HTCW
High Temperature Conversion of Waste

Ground-breaking
Waste to Energy Technology

Total Disposal of all waste types — All-in-one Technology

From the best of traditions in German engineering, using the state-of-the-art technologies from the steel industries radically adapted for new purpose:

The gasification of all types of waste with exemplary energy production
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HTCW pushing the boundaries of waste processing

- HTCW patent gasification process transforms 97-99% of all types of waste into gas, heat, steam and electricity (or diesel, gasoline, methanol).

- Independent studies show HTCW’s superior net energy efficiency and clean syn-gas production, assuring long-term energy price stability.

- One single site plant instead of different technologies for different types of waste. Gasification of all waste types with high & low CV's mixed, needing no pre-sorting or shredding, thus giving control of profit targets.

- Zero emission and no ash residue, leaving 1 - 3% dust and salts. With HTCW "Zero Waste" now becomes a reality, also reducing disposal costs.

- Scalable from small single or multi-location sites to large industrial plants. Economically integrated into existing infrastructures.

Environmentally safe and operating between 1500°C (2700 F) and 2500°C (4500 F), HTCW can process mixed municipal and industrial waste such as:

- Toxic Waste
- Lacquers
- Paints
- Scrap Tires
- Rubber
- Electronic Scrap
- Asbestos
- Scrap Metal
- Clinical Waste
- Paper
- Industry Waste
- Compound Materials
- Oil Sludge
- Coal Gangue
- etc. ...

... in fact, anything except nuclear waste
Adapted for new purpose, HTCW patent gasification technology is a consequent development of the state-of-the-art metallurgical technologies from the foundry and steel industry, in existence for 200 years. The fully operational R&D plant in Arnstadt in Germany was tested under continuous operation in compliance with strict EC guidelines and 17. BImSchV (German Federal Emission Protection Decree).

Gasification instead of Incineration

Gasification is the process of turning a substance into gas. Due to a controlled and limited oxygen supply into the HTCW process, combustion of the feed material is prevented. This is not incineration. There is no formation of typical combustion by-products like ash or smoke. With temperatures between 1,500 and 2,500°C, pollutants in the waste material such as dioxins, furans and Chromium Carbonyl (Cr 6) are completely cracked into harmless or reusable compounds.

Markets for HTCW Plants

- Private recycling-companies
- Local communities
- Processing industries
- Waste recovery and waste disposal companies

Value Products (Output)

- High fuel quality synthesis gas for electricity, heat, methanol or diesel production or for direct sale to an external user
- Heat for district heating, production of steam for industrial processes (e.g. paper mills) or in water desalination plants
- A mineral slag, e.g. for further processing for the construction industry, containing non-leaching minimal heavy metal oxide
- A cast-able metal alloyed with heavy metals usable as ingots/pig iron for steel foundries
Development of HTCW Gasification Technology

Waste is an ever growing problem in today’s society. In the future there will be more of it, containing more toxins than today.

Land filling is not a solution. Incineration has many disadvantages. Gasification is becoming more accepted, where HTCW occupies a unique space.

In 1997 the goal of our research was to find a solution for the waste problem that would not pollute the environment, would make use of waste as a raw material and would also safely destroy hazardous wastes.

The Cupola Furnace Technology, which has been in use for more than 200 years in the metallurgy for the production of cast iron, was the base of the development of the HTCW gasification technology.

During years of development work by the KBI Group, the principle has been revised and adapted into the field of waste treatment, then painstakingly researched and developed. The essence of this patented technology is a high-temperature gasification reactor that works as a non-pressurized shaft-reactor, on the principle of a predominantly prevailing direct current with a packed bed of feed materials (waste) and additional materials.

The basic characteristics

- Environmentally responsible process
- The shaft furnace principle with controlled pyrolysis
- The use of technical oxygen (O₂)
- The consistent feeding of the shaft gases into the high-temperature area for conversion of the resulting pyrolysis products
- Gasification in a high-temperature area between 1,500 and 2,500° Celsius
- High efficiency conversion of all organic components into a clean fuel-quality synthesis gas and its further conversion into either electrical energy and/or heat, steam or methanol, diesel or gasoline
- Close to 100% conversion of input material into value products under avoidance of almost all environmental impact
HTCW gasification processes mixed waste-streams of random compositions (Input)

Feed materials can consist of random waste substances or a specific mix. HTCW gasification technology is intended for waste utilization of any kind (except radioactive). Organic content is turned into energy generation (gas, heat). Different plant designs are available for individual requirements set by waste types and capacities.

