Keeping the thermal conversion and the steam production rates constant as well as optimizing the operation of the flue gas treatment system requires that the entire process be continuously monitored and the operation automatically corrected according to the actual conditions.

Thus – regardless of the make and design of an thermal treatment plant – an advanced control and monitoring system (CMS) is required.

Waste pre-treatment and feeding

Mass burn incinerators accept bigger items, only larger items should be shredded before being put into the waste bunker. The waste is fed by a crane into a hopper from where it is introduced in the furnace by a feeding device. This must operate automatically as required by the CMS and feed a specific quantity of waste into the furnace and onto the grate.

Grate

When introduced onto the grate, the waste is first dried, then partly pyrolysed under formation of combustible as well as incombustible
Mass burn waste to energy plant with a centre flow furnace, a steam boiler with three vertical radiation passes and a horizontal convection pass and a semi-dry flue gas treatment plant.

The combustible gases burn above the grate. The remaining waste is subsequently burned out on the grate to a TOC content of less than 3% before it falls into the – normally wet – bottom ash system. The system may also be designed in accordance with the required leaching properties of the bottom ash.

Primary combustion air is supplied from underneath through small openings in the grate. The air supply is determined by two considerations: Firstly, enough air must be supplied to cool the grate (air-cooled grate), and secondly, enough air must be supplied to sustain the (primary) combustion. Normally, the former quantity is the larger. Thus, by partly cooling the grate by water (water-cooled grate), it is possible to adjust the primary air supply to exactly the flow needed for the primary combustion process, only. Numerous samples of grate siftings shows a very good burnout and in the same order as the main ash flow.

The small openings in the grate carpet allow, on the other hand, smaller particles of the waste to fall through the grate as grate siftings. The siftings are collected, and normally they are mixed into the bottom ash, but they may be removed separately and possibly returned to the feeding hopper.

**Post combustion chamber**

Modern standards require that the flue gas be exposed to a temperature of min. 850°C for a time of min. 2 seconds after the last secondary air injection. The furnace must therefore have a post combustion or afterburning chamber of a certain height above the grate. The final burnout of the flue gas takes place in that chamber, and secondary combustion air is added in the required amount and in a way that secures maximum turbulence.

It is in the post combustion chamber that the auxiliary burner(s) are located (if installed) and that the injection of ammonia (NH₃) or urea ((NH₂)₂CO) for NOₓ reduction according to the SNCR process is made.

**Flow design and flue gas re-circulation (FGR)**

The total air supply to the combustion process is the sum of the primary and secondary air. To secure complete burnout it is necessary to operate at a certain surplus of air. The excess air passes all the way through the boiler and the flue gas treatment system to the chimney and – depending on the flue gas temperature in the chimney – it represents a loss of energy and hence a loss of thermal efficiency.
in the chimney – it represents a loss of energy and hence a loss of thermal efficiency.

The excess air ratio can be reduced on the primary side by using a water-cooled grate and on the secondary side by re-circulating a part of the treated flue gas (FGT).

It is also of importance whether the entire gas flow through the furnace is counter flow, centre flow or parallel flow as explained later on in the present publication.

Thus, the air supply and the volumetric mixing of primary flue gases with secondary air is a delicate design feature. Computerized Fluid Dynamic (CFD) modeling is an important tool in this design operation.

Boiler design
Boilers for Waste Fired Power Plants are normally water tube boilers and most often they have four passes: 3 vertical radiation passes and a convection pass. The first of the radiation passes is integrated in the furnace as the post combustion chamber. The convection pass, in which the evaporators, superheaters and economizers are located, may be vertical or horizontal.

When designing a boiler for waste firing it is important to take the special risk of corrosion into account. This risk is mainly due to the release of chlorine from the waste during the combustion combined with condensing components of the metals Zn and Pb. In practice this limits the steam parameters to a maximum of around 400°C and 50 bar.

Corrosion protection
HCl is highly corrosive at high (> 450°C) as well as at low (<110°C) temperatures. To prevent corrosive attacks on the furnace boiler system the heating surfaces in the radiant part is protected by a resistant refractory material and/or welded high-alloy materials. In the radiant passes the flue gas is cooled slowly to a temperature of less than 700°C before it – in the convections pass – is further cooled by the heating surface bundles there.

To prevent low temperature corrosion the feed water should be preheated to minimum 125°C before being introduced in the boiler.

Flue gas treatment (FGT)
In the boiler the flue gas is cooled to 150-200°C depending on the subsequent FGT process selected. The process may be dry, semi-dry or wet.

In or after the FGT system it is possible to recover additional heat in economizers or by condensing part of the water vapor content of the flue gas.

An induced draft fan creates the necessary under pressure through the whole waste to energy plant and a series of emission monitors checks that the flue gas complies with the relevant emission limit values before it is discharged through the chimney. The monitoring results are sent to the CMS system.

On the commercial side
A new era requires new initiatives. The market opens and liberalization sets new rules and demands economically optimal operation of the complex plants in the waste sector.

The increasing liberalization of the waste and energy sectors is already affecting the waste management companies. The shift from monopoly to free competition will be easiest for the companies that have prepared themselves – new business models and new technology will be decisive competitive parameters.

The operation is facing new challenges, when competition increases and becomes more influential in the coming years.

Due to the high investment costs of establishing thermal waste treatment plants, new operation models are becoming more popular and include financing models such as BOO and BOOT.

Modern waste fired power plants are built to last 30 years and to make money for the community or their owner. In order to finance the plants in ways that make them affordable to the operator, the community, county or region requires a solid and sustainable foundation with optimum life-cycle cost.

Availability
As basis of a sound business model, predictability is one of the most important issues. If the revenue is not predictable then the return of investment becomes unpredictable and thus the whole fundament of the business is questionable or at least very risky.

To ensure your operation the availability is maybe the one most important parameter of your whole plant. Availability can be charac-
terized as a combined measure of performance, reliability and effectiveness.

Every hour counts and this is where the profit is made.

Cost-benefit considerations
Proven solutions and technology form the basis for a sound and financial viable project with the highest return on investment for the community. A business model involves many revenue and cost flows and numerous parameters shall be considered for a true cost-benefit scheme.

Implementation costs is of course important but cannot be evaluated alone. Over the lifetime of the plant, the implementation costs will balance out. The cost of operation and maintenance will affect the project in its full lifetime the next 30 years. The secondary side-effects from a non-performance operation are loss of income, penalties, pollution and breach of contracts.

For an optimum return-on-investment, lifecycle costs shall be assessed.

Operation vs. personnel costs
Operating the plant require real people. With a plant designed for low personnel costs a limited number of persons is necessary.

The operators normally work in three shifts with the administrative and maintenance personnel work during the day only. With holidays, illnesses, etc. a total of 8 operators are required. Plant management, administration and daily maintenance are handled by 6 persons. The 2 administrative people also handle waste registration, etc. In total a minimum of 14 persons can manage the plant. This does not include manpower for residue handling, plant cleaning, etc.

For main revision of the plant, extra help will be required from outside entrepreneurs. The contractor can supply assistance for inspection, revision and optimization. In practise the number of persons employed is normally somewhat higher.

Decisive parameters for the selection of technology
In Europe the selection of the right thermal treatment solution is in most cases based upon a selection model where certain parameters are decisive and prevailing for the evaluation.

The parameters related to the overall performance and commercial viability are extracted from each proposal and compared against each other. The technical aspects are often indirectly evaluated thorough other indicators.
The Vølund Waste Technology

Our six elements approach focuses our research & development and engineering activities on the areas that we believe will benefit our customers and end-users and the environment in the most favourable way.

<table>
<thead>
<tr>
<th>Focus area</th>
<th>Objective</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste flexibility</td>
<td>Focus on design to meet local requirements</td>
<td>Adjustability to changing properties of waste</td>
</tr>
<tr>
<td>Thermal design</td>
<td>Modular &amp; clean combustion and boiler technology</td>
<td>Optimization of thermal performance</td>
</tr>
<tr>
<td>Environment</td>
<td>Emission minimization with advanced tools and technologies</td>
<td>Achievement of the lowest possible emission of effluents to the environment</td>
</tr>
<tr>
<td>Performance &amp; efficiency</td>
<td>Life-cycle optimized for lowest impact and highest ROI</td>
<td>Achievement of the highest possible efficiency and value</td>
</tr>
<tr>
<td>Availability engineering</td>
<td>Careful attention to the design of critical components</td>
<td>Optimization of business operation</td>
</tr>
<tr>
<td>Operation &amp; maintenance design</td>
<td>Strong focus on the lowest possible operation &amp; maintenance costs</td>
<td>Easy daily supervision - low overhead</td>
</tr>
</tbody>
</table>

Platform technology

VølundSystems™

BS Technology™

VølundSystems™
THREE CORE CONCEPTS

Our three core concepts are tailor made to fulfill the market needs based on input received from our customers. The three solutions are packaged, scaled and delivered pre-engineered and can be implemented in a short time. This approach reduces the risk factor connected with the technology and its implementation and will significantly attribute to the success of the project. Together with our approved local partners we accumulate and utilize the experience gained from the repeated implementation of projects and application of our technologies.

VALUE Valund Systems Technology

- proven & rock-solid
- lowest operating and maintenance cost
- efficient
- BAT
Packaged & delivered only as pre-engineered modules in the range of 2-5-10-15-20-25-30-35-40 t/h

See overview page 36
See details page 38

OPTIMIZED BS Technology

- highest efficiency
- advanced combustion technology
- minimum loss of ignition
- customized to meet your needs
- BAT
Packaged as pre-engineered modules in the range of 2-5-10-15-20-25 t/h

See overview page 36
See details page 39

ENVIRONMENTAL Rotary Kiln Grate Technology

- meets the stringent environmental requirements
- long residence time at high temperature
- an effective way to destroy contaminants
- sintering of bottom ash
- minimum leaching
- BAT
Packaged & delivered only as pre-engineered modules in the range of 5-10 t/h

See overview page 36
See details page 40
Waste Technology Concept – Overview

Extracting energy from waste is a demanding task as explained earlier in this publication. The result of our strong focus at research and development is innovation turned into mature and well-functioning products. This can however only be done when combined with applied experience and knowledge.

We have developed the technologies and plant components to make them conform to modern requirements with the objective to develop and improve the systems to meet future challenges to waste treatment. All modules are confirming to EU standards.

The features and benefits of the technologies embedded in our modules are listed below. The overview is followed by a detailed description of selected modules and components on the following pages.

<table>
<thead>
<tr>
<th>Module</th>
<th>Feature</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pusher feeding</td>
<td>Efficient, smooth feeding, fuel flexibility</td>
<td>Long lifetime, low cost</td>
</tr>
<tr>
<td>Parallel-flow furnace</td>
<td>Flexible combustion condition</td>
<td>Complete burn-out of gases</td>
</tr>
<tr>
<td>Centre-flow furnace</td>
<td>Compact furnace layout</td>
<td>Lowest cost</td>
</tr>
<tr>
<td>Staged combustion</td>
<td>Low NOx</td>
<td>Low primary NOx formation, low SNCR consumption</td>
</tr>
<tr>
<td>Low excess air</td>
<td>Decrease in the amount of flue-gas</td>
<td>High efficiency and low stack loss</td>
</tr>
<tr>
<td>VoluMix™</td>
<td>Supreme gas mixing</td>
<td>Uniform temperatures and flow in the furnace, burn-out</td>
</tr>
<tr>
<td>Flue gas recirculation</td>
<td>Improved gas mixing and furnace/boiler temperature control</td>
<td>High efficiency, low emissions</td>
</tr>
<tr>
<td>SNCR</td>
<td>Ammonia-based reduction of NOx gases</td>
<td>Reduced FGC costs and reheating of flue gas</td>
</tr>
<tr>
<td>Advanced deNOx control</td>
<td>Integrated NOx reduction</td>
<td>Low NOx emission control. substantial FGC savings</td>
</tr>
<tr>
<td>Inconel</td>
<td>State-of-the-art corrosion protection</td>
<td>High availability, low maintenance cost</td>
</tr>
<tr>
<td>Complex refractory</td>
<td>Newest lining material</td>
<td>Protection with long lifetime</td>
</tr>
<tr>
<td>Multi-fuels</td>
<td>Adjustable to a wide range of fuels</td>
<td>Flexible operating schemes</td>
</tr>
<tr>
<td>Biomass</td>
<td>Co-firing of a wide range of biomass fuels</td>
<td>Renewable energy tariffs, auxiliary fuel for low heating value adjustment</td>
</tr>
<tr>
<td>Hospital waste module</td>
<td>Separate combustion chamber for pathological waste</td>
<td>Added income, independent operation</td>
</tr>
<tr>
<td>Sludge waste module</td>
<td>Co-combustion of sludge waste</td>
<td>Added income</td>
</tr>
<tr>
<td>Variable preheating</td>
<td>Adjustment to calorific value of the waste</td>
<td>Highest degree of burn-out &amp; efficiency</td>
</tr>
<tr>
<td>Module</td>
<td>Feature</td>
<td>Benefit</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Rotating water cleaning in radiant parts</td>
<td>Cleaning with boiler in operation</td>
<td>Maximization of efficiency and availability</td>
</tr>
<tr>
<td>of the boiler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-cooled wear zone</td>
<td>Avoidance of slagging</td>
<td>Reduction of the area of un-cooled refractory, high availability</td>
</tr>
<tr>
<td>Boiler preheating</td>
<td>Faster run-up</td>
<td>High availability</td>
</tr>
<tr>
<td>Vølund Control System</td>
<td>Our basic state of the art control system</td>
<td>User-friendly, well designed, complete and easily operated</td>
</tr>
<tr>
<td></td>
<td>provided on all plants</td>
<td></td>
</tr>
<tr>
<td>ACC – Automatic Combustion Control</td>
<td>Adjustment to non-predictable waste streams</td>
<td>Optimized production, uniform combustion</td>
</tr>
<tr>
<td>CFD optimization</td>
<td>Advanced guidelines for furnace &amp; boiler</td>
<td>Uniform temperature &amp; flow field, extremely low CO emission and corrosion</td>
</tr>
<tr>
<td></td>
<td>design</td>
<td></td>
</tr>
<tr>
<td>Integrated plant design</td>
<td>3D visual modelling of the plant using PDMS</td>
<td>For smooth EPC integration and sub-assembly</td>
</tr>
<tr>
<td>Ferrox®</td>
<td>Stabilization and immobilization of heavy</td>
<td>Environmentally safe disposal of residues</td>
</tr>
<tr>
<td></td>
<td>metals in various residues</td>
<td></td>
</tr>
<tr>
<td>Sintering process</td>
<td>Stabilization and immobilization of bottom</td>
<td>High quality bottom ash, low leaching</td>
</tr>
<tr>
<td></td>
<td>ash residues</td>
<td></td>
</tr>
<tr>
<td>WasteBoost™</td>
<td>Increased steam temperature</td>
<td>High electrical efficiency</td>
</tr>
<tr>
<td>Service Plan</td>
<td>Tailor-made service plan to fit your plant</td>
<td>Availability with the highest assurance and lowest cost</td>
</tr>
<tr>
<td></td>
<td>and need with strategic spare part program</td>
<td></td>
</tr>
<tr>
<td>Simulator &amp; Analyzer</td>
<td>Simulator and analyzer tool for real life</td>
<td>Model based simulation of plant behaviour</td>
</tr>
<tr>
<td></td>
<td>plant experience</td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>Training program tailor made for your staff</td>
<td>Excellent training program for your staff that makes them qualified to</td>
</tr>
<tr>
<td></td>
<td>and compliant with local requirements</td>
<td>handle tangible real-life situations</td>
</tr>
</tbody>
</table>
**Feeding system**
The fuel feeding process – for an ideal, controllable combustion.

Feeding means dosing the right quantity of fuel to the grate for steady combustion and energy production.

Proper feeding is continuous and adjusted to the grate transport capacity to ensure an even fuel layer across the grate, thus enabling a steady energy output.

This consistent feeding ensures minimal environmental impact because it promotes ideal, controllable combustion.

The correct design of the feed hopper prevents waste clogging and ensures a continuous waste transport to the water-cooled chute. Two powerful hydraulic gates are placed between chute and hopper. These gates can be closed in the event of a fire in the chute, and they will close automatically in the event of power failure.

The water-cooled feed chute is made of heavy steel plates. The smooth sides have a negative inclination to ensure a free waste transport through the chute to the feed platform. The chute cooling system makes it fire-resistant.

The grate is fed at a variable rate adjusted to the energy production by means of a hydraulic pusher. The front and top sides of the feed pusher are covered by exchangeable wear plates. The sides of the water-cooled feed chute are covered by exchangeable cast-iron plates up to the height of the top of the feed pusher.

The continuous slow forward movement of the feed pusher at a variable rate adjusted to the energy production results in a steady and continuous feeding of the grate.

**Combustion Grates**
A combustion grate is a transport device with that moves the burning fuel from the inlet through the furnace to the bottom ash outlet. During transportation the fuel is mixed, and combustion air is added. Volatile material is released to the furnace and fixed carbon is burned on the grate.

The grate is an integrated part of the furnace, where the fuel is converted into energy. Our grates are designed to provide reliable transport of the waste from the furnace inlet through the furnace. This ensures drying, ignition, combustion and energy release, and complete burn-out before the bottom ash outlet.

Our combustion grates are unique:
- Our grate systems are designed for: long-term operation, stable and optimum combustion (regardless of fuel quality) and easy access for low-cost maintenance. The burn-out of the bottom ash is very high.
- Since their launch, our grate systems have been continuously updated, and they are...
among the most reliable and optimal solutions on today’s market.

We offer updated spare parts for all our grates and plant optimization for achievement of the best possible combustion with minimal environmental impact.

**DynaGrate®**

DynaGrate® is the result of 40 years of development. The proven air-cooled DynaGrate®, is ideal for combustion of refuse with very high combustion efficiency for greater energy recovery while limiting environmental pollution.

The patented water-cooled DynaGrate® has been through approx. 32,000 hours of prototype operation and approx. 32,000 hours of commercial operation (up to year 2006).

The watercooled DynaGrate® is distinguished by its suitability for high calorific fuel and offers full integration with the air-cooled DynaGrate®, providing complete freedom within the grate area, whether air-cooled, water-cooled, or both.

DynaGrate® is capable of handling all sorts of unsorted waste and has the possibility of biomass co-firing.

**How the grate works**

The grate resembles a staircase. The individual steps – the grate bars – are alternately placed horizontally and vertically. These grate bars are mounted on shafts and, as the grate bars of one axle interferes with the bars of the adjoining axle, a continuous grate carpet is formed. When the axles turn 60 degrees in opposite directions during the movement of the grate, the steps are changing from vertical to horizontal and from horizontal to vertical.

The water-cooled version of the DynaGrate® is outstanding because the cooling system is integrated in the shaft which is also support for the grate bars. Thereby there are no moveable parts under the grate and the risk of uncontrolled stops are minimized.
The changing of the steps from horizontal to vertical and vice versa produces a waving longitudinal movement. This produces optimum turnover and distribution which ensures the drying, conveying, and combustion of the waste bed.

The driving mechanism, which is situated outside the furnace, provides a constant 2 mm gap between successive grate bars in all axle positions. It is through this 2 mm gap that the combustion air is added between the successive bars.

The grate movement ensures that the air gaps are always clean and free from particles. No physical contact exists between the individual bars during the grate movement.

A grate consists of modules which can be combined to grates of various lengths and widths. The largest width of one grate line is 4.8 meters. Larger grate widths can be achieved by placing several lines side-by-side. There are no limits to the number of sections which can be combined or to the grate length. The grate is placed at a 25 degree inclination from the horizontal axis.

The individual sections can be operated independently of one another at a velocity adapted to the energy release. Each grate section is equipped with a complete driving mechanism, including double-acting hydraulic cylinders. The driving mechanism also ensures that the gap between two subsequent grate bars remains constant during the grate movement.

Apart from the obvious process advances with high calorific refuse, the water-cooled DynaGrate® offers full integration with the air-cooled DynaGrate®, which provides BWV's clients with complete freedom toward the grate area, whether it be air-cooled, water-cooled, or combined.

### Air-cooled DynaGrate®

<table>
<thead>
<tr>
<th>Process advantages</th>
<th>Mechanical advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air gap of 1.5-1.8% of the projected area, giving uniform air distribution through individual grate sections. Fuel can be heavy, light or heterogeneous, such as household or non-hazardous trade and industrial waste.</td>
<td>No physical contact between moving grate parts, thus limiting wear and reducing the mechanical forces to which the grate is exposed during operation.</td>
</tr>
<tr>
<td>Agitation of the waste fuel, giving efficient combustion and ensuring very low CO emission</td>
<td>Air-cooled side plates secure their durability. Thermal grate expansion does not affect gaps between outer grate bar and side plate.</td>
</tr>
<tr>
<td>The grate is operated close to sub stoichiometric conditions, giving low bed temperature and thus minimizing bottom ash melting and caking. The result is a high degree of burnout and fine-grained bottom ash</td>
<td>Driving mechanism situated outside the furnace prevents grate siftings, molten tin, aluminum, etc. from fouling and blocking the system. Easy access for maintenance.</td>
</tr>
<tr>
<td>Slow and continuous grate movement, giving small quantities of dust and fly ash</td>
<td>Adjustment and lubrication can be carried out from outside the furnace.</td>
</tr>
<tr>
<td>Minimal unburnt organic compounds in combustion gases</td>
<td></td>
</tr>
<tr>
<td>Uniform and steady combustion results in uniform energy production and an almost constant combustion gas flow</td>
<td></td>
</tr>
<tr>
<td>High availability and long continuous operating time</td>
<td></td>
</tr>
</tbody>
</table>

DynaGrate®
In addition the benefits of Mark 5 the following benefits apply for the Mark 6 version:

**Water-cooled DynaGrate®**

<table>
<thead>
<tr>
<th>Process advantages</th>
<th>Mechanical advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grate surface cooling is independent of combustion; air can thus be added and adjusted for optimal combustion</td>
<td>Cooling water is led to and from the grate through the shaft ends and to the middle sections of the shafts through pipe connections</td>
</tr>
<tr>
<td>Excellent primary air distribution, minimizing excess air and giving reduced quantities of combustion gases</td>
<td>Fans may be smaller</td>
</tr>
<tr>
<td>Minimal corrosion due to low grate surface temperature</td>
<td>No grate bar damage due to temporary cooling system failure</td>
</tr>
<tr>
<td>Constant high flow of cooling water through the grate bars, avoiding local boiling</td>
<td>Separate cooling system for each grate section provides protection against total cooling water failure</td>
</tr>
<tr>
<td>Low differential temperature over the grate results in low thermal stress</td>
<td>Water cooling provides adequate grate durability for combustion of high calorific refuse which causes high thermal stresses in the grate.</td>
</tr>
</tbody>
</table>

As the water-cooled grate has the same pattern of movement, the grate bars have the same fundamental geometric design as the air cooled versions.

The grate bar is machined as a hollow section with channels designed with the purpose of leading the cooling water to the areas with the highest heat load. The large quantity of circulating water, through the individual grate bars, results in a small temperature difference above the individual grate bar in order to minimise the risk of local boiling.

The cooling water flow is led from each shaft through two concentrically placed pipes in the shaft. These pipes lead the water, through a fixed piping system in the middle section of the shaft, to the individual grate bars. The individual grate bars are connected in series. The water is also returned from the grate bars through the piping system. Standard steam hoses are used for leading the water from the fixed piping system outside the furnace and to the shafts, which move over a 60 degree angle. The hoses are placed outside the furnace in order to avoid exposure to hot ashes, melted tin, aluminum, etc. that could damage the hoses. As a result of this construction, any types of flexible connections are avoided inside the furnace.

**Lowest in Europe**

The majority of the WFPPs in Denmark shall be neutral and must not create a profit.

The costs are covered by sales of energy (power and heat) and the remaining cost is covered by the gate fee (tipping-fee). The lower the energy prices the higher the gate fees.

The typical price (gate fee) for thermal treatment in Denmark is 27 EUR per ton. The Danish prices are among the lowest in Europe. The most expensive is close to 200 EUR per ton.
THE VØLUND GRATE

The Babcock & Wilcox Vølund air-cooled grate is the traditional longitudinal beam grate – a thoroughly proven design, highly suitable for continuous high-efficiency combustion of mixed household and bulk industrial waste with minimal emission of harmful substances and maximum energy recovery.

The step grate is of a rigid design, specially developed for heavy-duty and high-temperature operation with a high availability and operational reliability thus ensuring minimal shutdown for routine maintenance and cleaning.

- Minimum emission of harmful substances and maximum energy recovery
- High availability and operational reliability with minimal downtime
- Perfect air distribution and minimal power consumption
- Combustion of all types of waste
- High thermal efficiency
- Handling of unsorted waste
- Low total organic carbon in ash content
- Possibility of biomass co-firing

The grate movement is like a “walking floor” and is unique in its simplicity and low mechanical wear. The combustion air is blown in and up through many small gaps, ensuring perfect air distribution. This results in combustion of the waste with minimal power consumption for air injection and grate movement. Inspection and maintenance during the planned yearly stoppages are also very simple because all servicing of grate bars, grate blocks, grate girders and rollers takes place in the furnace above the grate with hand tools only, and there is no need to work below the grate.

The grate is divided into a feeding section with pusher, a combustion grate and a burnout grate. Our grate has four sections, two of which form the combustion grate at an angle of 15° whereas two sections form the burnout grate at an angle of 7.5° to the horizontal plane. A one metre high vertical grate transition between the combustion grate and the burnout grate ensures that waste lumps are broken up and burned.

The grate sections are integrated into one unit, and all sections are operated and controlled individually. This means that each section has its own grate drive and control system for combustion air.

The individual components used in the grate design are specially developed for highly variable loads and high temperatures. The result is high reliability with minimal downtime.

The water-cooled grate version is fully compatible with the air-cooled version, i.e. with the same modular design, lengths, widths, declination, vertical grate transition, etc. The air-cooled grate blocks on the grate girder are replaced by water-filled blocks, and water-cooled long blocks in the full length of each grate girder.

A grate solution can have partly or fully water-cooled sections. For example, the combustion grate sections can be water-cooled while the burn-out grate sections is air-cooled. The water-cooled grate has relatively few inlet holes for combustion air, which is injected at high speed. This largely prevents burned-out ash and molten metals such as aluminium from falling through the grate down into the primary air hoppers underneath the grate.
The water-cooling of the grate allows the operator to inject combustion air when considered necessary, and also to reduce the injection of combustion air to zero in certain areas because the water is doing the cooling, and the air is used for combustion of the waste only. For the same reason, preheating of the combustion air becomes a very flexible option which can be used for improving and optimizing combustion.

The cooling water enters the bottom of the long block and flows down to the lower end, then rises up and flows along the grate surface in a separate upper chamber to the upper end and then down to the outlet close to the inlet at the bottom.

The heated water is cooled down again, typically in a heat exchanger to preheat the combustion air, or in a water heat exchanger connected to a district heating system.

Air-cooled Vølund grate

<table>
<thead>
<tr>
<th>Process advantages</th>
<th>Mechanical advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good air distribution with low velocity</td>
<td>Minimizing of dust and particle release from the fuel bed</td>
</tr>
<tr>
<td>Minimum emission of harmful substances and maximum energy recovery</td>
<td>Integrated pusher feeding system</td>
</tr>
<tr>
<td>Effective grate cooling from the primary air</td>
<td>Long life time</td>
</tr>
<tr>
<td>Low pressure loss across the grate</td>
<td>Minimizing fan energy consumption</td>
</tr>
<tr>
<td>Minimal power consumption</td>
<td>High availability</td>
</tr>
<tr>
<td>Bulky material</td>
<td>Heavy duty</td>
</tr>
</tbody>
</table>

In addition the benefits of air-cooled grate the following benefits apply for the water-cooled version:

Water-cooled Vølund grate

<table>
<thead>
<tr>
<th>Process advantages</th>
<th>Mechanical advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grate surface cooling is independent of combustion air so that air can be added and adjusted for optimum combustion</td>
<td>Modular grate design</td>
</tr>
<tr>
<td>Minimal corrosion due to low grate surface temperature</td>
<td>Long life time</td>
</tr>
<tr>
<td>Constant high flow of cooling water under the grate surface preventing boiling</td>
<td>Operational reliability</td>
</tr>
<tr>
<td>Low differential temperature over the grate results in low thermal stress</td>
<td>Simple control</td>
</tr>
<tr>
<td>Minimal power consumption</td>
<td>Energy from grate cooling used for air preheating</td>
</tr>
<tr>
<td>Bulky material</td>
<td>Heavy duty</td>
</tr>
</tbody>
</table>

70 years of experience

We have gained extensive experience by supplying more than 500 combustion grates over the last 70 years.

Our clients consider our grate systems are considered by our clients to be very robust and the optimal solution in all plants where they are installed.
As a result of the direction of the flue gas flow related to the waste transport on the grate, furnace geometry is a very important feature for optimizing combustion; in general, there are 3 different furnace/boiler design configurations:

- Counter flow = gas flow in opposite direction of the waste flow
- Centre flow
- Parallel flow = gas flow in same direction as waste movement

We provide two designs:

**Parallel-flow furnace**

The parallel flow principle offers a number of advantages with regard to combustion, including low NO\_x formation. This is important because of the emission limits for NO\_x.

- High combustion efficiency
- Good burnout of solid residues and flue gases
- Improved clinker quality - low leaching ability
- All pyrolysis gases must pass through maximum temperature zone
- Long residence time in reaction zone
- Water cooled furnace with ceramic coated walls or Inconel lining
- Very low CO + NO\_x emission

On the other hand, the parallel flow furnace has some disadvantages concerning heat transmission and water/steam flow conditions. The centre flow configuration is a less complicated design and gives a simpler and better water circulation system and consequently a lower price for the construction of the boiler. Moreover, the size of the furnace wall area is minimized, thereby reducing the cost of refractory or Inconel*, see below.

**Centre-flow furnace**

The Velund centre flow:

- Integrated furnace, post combustion chamber and boiler.
- Optimized flue gas flow in the system:
- Uniform temperatures and heat loads
- Minimized corrosion risk
- Good water circulation
- Optimized for volatile fuels with high heating values

The centre flow furnace succeeded by a boiler with a large radiation pass, which also comprises the post-combustion chamber, is ideal for industrial waste with high heating values. In this way the volatile elements of the fuel can be carried to the post-combustion chamber and burnt out relatively fast. The release of energy will be absorbed by the boiler. Furthermore, the boiler will be able to absorb a great part of the thermal radiation from the furnace. Moreover, a somewhat higher flue gas temperature in the radiation pass will automatically result in a higher surface heat load. In this way the radiation part will be smaller but more efficient.

**Water-cooled wear zone**

Our water-cooled wear zone was primarily developed for our larger hanging boiler, to reduce the area of uncooled refractory in the furnace of our waste-to-energy boilers. The disadvantage of uncooled refractory is that it tends to cause the build-up of large volumes of slag, which may in some cases disturb the operation of the plant. Especially on the lower part of the furnace side walls, build-up of slag may interrupt the waste flow and therefore heavily influence the combustion process. In extreme cases this may shut down the plant. Consequently the advantage of reducing the refractory volume is the resulting reduction in maintenance costs.
The wear zone itself is a fully welded structure with relatively thick-walled tubes and plates. This is primarily to ensure structural stability, but also to provide a large allowance for erosion in order to withstand the inside pressure in the wear zone. The wear zone is either part of the evaporator or part of a separate circuit (such as a district heating circuit). The circulation principle depends on whether the wear zone is part of the evaporator (natural or, in some cases, forced circulation) or part of a separate circuit (forced circulation). In cases where the wear zone coolant temperature is high (i.e. above 230°C), the wear zone is protected with Inconel, a nickel-based alloy with outstanding characteristics as regards high temperature corrosion in waste-to-energy boilers.

**Vølund Boiler Systems**

Babcock & Wilcox Vølund have been designing and building water tube boilers for firing oil, gas or solid fuels for decades. Our wide range of boilers and many years of experience in supplying energy plants enables us to perform any task for our clients. Our boiler range includes:

- Steam boilers for saturated and superheated steam
- Hot water boilers
- Waste heat boilers for waste-fired power plants and gas turbines

The steam boiler converts the flue gas energy into high pressure steam. The arrangement is normally a four-pass boiler with two designs for the last pass. The Vølund boiler features include:

- Optimized and integrated SNCR NOx reduction process
- Very low NOx emission
- Hot water or steam/electricity production

The first two or three passes are dominated by radiant heat transfer. In the last pass convection is the dominant form of heat transfer and Babcock & Wilcox Vølund have two designs for this part of the boiler.

**Convection Pass**

The convection pass of a boiler is characterized by the mode of energy transfer from the hot flue gas to water or steam which is primarily via convective heat transfer. On waste-to-energy boilers the flue gas temperature (at the entrance to the convection pass) is typically below 700°C, which makes it possible to have heating surfaces inside the flue gas, rather than surrounding the flue gas, as in a typical radiation pass.

The arrangement of heating surfaces inside the flue gas as tubes makes it possible to optimize the heating surface area in a given space. This means that the total size of the boiler and, ultimately, the size of the plant building can be optimized. However, the burning of some fuels (such as waste) generates a high concentration of particles, which are sticky at high temperatures. To avoid a blockage in the flue gas path, the flue gas temperature must therefore be below a certain temperature, which limits the use of convective heating surfaces.

Typically, the heating surfaces in the convection pass are cleaned by means of soot blowers or a rapping device, depending on the arrangement of the heating surface. Normally, the convection pass is placed immediately before the economiser, which is also a convective heating surface.

---

**Did you know that...**

- ...for every ton of waste landfilled, greenhouse gas emissions in the form of carbon dioxide increase by at least 1.2 ton?
- ...environmental emissions from WFPs have been reduced up to 99% since 1980?
- ...two tons of waste equals one ton of coal?
- ...Europe currently treats 50 million tonnes of wastes at waste-to-energy plants each year, generating an amount of energy that can supply electricity for 27 million people or heat for 13 million people.

**Fire**

A form of combustion, is a chemical reaction involving two or more chemicals where the molecules will readily react with each other to form additional chemicals. Linguistically, the word fire refers to the combination of the brilliant glow and large amount of heat released during a rapid, self-sustaining burning of combustible fuel. Fire is an exothermic oxidation process by which heat and light energy are given out. Fire starts when a fuel with adequate supply of oxygen or other oxidizer is subjected to enough heat, and it is sustained by the further release of heat energy in the process, as well as a continuous supply of oxygen and combustible fuel.

Fire is extinguished when one or more elements of heat, oxidizer, or fuel is removed; this concept is used in the fire triangle. The unburnable solid remains of a fire are termed ash.
**Horizontal arrangement boilers**

Our horizontal boilers are characterized by the fact that the flue gas in the convective heating surfaces travels horizontally.

One of many advantages of the horizontal design is that the heating surfaces can be cleaned by means of a so-called rapping device which, unlike the traditional steam soot blowers, does not consume steam.

Another advantage of the horizontal design is that the support for the heating surfaces can be placed outside the flue gas. Large steel beams can thus be used for support, making it possible to design larger boilers.

As far as the cleaning of the convective heating surface is concerned, the horizontal design means that dirt from the cleaning process enters the hoppers without passing other heating surfaces on its way, thus reducing the risk of blocking the tube bundles and this result in a better availability.

**Vertical arrangement boilers**

It is characteristic of our vertical boilers that the flue gas in the convective heating surfaces travels in the vertical direction.

The convective heating surfaces in this type of boiler are usually cleaned by soot blowers. Cleaning with soot blowers is very effective and minimizes the risk of blocking of the tube bundles. To avoid sootblower-induced erosion, hot tubes (i.e. superheater and evaporator tubes) are protected by stainless steel tube shells.

It is one of the advantages of the vertical boiler type is that very compact boilers can be designed because the vertical heating surfaces can use a common hopper for ash extraction, thus optimizing performance per ton of steel in the boiler. The arrangement of the tubes means that the tube bundles do not need separate drains - a major advantage in terms of the time required for replacing the bundles.
**CORROSION PROTECTION**

Household and industrial waste are fuels that contains most of the elements in the periodic system. Depending on the character of the combustion, various chemical combinations will be formed.

Depending on local temperatures and oxygen supply, the Na, Ca, Cu, K, Cl, S, Cr, Pb, Zn, Fe, Sn and Al contents in particular will take part in various chemical reactions, the end-products of which may cause corrosion. The use of waste as fuel therefore makes major demands on the plant’s resistance against corrosion. This section deals exclusively with the flue gas area.

Corrosion attacks in a waste-fired boiler can in principle be divided into two main types.

- Low-temperature corrosion
- High-temperature corrosion

Low-temperature corrosion appears in the boiler and on other surfaces where the temperature is under approx. 135°C. It is caused by condensation of the acidic sulphurous and chlorine-containing gases. This type of corrosion is temperature-dependent. New plants are being designed in order to avoid low-temperature corrosion.

High-temperature corrosion (HT-corrosion) is more complex and only appears on the heating surfaces in steam boilers in particular on:

- Evaporator heating surfaces
- Superheater tubes

Depending upon local conditions tube wall temperatures (metal temperature) above 260°C may cause attacks of various HT-corrosion.

In general, increasing metal temperatures and increasing gas temperatures will increase the corrosion rate, which is measured in mm tube wall per year, where the metal temperature being the most important factor.

The corrosion rate is influenced by the thickness and composition of the ash layer, the HCl and H₂SO₄ content of the gas, and the surplus/deficiency of oxygen in the gas at the tube wall.

The corrosion rate can be reduced by using high-alloy tubes and/or by protecting the tubes with refractory lining or welded high-alloy materials such as Inconel®. The choice between refractory lining and Inconel® depends on:

- The plant size
- Regulatory requirements on the retention time of the flue gases
- Variation in heating values
- Which type of heating surface and design is chosen

If refractory lining is chosen as protection, the choice between the different lining types will be based on requirements regarding the resultant heat conduction, the residual porosity and the smoothness of the lining surface.
ASH SYSTEM
The burnt-out, sterile bottom ash leaves the grate through a refractory lined clinker outlet. Standard cooling is achieved in a water tank, equipped with a steel belt conveyor or pusher system that transports the bottom ash from the tank. The water tank also forms an air-tight seal between the hot furnace chamber and the cold and clean ambient air in the building.

Some ash and heavy, fine particles such as grit, sand, glass and molten metals (called grate siftings) fall down through the air gaps in the grate surface into the combustion air hoppers under the grate. This small quantity of grate siftings is similar in properties to the bottom ash, and the grate siftings are normally mixed into the bottom ash and transported out from the plant via a common conveyor system.

Magnetic separators and screens removes scrap iron and over-size items from the bottom ash. The resulting quality of the bottom ash permits its use as secondary aggregate building material, for example as road or parking lot foundation. The bottom ash is normally aerated and carbonized in big piles by atmospheric air for several months before being used.

VØLUND ROTARY-KILN TECHNOLOGY
Effective reduction on effluents takes place by thermal treatment at high-temperature with a long residence time. Essential to the technology is the rotary kiln where the toxic elements are destroyed by thermal treatment while extracting the energy content. During the process the residual bottom ash is sintered and the quality of the ash is improved with stabilization of heavy metals.

<table>
<thead>
<tr>
<th>Rotary kiln technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Process advantages</strong></td>
</tr>
<tr>
<td>Slow rotation, variable speed, ceramics lined cylinder</td>
</tr>
<tr>
<td>High temperature long residence time for complete char burn-out and low emissions</td>
</tr>
<tr>
<td>Sintering process</td>
</tr>
<tr>
<td>Total dioxin level</td>
</tr>
</tbody>
</table>

Bottom ash for roadbuilding
The slag from a WFPP can be utilized for construction and road building. The slag is a result of the combustion process in a WFPP and corresponds in weight to 20% of the original waste input. Iron and other metals are automatically removed from the slag in a sorting process and the resulting sorted slag is reused in construction projects.

In 2003 the Danish WFPPs produced 645,000 tons of slag, of which the 98% was reused as construction material.
**NO\textsubscript{2} EMISSIONS**

The EU emission limit value for NO\textsubscript{2} emission is 200 mg/Nm\textsuperscript{3} NO\textsubscript{2} 11% O\textsubscript{2}, dry. In order to meet this limit under all operational conditions it is necessary to remove NO\textsubscript{2} from the flue gas. Babcock & Wilcox Vølund has carried out an extensive R&D program. Various technologies were investigated, such as water injection, staged combustion, flue gas recycling, re-burning and selective non-catalytic reduction (SNCR).

**SNCR – Selective non-catalytic reduction**

This process is used for reduction of the NO\textsubscript{2} and is based on injection of Ammonia or Urea into the post-combustion chamber (PCC). The ammonia will reduce the NO\textsubscript{2} to nitrogen, and the ammonia will at the same time be oxidized to nitrogen. This means that both the NO\textsubscript{2} and the injected ammonia will be converted to the harmless gas nitrogen and water, which is the main component in the atmospheric air. This reaction can only take place within a certain temperature range in the PCC. Therefore knowledge of the temperature profile in the PCC is extremely important for the design and operation of an SNCR system. The temperature range for SNCR is 850 – 950°C as illustrated below\cite{18}.

The total NO\textsubscript{2} reduction with ammonia or urea depends on three classical reaction mechanisms and thereby also on the following design and operational parameters:

- Temperature
- Turbulence
- Time

Another important factor is the waste composition including: the calorific value and the amount of nitrogen bound in the waste.

With our integrated SNCR system it is possible to achieve 70 – 80% NO\textsubscript{2} removal with a slip of ammonia (un-reacted ammonia) within the range of 5 – 10 mg/Nm\textsuperscript{3}.

**Why not Selective Catalytic Reduction?**

Unless specific circumstances prevail, Vølund recommends that NO\textsubscript{2} be reduced by SNCR. The investment in SCR (Selective Catalytic Reduction) is high, and the system is complex. Maintenance is expensive and consumables in addition to ammonia are natural gas (or low sulphur oil) and power due to a high pressure drop in the catalyst. At the same time the service life of the catalyst is only 4 – 5 years. On the other hand the SCR removes dioxins from the flue gas.

The SCR technology is based on the same chemical reactions as the SNCR. The difference is that the reaction takes place at a much lower temperature and involves a catalyst as a medium. The reaction temperature for the SCR is within the range of 200 – 350°C, depending on the flue gas composition. This typically is a higher temperature than the flue gas temperature from a modern high efficiency waste incinerator. SCR systems achieve more than 90% NO\textsubscript{2} removal with an ammonia slip of less than 5 mg/Nm\textsuperscript{3}.

Significant savings in investment and operating costs are obtained using the BWV Advanced deNO\textsubscript{x} control. This is typically 10 times cheaper compared to using NO\textsubscript{2} cleaning based on SCR.

**Advanced deNO\textsubscript{x} control**

A combination of our VoluMix™ principle and our FGR system with the BWV parallel- or centre-flow furnace staged combustion design will typically produce a NO\textsubscript{x} concentra-
tion in the close vicinity of 200 mg/Nm³, 11 vol% O₂ dry without any denOₓ control[19]. This means that with a BWV furnace design combined with SNCR, the NOₓ emissions can be as low as 40 – 60 mg/Nm³.

Basically, the SNCR system consists of an ammonia storage with ammonia pumps and nozzles at different levels in the PCC. The investment in an SNCR system is rather low, and the equipment is simple and easy to maintain. The only consumable is the low cost ammonia base used. Furthermore, our research has shown that this technology has a great potential for integration with other flue gas cleaning technologies. Thus it is subject to our continued research and development activities within the company and in cooperation with other companies.

**VoluMix™**

With this technology secondary air is injected into the combustion zones at multiple places at different angles and air velocities. The flow fields include double, rotating swirls in the post-combustion chamber (PCC). The swirl method ensures good gas mixing and makes certain that we achieve longer residence time, complete CO burn-out together with fast O₂ control and uniform flue gas temperature – even in the corners.

The position of the VoluMix™ jets is an important control factor in the flue gas flow pattern in the PCC. The jets are placed according to several design requirements.

The jets in the front of the furnace ceiling are arranged with the purpose of moving hot gas to the front and penetrating into the hot layer above the middle grates. The purpose of the jets on the rear wall is to create turbulence in the inlet to the post combustion chamber and to suck hot combustion gases from the middle grates to the rear wall. Several rows of jets are placed in the inlet to the post combustion chamber. This creates a large area with good turbulence. Opposing jets are arranged to achieve very good mixing characteristics, provision of oxygen, and turbulence for CO burn-out.

Many design objectives can be listed, but the general idea is to gain maximum life time expectancy, low emissions and high thermal efficiency. These objectives result in a number of flow requirements:

- Good mixing in the furnace
- Reduced temperature peaks in the furnace for minimum thermal NOₓ formation
- Staged combustion
- Avoidance of hot spots in furnace and boiler which would speed up corrosion
- Obtaining turbulent conditions in the throat for optimum burn-out
- Even temperature and velocity distribution in the passes in order to maximize heat transfer and residence time
- Avoidance of impingement of particles on the walls in order to minimize corrosion/erosion.

The design and positioning of the VoluMix™ jet nozzles are carried out on the basis of a CFD flow field and combustion analysis[19]. The method enables us to achieve the lowest CO figures on the market - a measure of combustion quality.

**Excess Air**

The Vølund boiler design with staged combustion, centre/- or parallel flow furnace, FGR, etc., allows us to operate with a very low excess air ratio, which results in O₂ levels of 4-5% wet with low CO emission and no CO corrosion!
Waste combustion is one of the most complex combustion processes. The process in a burning refuse bed includes:

- Drying
- Ignition
- Pyrolysis
- Gasification
- Gas-phase combustion
- Solid-phase combustion

There is a strong connection between the burning rate and the amount of primary air, including the total amount of primary air and the distribution of air to the individual grate zones. The major difficulty in relation to the control and operation is the adjustment of operating conditions to compensate for changes in the waste quality and quantity.

The main objectives of our ACC system are to maintain a uniform flue gas temperature profile – thus reducing the size and number of high temperature regions and to control the primary combustion air distribution and ratio of primary to secondary combustion air flow. Furthermore, the system controls and adjusts the position of the main combustion zone to meet variations in the waste heating value. The system sensors are IR cameras and the signals are digitized and analyzed in a neural network-based control system with feed forward signal to the Vølund Control System\(^\text{\textsuperscript{[20]}}\).

The benefits of using the ACC system are:

- Increased annual waste throughput
- Improved steam production with more constant production rate
- Reduced stress on the turbine, less maintenance and stops
- Reduction in the use of auxiliary fuels
- Increased lifetime of boiler & refractory through a more constant thermal exposure of the plant components
- Reduction of excess air
- Reduced emissions
- Optimal quality of ashes through systematically controlled burnout
- Increased thermal efficiency
- Increased availability
Cleaning during operation
Slagging is one of the most critical operating problems related to the combustion of waste fuels.

Our solution to the slagging problem is two fold: 1) effective boiler CFD designs with minimal particle carry over and 2) advanced radiant water-jet cleaning systems for cleaning of the radiant part during operation. The system cleans the surfaces with jet sprays through special rotating nozzles on hoses lowered through the top of the boiler. The process and the system is fully automatic.

WasteBoost™
With increasing focus on power production and favourable tariffs in many markets there is a need for maximizing electricity delivery to the grid. Babcock & Wilcox Vølund continuously works to increase the steam parameters and to increase power efficiency up to 30%.

WasteBoost™ is used to increase the efficiency by using an external super heater powered by our updraft gasifier. The fuel can be biomass as for examples impregnated or contaminated wood.

The system also supports thermal waste treatment companies that wish to expand their business to treat certain wood wastes.

Vølund Service Plan
Maintaining the environmental and operating performance of your plant requires a rock-solid service plan. After we have delivered your plant we can assist you in keeping your asset in top shape. Our Service Plan program will protect your plant and assets.

Service Plan includes training of your staff, revision service, supervision, strategic spare part program and plant monitoring. Our trained engineers will assist you at any time on site.
Training – real life simulator based

Running your new advanced plant including the latest technologies requires training and hand over of experience from our experts. Your staff needs training of real life situations in a controlled environment. Our advanced simulator based training includes an exact simulator based model of your plant. During the first sessions with your staff we educate your instructors and enable them to conduct the next training sessions, using the simulator and training tools.

The simulator based training will take your operation and maintenance people through conditions of function and maneuvers not possible during normal operation. This what-if-I-do-this-or-that-happens situations will enable your staff to get the most out of the system and avoid unwanted situations, thus improving safety, performance and efficiency.

The operating staff gets a thorough knowledge of the energy and environmental aspects related to a WFPP facility. The operation of a WFPP involves the handling of large amounts of energy and significant environmental issues. Operational irregularities can have significant environmental impact and economic consequences. During the training program the personnel will be prepared for better identification of irregularities and other unexpected operating situations. The staff is also trained to use the simulator as a tool for analysing possible improvement actions before they are implemented. During the training a large part of the theory and experience is tried out on the simulator.

Waste Boost™ - superheating of the steam parameters with a Vølund biomass gasifier.
## Three Concepts

### Concepts Overview

<table>
<thead>
<tr>
<th>Optimized for</th>
<th>Low initial investment</th>
<th>Performance</th>
<th>Minimal Environmental Impact</th>
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<tbody>
<tr>
<td>Technology</td>
<td></td>
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<tr>
<td>Grate technology</td>
<td>Pusher Vølund grate</td>
<td>Pusher DynaGrate®</td>
<td>Feeding Grate Vølund Rotary Kiln</td>
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<tr>
<td>Grate Type</td>
<td>Pusher Vølund grate</td>
<td>Pusher DynaGrate®</td>
<td>Feeding Grate Vølund Rotary Kiln</td>
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<td>Air+Water</td>
<td>Air+Water</td>
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<td>1.5-1.8</td>
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<td>O₂ (%)</td>
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<td>Grate siftings (% of input)</td>
<td>&lt; 2</td>
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<td>Steam temperature</td>
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<td>Steam pressure</td>
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<tr>
<td>AWT Features</td>
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<tr>
<td>Staged combustion</td>
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<tr>
<td>VoluMix™</td>
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<tr>
<td>Integrated FGR (Flue gas recirculation)</td>
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<td>SNCR</td>
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<td>Advanced deNOx control</td>
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<td>ACC (Automatic Combustion Control)</td>
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<td>In operation cleaning</td>
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<tr>
<td>Water-cooled wear zone</td>
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<tr>
<td>Complex refractory</td>
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<td>Inconel®</td>
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<td>Service Plan</td>
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<tr>
<td>Emissions</td>
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<td>&lt; EU</td>
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<tr>
<td>Flue gas volume</td>
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<tr>
<td>Leaching clinker</td>
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<tr>
<td>TOC</td>
<td>&lt; 2</td>
<td>&lt; 2</td>
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<tr>
<td>Dioxins &amp; Furans</td>
<td>✓</td>
<td>✓</td>
<td></td>
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</tbody>
</table>

### Price vs. Performance

1. Investment cost
2. O&M Cost
3. Efficiency
4. Availability
5. Waste flexibility
6. Emissions
7. AWT modules
8. Cost-performance ratio

### Bottom line

- Short stop intervals: 4000 hours
- Maintenance intervals: 8000 hours
- Maintenance cost: < 1.5 %
- Operating costs: < 0.8 %
- Availability: 8000 hours
- Reliability: High
- Investment cost: Low
- ROI: High
FEATURES OVERVIEW

For an Optimized solution
Being a technology supplier, Babcock & Wilcox naturally take up the challenge to offer a modern, functional concept with practical and economic advantages.

This especially applies to environmental demands. It is also important, however that the mechanical equipment harmonizes with the architecture of today.

The architectural design of a WFPP has thus to adapt to the surroundings and to the environment in a harmonious and functional way. This calls for a new plant design, were the planning and construction work ensure that i.e. control and manoeuvring operations can be carried out safely and easily. Further the plant design shall be optimized such that cable and pipe layout and the component placing make up a well balanced plant.

The Optimized solution – our eco-friendly answer to thermal waste treatment. Below is a plant overview with selected embedded technologies and features.
Skovde community in Sweden...

...decided in 2002 to establish a company that should build and operate a new waste-fired CHP plant in Skovde. The transportation and landfilling of MSW and industrial waste from the communities of Skovde, Hjo, Tibro and Karlsborg should end. Instead, the energy in the waste was to be utilized and supplied as heat to the existing district heating system. The WFPP will mainly replace oil and wood chips as fuel in the heat supply. The new fuel is both MSW, commercial, and industrial waste. The plant also produces power that is supplied to the grid.

Ingemar Linusson, Project Manager, Skovde municipality says: "We have put great efforts into optimizing the new plant with respect to environmental and technical performance, design and economy. This will give us a well-functioning plant that will contribute to the community with cleaner air, better economy and safer energy supply."

Our recognized and well-proven technology is designed to fit the modern operating schemes with low capital and operating costs. Performance is among the best and the environmental performance meets the new stringent EU standards. The solution is scaled and packaged in 2-5-10-15-20-25-30-35-40 t/h systems ready for implementation.

Features
- Centre furnace design for optimum clinker quality and low NOₓ emission
- Optimized boiler and furnace design for reduced corrosion
- VoluMix™
- Individual adjustment of grate speed and combustion air
- Pusher for smooth feeding
- Advanced high-temperature protection of furnace and boiler
- Vølund Combustion Control Monitoring system
- Automatic, hydraulic grate adjustment system for good air distribution and minimized grate siftings

Benefits
- Long lifetime of grate
- High availability of 8000 hours
- Designed according to BAT
- Good bottom ash and flue gas burnout
- Low maintenance and operational cost

Skovde, Sweden

| Design capacity  | t/h | 8.7 |
| Daily capacity   | t/d | 156 |
| Annual capacity  | t/a | 52,000 |
| Lower calorific value | MJ/kg | 8.5 |
| Boiler steam output | t/h | 28 |
| Boiler pressure   | bar(a) | 16 |
| Steam temperature | °C | 217 |
| Electrical output | MW | 1.7 |
| Heat output       | MW | 18 |
| Availability      | %  | > 98 |
| Clinker           | t/y | ~ 10,500 |
| Fly ash etc.      | t/y | ~ 1,400 |
With focus on operating performance these solutions have been optimized. Standard packaged in 2-5-10-20-25 t/h, but still tailored to the customers’ needs with customizable features.

DynaGrate® with water-cooling matches the most demanding properties of municipal waste for maximum energy extraction and best possible combustion control. The heat extracted for cooling the grate is always returned into the process.

Furnace and boiler design are optimized for availability and performance by means of computer models. This guarantees good burnout of the flue gas and uniform boiler load.

Plant integration modeling in 3-dimensions is standard for smooth project implementation and a special Vølund Service Plan module is available for this solution.

### Features
- **VoluMix™**
- Inconel corrosion protection
- Patented pusher technology for smooth feeding and homogeneous energy production
- Intelligent combustion control system for maximum energy production
- Integrated SNCR (Selective Non-Catalytic Reduction) – nitrogen oxides reduction based on ammonia/urea
- Flue gas recycling and low excess air combustion
- Water-cooled grate and wear zone for optimum availability

### Benefits
- Long lifetime of the grate
- Highest availability of 8000+ hours
- Long intervals between maintenance
- Highest thermal efficiency available
- Lowest consumptions
- Tailormade to fit your needs

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#### RenoNord, Denmark

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design capacity [t/h]</td>
<td>20</td>
</tr>
<tr>
<td>Daily capacity [t/d]</td>
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<tr>
<td>Annual capacity [t/a]</td>
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<td>Lower calorific value [MJ/kg]</td>
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<tr>
<td>Steam temperature [°C]</td>
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<tr>
<td>Electrical output [MW]</td>
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<tr>
<td>Heat output [MW]</td>
<td>43</td>
</tr>
<tr>
<td>Availability [%]</td>
<td>&gt; 99</td>
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<tr>
<td>Clinker [t/y]</td>
<td>~ 30,000</td>
</tr>
<tr>
<td>Fly ash etc. [t/y]</td>
<td>~ 2,500</td>
</tr>
</tbody>
</table>

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*RenoNord in Denmark...*

...decided in 2002 that in order to serve the community of Aalborg in Denmark a new WFPP was needed to extend its facility.

The new plant will replace two existing lines from 1981. The existing line 3, which delivered in 1991, will be maintained as a spare line.

The plant chose our Optimized solution for maximum thermal performance and safer environmental operation. The air-cooled DynaGrate®, is prepared for later conversion to water-cooling. The waste is fed to the grate by a pusher, which ensures homogenous feeding without the risk of back-fire.

The new plant commences operation in 2005.
This next-generation waste processing concept for improved residue quality is based upon the Vølund rotary kiln (R/K) process technology and is an optimized thermal treatment method. This eco-efficient technology excels in a number of ways, including the reduction of the total CO₂ and dioxin levels, and includes the sintering of the bottom residual ash.

The waste is dried, pyrolyzed and mostly burned on the waste grate. The remaining fixed carbon is burned in the R/K. In order to burn the residual carbon in the clinker, a long residence time (45—60 min) and high temperature (950—1,050°C) are required. This cannot be achieved on a grate alone.

By heating the clinker to the softening temperature in the R/K, metals with low melting point, heavy metals and alkalis are evaporated from the clinker. Furthermore, the molecular diffusion rate is very high in near melt clinker. This sintering process ensures a very homogeneous clinker and the best clinker quality at the softening point.

Features:
- Proven Vølund Rotary-kiln technology
- Co-generation for highest efficiency
- Sintering of bottom ash residues at a temperature of 1,000°C with no additional fuel and no pure O₂ addition
- Wide, flexible firing scheme for low-to-high calorie refuse
- High throughput design, multiple line redundancy

Benefits:
- Normal bulky household waste
- Tolerance to varying calorific values
- Very low loss of ignition
- High quality residues, volume reduced up to 90%
- Requires no sorting and pre-processing
- Destruction of pathological and semi-hazardous wastes
- Sintering process with fixation of heavy metals
- Excellent burn-out TOC << 1%

The MAPO Ressource Recovery Plant, the newest plant in Korea, is an example of a best evaluated solution. The MAPO plant is located in the heart of Seoul between the two existing landfills and next to the Han river. The town selected the Vølund rotary-kiln technology for this advanced plant to serve the waste management of the Mapo-gu district. The main objective was to select a technology with the highest efficiency and the best environmental performance, including the lowest emissions with the best bottom ash quality for minimum leaching. The chosen technology should also be proven with actual references.

The dioxin content at boiler outlet is expected to be less than 2.0ng-TEQ/Nm³ and at the chimney it is less than 0.01ng-TEQ/Nm³.

Halla Environment & Energy has constructed this plant.

<table>
<thead>
<tr>
<th>MAPO, Seoul, Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design capacity</td>
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<tr>
<td>Daily capacity</td>
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<td>Steam temperature</td>
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<tr>
<td>Heat output</td>
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<tr>
<td>Availability</td>
</tr>
<tr>
<td>Clinker</td>
</tr>
<tr>
<td>Scrap iron</td>
</tr>
<tr>
<td>Fly ash etc.</td>
</tr>
</tbody>
</table>
Behind the scene

The focus of our engineering resources

The Technology Group is constantly working with product development projects in order to improve our present technology and maintain our leading position within waste-to-energy systems. Our goal is to supply a modern, reliable technology which fulfills the requirements and minimizes the risks for investors, developers, and operators. Our objective is to continuously develop our combustion grate, furnace and boiler systems. Our product development is concentrated on the following areas:

- Advanced computer modeling of combustion systems and boilers - Computational Fluid Dynamics applied to waste treatment processes
- Improvement of the water-cooled combustion grate and furnace design for waste combustion
- Use of Plant Design Management System (PDMS)
- Plant heat & mass balance simulation.

Waste combustion – what is this grate thing?

Thermal waste treatment is one of the most complex combustion processes. The processes in a burning refuse bed include: drying, pyrolysis, ignition, gasification, solid and gas combustion. The figure below is a simplified illustration\(^\text{21}\) of the refuse bed processes on the grate.

The process is mainly controlled by mass and heat transfer. In the illustration a large part of the grate length has a deficit of oxygen (fuel rich condition) resulting in formation of combustible gases. The energy of the waste is released partly in the fuel layer and partly in the furnace room as combustible gases. Although the thermal treatment process in the waste on the grate receives a certain amount of excess combustion air, gasification will take place in certain areas.

Consequently, controlling the injection of primary air enable distribution of the individual reaction zones to obtain optimal combustion.

Staged combustion

Staged combustion can be provided in several ways. One method for staging the combustion is a stepwise addition of combustion air to prevent complete combustion from taking place at the first stage.

The changed stoichiometric rate will result in an increased flow of unburned gases into the furnace room. The energy released from the combustion process will move from the fuel bed to the furnace room, and a large part of the furnace room will be operating under slightly fuel-rich conditions.

Simplified process of the combustion process that takes place on the grate

Did you know that...

- the first waste incineration plant in Denmark was commissioned in 1903!
- In 2005 a total of 29 modern WFPPs are in operation in Denmark and combusts a total of 3,3 million tons of waste every year!
- By combustion of one ton of waste a WFPP can produce approximately 2 MWh (75%) district heating and approximately 2/3 MWh (25%) electricity.
The amount of chemically bound nitrogen in the waste (fuel-N) has a considerable influence on the total amount of NO\textsubscript{x} formed during the combustion process. Approximately 80% of the fuel-N will be released during the pyrolysis (volatile components), and 20% will remain in the de-volatized waste. The volatile nitrogen components is converted into different nitrogen compounds, mainly ammonia, NH\textsubscript{3}, and hydrogen cyanide, HCN\textsuperscript{[22]}.

These two compounds are key elements in a very complex reaction mechanism. NO\textsubscript{x} reduction through air staging is quite complex and involves more than 20 intermediate chemical species and over 200 reactions. A simplified diagram\textsuperscript{[23]} of the main NO related reactions under these conditions are shown below.

The fate of the HCN is determined mainly by the availability of oxidants, generally in the form of O and OH radicals. If oxygen is available, the predominant reaction product will be NO. If oxygen is not available, as during staged combustion, some of the volatile nitrogen components will be converted into N\textsubscript{2}. Fuel-N in the de-volatized waste will either be oxidized to NO\textsubscript{x} or converted to N\textsubscript{2} depending on the combustion conditions.

For thermal waste treatment 5% to 50% of the nitrogen content in the waste will be converted to NO\textsubscript{x} and become a part of the total contribution to the NO\textsubscript{x} emission from the plant.

The flue gas recycling also makes it possible to reduce the excess air flow and control the flue gas temperature in the furnace. The result is a lower flue gas loss and consequently a higher total thermal efficiency of the plant. Moreover, the limitation of temperature peaks and a lower level of oxygen in the furnace will result in less NO\textsubscript{x} emission.

Recycling of the flue gas to the combustion zone causes both an increase of the total heat capacity for the combustion gas, and consequently a reduction of the flame temperature, and a reduction of the O\textsubscript{2} partial pressure in the combustion zone.

According to the Zeldovich mechanism both of these alterations will reduce the thermal NO\textsubscript{x} formation. It will typically be possible to achieve a 30% reduction of the NO\textsubscript{x} emission. The result strongly depends on the content of chemically bound nitrogen in the waste and on the thermal load in the furnace room. In many cases the reduction is less, 10% -20%, and the effect is mainly due to a decrease in the O\textsubscript{2} partial pressure. The amount of high temperature (>1400°C) volumes in the furnace is very limited and the thermal NO\textsubscript{x} formation is low.

**Flue Gas Recirculation**

Babcock & Wilcox Vølund has developed an integrated flue gas recycling (FGR) system for use in combination with staged combustion for furnace temperature and pollutant emission control. The main advantages of using this technology are:

- Expansion of superheating range
- Improved plant efficiency by replacing secondary air by recycled flue gas
- Reduction of the NO\textsubscript{x} emission
- Improved mixing and thereby reduced product of incomplete combustion (TOC).

In new thermal waste treatment plants the thermal furnace room control may be achieved by recycling of flue gas. Part of the cooled flue gas is taken out after the electrostatic precipitator and is led back to the furnace. The recycled flue gas is injected in the same way as secondary air to the furnace room and post-combustion chamber and is used for cooling and effective mixing of combustion products. This makes it possible to reduce the amount of secondary air.

**Modern design tools for waste fired power plants**

In order to achieve the best possible design of the system, Babcock & Wilcox Vølund uses Computational Fluid Dynamics (CFD) programs as a tool for detailed engineering. CFD simulation is an effective method for evaluation of different design alternatives that are otherwise too expensive, time consuming or impossible to test. We also use Plant Design...
Management System PDMS programs for effective plant design.

**CFD optimization**
Computational fluid dynamics is a method used for solving the Navier-Stokes equations with numerical methods. Also included in the method are discrete phase models such as transport, evaporation, and combustion of particulate.

The exhaust gases from the combustion are composed primarily of carbon dioxide, oxygen, nitrogen, and water vapor. Depending on the waste composition, however, the exhaust gases may also contain undesirable constituents that are by-products of the combustion process, such as acid gases (HCl, HF, SO₂, and NOₓ), dioxins/furans, suspended solid particles with a potential content of condensed metals (Cd, Hg) and unburned non-volatile organics. The exhaust gases may also contain products of incomplete combustion such as unburned organic matter, and CO. The levels of these combustion by-products are very plant specific and depend on a variety of factors such as waste composition and combustion system design as well as operating parameters (e.g. temperature and exhaust gas velocity). For combustion to be an effective method for destroying hazardous components in the waste, the combustion must be complete also in the gas phase. Three critical factors ensure the completeness of combustion:

1. the temperature in the furnace room,
2. the length of time the waste/gases is maintained at high temperature,
3. the turbulence or degree of mixing, of the combustion gases.

The secondary air jets contribute with by far the largest part of the momentum flux into the furnace.

The furnace is the critical component with regard to optimizing the performance. The philosophy of the Babcock & Wilcox Vølund design concept is to create conditions in the furnace that will ensure:

- Movement of hot gas to the front of the furnace for drying/ignition purposes
- Create fuel rich conditions in order to minimize NOₓ formation
- Good mixing above the hot centre grates in order to minimize production of thermal NOₓ
- Creation of oxygen rich conditions above and in the last bed for good char burn-out in the clinker
- High radiant heat flux to the last grate in order to facilitate good char burnout in the clinker
- High turbulence conditions in the throat for good burnout of combustible gases and particles

The combination of Babcock & Wilcox Vølund’s many years of experience and the use of the most advanced design tools and pollutant control technologies results in the best available waste to energy plant on the market.

**PDMS - Integrated plant design**
We use pre-modeling of the plant layout to ensure smooth integration and optimal layout of systems, components and piping etc. The Babcock & Wilcox Vølund plant design utilizes 3D modeling with the PDMS plant design management system. With this system we can take you on a walk-through of your plant before it is built, but in a photo realistic 3D environment. You can walk around the galleries, look at your equipment and go inside the boiler. The example plants presented in this paper are all modelled with PDMS for your insurance.
On the horizon

The focus of our R&D activities

The Research and Development Department at Babcock & Wilcox Vølund is highly dedicated to developing state-of-the-art technologies for the future. Our main areas of focus are novel approaches to the conversion of Municipal Solid Waste to energy, and gasification/combustion technology.

Most of our R & D projects are carried out in cooperation with national and international universities, research institutes and various business partners. Several projects involving other areas of our company are also in progress. The projects are frequently sponsored in part by national and international research programmes, and actual experimental work is carried out at the facilities of partners and customers and, of course, at our own facilities.

Our research and development is concentrated on the following areas:

- Advanced computer modeling of combustion systems and boilers
- Advanced Combustion Control systems and harmful emissions control
- Partnership in a long-term basic research program with the CHEC group at the Danish Technical University, DTU.

Electrical efficiency

In Denmark thermal treatment of waste has been an important part of our waste handling, and as a consequence of EU-legislation the share of waste to be combusted is increasing in Europe. The development of technologies which increases the energy utilisation of waste combustion and simultaneously reduces the environmental impact is thus a natural and important consequence of the influence that thermal treatment of waste has in our society.

The electricity production and handling of the bottom ash are two of the most important parameters influencing on the economy of a waste to energy plant.

In Southern Europe on the whole the electricity production in waste to energy plants are essential for the overall economy of the plant and often decisively whether the plant is being erected or not. In several Northern European countries (e.g. Sweden or Germany) a considerable contribution is given for electricity produced from waste. And in Southern Europe the value of heat is very low and the electricity production will thus be the most important income together with the reception fee (the charge a waste to energy plant collects for treating waste). Electricity generated from waste incineration may replace fossils and thus reduce the CO2-emission and contribute to reach the Kyoto objectives. In Denmark it is a demand that all new major waste to energy plants must be combined heat and power plants. The electricity production typically makes up for 10-20% of the revenues at a Danish combined heat and power plant.
Today BWV work on a project to increase the super-heating temperature in the boiler of a combustion plant. An increase of for example 50°C of the super-heating temperature will be able to increase the electrical efficiency by approx. 4%. An increase of the electrical efficiency will thus influence substantially on the economy of the Waste Fired Power Plant.

**Bottom ash**
The bottom ash makes up the biggest amount of ash from waste combustion and consists of non-combustible constituents. In certain countries, e.g. Denmark, the bottom ash is being recycled and used for constructional works. In other countries the ash is being deposited which typically costs around 60-110 EUR each tonne. One of the environmental impacts of the ash is the leaching of heavy metals. Another aim of the R&D project is to obtain a reduction of the heavy metal leaching in order to reduce the environmental impact and save costs for cleansing of percolate from deposits. In Denmark the maturation period of bottom ash in order to obtain an acceptable heavy metal leaching (especially lead) can be avoided or reduced.

**Next generation sintering process**
To stabilize the residual bottom ash and improve the ash quality, our method of sintering in a rotary kiln is used to stabilize heavy metals.

The physico-chemical treatment causes changes, not only in porosity and density, but also in the incorporation of metal ions into the silicate and oxide lattice of the matrix. The Sintering process is a good solution and a cost effective alternative to melting facilities with very high initial and operational cost with complicated facilities and very high energy consumption.

- Testing of sintering of different residues as for example flyash
- Substantial reduction of TOC
- Significantly improved bottom ash quality as regards leaching of heavy metals.
- Significant improvement of fixation of heavy metals at a temperature of 1,000
- One hour residence time, slow rotation for mixing (2~6 rph).

Waste is the only fuel, no oil, gas, coal or electricity and no pure O₂ is added.

**Ferrox® - stabilization**
The managing of the gas treatment residues is usually associated with high costs and an environmental risk. The Ferrox*-process is developed to manage combustion residue in an environmentally safe way at a low cost. Compared to the costs of traditional cement stabilization, the Ferrox*-process has the advantage that it reduces the overall mass of the residue that has to be disposed of combined with a good stabilization.

The Ferrox*-process stabilizes the residues, whereby the release of heavy metals and salts is substantially reduced compared to the untreated residues.

The process does not yield a new heavy metal polluted waste stream, but immobilizes the heavy metals in the residue. The salts are extracted from the residues during the process. The result is a stabilized residue, which is easy to dispose of in an environmentally safe way.
ACC – Automatic Combustion Control system, a system that optimizes the combustion process.

Acceleration – A vector quantity that specifies rate of change of velocity.

APC – Air Pollution Control system, a system that reduces emissions = FGC.

BOO – Build Own Operate

BOOT – Build Own Operate Transfer

CFD – Computational Fluid Dynamics is a numerical tool for calculating flow patterns, combustion, particle transport, thermal loads etc. inside a furnace and boiler.

CHP – Combined Heat and Power a method of increasing overall efficiency of a WFPP by generating heat as well as power at the same time from the fuel.

CMS – Control and Monitoring System.

CO – Carbon monoxide.

CO₂ – Carbon dioxide.

Co-generation – see CHP.

Combustible waste – Waste which can be combusted.

Combustion – the process of burning.

Commercial Waste – solid waste generated by businesses and institutions.

Compost/composting – is a common name for humus, which is the result of the decomposition of organic matter. Composting occurs naturally in most environments, such as in landfills.

deNOₓ – NOₓ reduction

Dioxin – umbrella term for more than 200 organic compounds, 17 of which are highly toxic and are enriched in fatty tissue (see page 6 for explanation).

EPC – Engineer, Procure, Construct.

ETS – Emissions Trading System

EU – European Union

FGC – see Flue Gas Cleaning.

Flue Gas – mixture of gases from combustion i.e. from the outlet of a boiler.

Flue Gas Cleaning – a system of devices that removes substances like NOₓ, SO₂ and dioxins from a flue gas.

Flue Gas Recirculation – method of decreasing the amount flue gas.

Fly ash – Combustion residues which is transported with flue gases out of the boiler.

GDP – Gross Domestic Product

GHG – Green House Gas.

GWh – gigawatt–hour (10⁶ Watt–hour) (unit)

H₂ – Hydrogen

H₂O – Water

ha – hectare (10⁴ square meters) (unit)

Hazardous waste – Waste that is toxic, carcinogenic, explosive, or flammable.

HCl – Hydrogen Chloride.

Household waste – Waste coming from households.

Inceration – see WTE

Industrial waste – Waste arising through an industrial process.

IPP – Independent Power Producer.

IPPC – Integrated Pollution Prevention and Control, an EU directive.


kWh – kilowatt–hour (10³ Watt–hour) (unit)

Landfill – A controlled site for depositing waste.

LCV – Lower Calorific Value

Leaching – a process were soluble materials in a substance, such as minerals, chemicals, metals or salts are dissolved in soil or by water.

mg – milligram

MJ – Megajoules (10⁶ joules)

MJ/Nm³ – Megajoule per Normal cubic meter

MSW – Municipal Solid Waste, see Household waste.

MW – megawatt (10⁶ Watt) (unit)

MWe – megawatt electrical (10⁶ Watt electrical) (unit)

MWh – megawatt–hour (10⁶ Watt–hour) (unit)
MWh – megawatt thermal (10^6 Watt thermal) (unit)

N_2 – Nitrogen

NGOs – Non–Governmental Organizations

NH_3 – Ammonia

Ni – Nickel

NIMBY – Not In My Back Yard, referred to as the syndrome that everybody can see the benefit of i.e. a sewage water cleaning facility, but few people want it placed near their home even though it is not a nuisance.

NO_x – nitrogen oxides are GHG and contribute to acid rain and reacts to form ground level ozone and smog. NO_x are removed with SNCR and SCR.

O_2 – Oxygen

Pb – Lead

PCC – post combustion chamber.

PDMS – Plant Design Management System.

PFI – Private Finance Initiatives.

PJ – petajoule (10^{15} Joule) (unit)

RDF – Refused Derived Fuel.

RE – Renewable energy.

Refuse – another term for Waste

RES – Renewable Energy Sources.

SCR – Selective Catalytic Reduction, method for reduction and removal of NO_x.

Sintering – the process where powder and small particles of metals and ceramics melts and solidify when heat is applied. Sintering is used to achieve a high density and low porosity material.

Slag, bottom ash – material which is not combustible, for example, glass, scrap iron, and stone–like material. After separation of metals etc. and sieving the result is a product that can be reused as construction material.

SNCR – Selective Non–catalytic Reduction, method for reduction and removal of NO_x.

SO_x – Sulphur oxides contribute to acid rain. SOx is removed with APC system

Staged Combustion – method of controlling combustion by design of furnace temperature, flow, velocity and the mixture of flue gases, air and oxygen.

Steam parameter – typically refers to the temperature and pressure of the steam generated in a boiler.

Stoichiometric – a stoichiometric reaction is defined as a unique reaction in which all the reactants are consumed.

SRF – Solid Recovered Fuel.

t/d – tonnes per day

t/h – tonnes per hour

TJ – terajoule (10^{12} Joule) (unit)

TOC – Total organic carbon content

TWh – terawatt–hour (10^{12} Watt–hour) (unit)

VoluMix™ – method of mixing flue gases by air injection in the combustion chamber for optimized gas blending

Waste – general term for normal waste. See also MSW.

Waste management – Methods and processes involving the collection, transport, recovery, and disposal of waste.

WasteBoost™ – method of increasing the electrical efficiency on WFPP by increasing the steam parameters to the turbine.

Waste–to–Energy – is a method of extraction of energy from waste, and defined as a combustion process in which the organic fraction of solid waste is combusted and the released heat is utilized to generate hot water, steam, and electric power, leaving the inorganic fraction (ash) as a residue.

Water Injection – method of controlling the temperature in a furnace and boiler.

WFPP – Waste Fired Power Plant.

WTE – see Waste–to–Energy.

Zn – Zinc
References and literature

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[9] 100 years with Waste Incineration, Heron Kleis, Babcock & Wilcox Velund & Søren Dalager, RAMBØLL


[14] Millennial Northern Hemisphere (NH) temperature reconstruction (blue) and instrumental data (red) from AD 1000 to 1999, ref. www.grida.no


Lights of Asia at night from space
(Image courtesy U.S. National Aeronautics and Space Administration)

Wikipedia, the encyclopedia http://en.wikipedia.org
**Recommended Literature**

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Heron Kleis, Babcock & Wilcox Vølund & Søren Dalager, RAM-BØLL

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RenoSam, an association of 31 Danish and 2 Faroese waste management companies; *Effective Waste Management, Effekttive affaldshåndtering*, Benchmarking 2005. September 2005 www.renosam.dk

RenoSam & Rambøll: *The most efficient waste management system in Europe • Waste-to-energy in Denmark*, April 2006.

**European Union directives:**

RVF - The Swedish Association of Waste Management (Svenska Renhållnings-verkstätterna); *Swedish Waste Management* 2005, www.rvf.se

United Nations Department of Economic and Social Affairs; *Agenda 21*, http://www.un.org/esa/sustdev/documents/agenda21/

Phylis ECN data base composition of biomass and waste.

**The Viability of Advanced Thermal Treatment of MSW in the UK**, Fichtner Consulting Engineers Ltd, Published by ESTET in March 2004.


Th. Klasen, K. Görner, The Use of CFD for the prediction of problems areas in site a waste incinerator. 5 th. Conference on Industrial Boilers and furnace.

**Recommended www links**

ISWA - The International Solid Waste Association: www.iswa.org

EU Union Waste Policy:  
http://ec.europa.eu/environment/waste/index.htm

CHEC - Research Center, DTU: www.chec.ktdtu.dk
More than 300 Solutions Worldwide

We have supplied more than 500 waste-to-energy lines over the past 80 years. This extensive experience is one of the reasons why we are a leading supplier of equipment and technologies for waste-to-energy plants.

We have been continuously developing our range of boilers, grates and combustion systems for many years – systems which enable us to solve our clients’ problems and fulfil their needs. Our expertise and our technologies ensure optimum energy utilisation and reliability with maximum consideration of the environment.

To guide our clients towards the best possible solution for their specific needs, we can usually provide similar references based on already optimized plants. This will provide the client with a high degree of security and the necessary performance together with an attractive price and an optimized schedule.

Our Profile

Babcock & Wilcox Vølund is one of the world’s leading suppliers of equipment and technologies designed to convert household waste and bio-fuels into thermal energy.

Our solutions provide a unique combination of:

- High-quality products
- Broad multi-disciplinary experience
- Empirical designs
- Strong project management skills

Facts at a glance:

- Headquarteres in Esbjerg, Denmark
- 100% owned by Babcock & Wilcox Power Generation Group, Inc. in Barberton, Ohio, USA

We offer our customers an exceptional degree of multinational synergy: 135 years of thermal energy production in North America combined with 70 years of experience in Europe.

With technologies based on research and development over a period of more than 70 years, Babcock & Wilcox Vølund have gained exceptional experience within bio-fuels and thermal waste treatment. This experience combined with our multi-disciplinary know-how is one of our core strengths.

What Vølund may offer

As explained in detail in this publication Vølund offers proven waste fired power plants in a range of capacities according to the Vølund Advanced Waste Technology Concept. The plants comply with the European BAT recommendations.

Vølund and its partners may deliver such plants as separate supplies – or the complete Waste Fired Power Plants including steam turbine/generator sets and the necessary flue gas treatment installation on a turnkey basis. Vølund does not produce steam turbines and flue gas treatment equipment, but co-operates with the leading international suppliers of such equipment.

International cooperation

BWV has a long tradition to partner with the best locals in the business. We continously strive to be a sustainable value added technology provider for our partners and licensees. Please see www.volund.dk for our partner in your region.

Babcock & Wilcox Vølund is member of ISWA, International Solid Waste Association (www.iswa.org).
**OUR EXPERIENCE IN ASIA**

Since 1970 we have built more than 60 plants in the Asian region including Japan, Korea, Taiwan and Thailand.

In Korea the MAPO plant with advanced rotary kiln technology is an example of how a modern plant fulfils the stringent requirements.

The MAPO plant, which is the newest plant in Korea, is an example of a best evaluated solution. The MAPO plant is located in the heart of Seoul between the two existing landfills and next to the Han river. The city selected the VølundSystems™ rotary-kiln technology for this advanced plant consisting of three lines of 10.5 tonnes of waste per hour to serve the waste management of the Mapo-gu district. The main objective was to select a technology with the highest efficiency and the best environmental performance, including the lowest emissions with the best bottom ash quality for minimum leaching. The chosen technology should also be proven with actual references.

The MAPO plant was constructed by our partner Halla Energy & Environment in South Korea. After collecting, recycling and reusing the various elements in collected waste, Babcock & Wilcox Vølund can provide thermal treatment as one of the ways of treating the remaining waste in an environmentally friendly way.
Babcock & Wilcox Vølund is one of the world’s leading suppliers of equipment and technologies designed to convert waste and biomass into thermal energy.

Founded in 1898 and headquartered in Esbjerg, Denmark, the company is 100% owned by Babcock & Wilcox Power Generation Group, Inc. in Barberton, Ohio, USA.

Our companies currently employ over 10,000 people worldwide of which over 400 are employed by Babcock & Wilcox Vølund.