For instance:
- Household waste
- Bulky waste
- Mechanically treated waste (bulk material, waste wood, old cars, car shredder residue)
- Industrial and trade waste
- Biological materials of any kind
- Hazardous waste
- Clinical waste
- Waste from paper industry
- Scrap tires, rubbers
- Scrap metal
- Compound materials
- Asbestos
- Coal Gangue
- Oil sludge....
- ... in fact any waste, except nuclear

Minimal requirements:
- The optimum moisture range should be between 10 and 25 %. It is possible to process waste with higher moisture content by mixing it with other waste streams or use the reactor’s heat for pre-drying.
- The mixed calorific value of the feed material (waste) and additional material should be at least 12 MJ/kg. If less, addition of coke or other waste material with a high calorific value is added, such as wood or rubber.
- The particle size must be adjusted to the inlet of the HTCW reactor (about 500 mm).

Pre-sorting (e.g. removal of metals, stones etc.) is not required, nor shredding. Depending on the composition of the feed material, addition of dusty and fine-grained substances can be added to the waste stream up to a certain ratio; this can also be in briquette form. In controlled quantities, liquids contained in solid waste or containers can be added; further it is possible to insert certain quantities of liquids or semifluid material through a special feeding channel.
From Waste to Value (Income Sources)

Feed Material

HTCW Process

Electricity and Heat

Methanol or Diesel

Direct delivery to an External User

Synthesis Gas

Meltings

Metal Alloy

and

Mineral Slag

Heat

Water Desalination

Heat Exchanger

Drinking Water

Thermal Energy
HTCW Gasification and Economy

HTCW distinctive environmentally safe process disposes of and utilizes mixed, hazardous and clinical wastes of all types. The inclusion of these toxic wastes provides unparalleled flexibility to achieve target financial returns.

Zero emissions, ecologically neutral products, the use of all waste as a resource, high energy utilization and process-integrated pollutant destruction provide compelling arguments to allay concerns and objections from citizens and media.

Where decentralized HTCW gasification plants are installed, waste tourism will be a thing of the past. They are easy to integrate into existing infrastructures and the lower economic risks (compared to the risk involved in large plants) provide further factors toward acceptance.

A New Approach to Profitability and Reputation

- Highest net energy efficiency among competitors (i.e. net yields for sale to energy customers)
- High quality, clean syngas, preventing untimely wear and tear of expensive gas cleaning equipment
- HTCW gasification can process all waste types and high/low CV range mixed, needing no pre-sorting or shredding, thus giving control of profit targets - maximum customer service with single location processing (i.e. just one technology for all kinds of waste)
- Almost 100% material transformation of the input waste into environmentally friendly products which can be sold at market prices. No exhaust emission and almost no disposal costs.

HTCW Exports

HTCW specifications are in accordance with German and European ecological technology standards and conditions and are among the best in the world. Based on a thorough market and business survey, adaptations will be made in compliance with local or national laws where applicable. Each project is bespoke designed according to specific requirements.

HTCW modular design enables the planning of the most economical roll-out of a longer term expansion plan and avoids the biggest problems associated with smaller and also larger plants which require expansion when demand rises.

Investment costs

Investment costs of an HTCW gasification plant depend on the configuration of the plant and type of gas and heat usage (for heat, electricity, methanol, diesel or gasoline).
Ideally, industrial-scale waste processing should result in:

- no or minimal pre-treatment
- optimum volume and mass reduction
- destruction of hazardous materials
- utilization of waste as a resource
- optimum energy potential utilization
- produce no or negligible residues for safe disposal

The HTCW gasification process meets these standards by its efficient thermal and chemical transformation of highly diverse waste materials into energy (gas) and other value products (heat, metal alloy and mineral slag) without adverse environmental effects.

Feed material (waste) needs only minimal preparation. Objects are reduced in size to fit into the reactor inlet and to prevent blockages once inside the reactor shaft. Any metallic or mineral content is in fact advantageous to the process. Depending on the composition of the feed material, additional materials such as coke and limestone are added as needed.

The various high-temperature melting gasification stages transform the physical and chemical characteristics of the feed material and thus volume is reduced. Gas, metals and mineral slag are produced by the process, all of economic value.

The organic components descending down the furnace shaft are subject to a controlled pyrolytic decomposition and a gas is formed. This pyrolysis gas is fed into the high-temperature area. There it becomes a gasification agent with the aid of injected oxygen. With reaction temperatures between 1,500 and up to 2,500°Celsius the organic compounds are decomposed into low-molecular substances.

What sets HTCW apart is its net efficiency, i.e. the net energy yield available for supply to an energy customer.

With the destruction of organics and the by now concentrated non-organic materials turned inert, the hazardous components are destroyed.

The 1 - 3% remaining slurry of concentrated salts and dust require disposal.

Gasification occurs under temperatures between 1,500 and 2,500°C under reduced conditions. Thus, a large share of hydrocarbon content is split inside the gasification reactor. Primary formation of dioxins and furans is practically impossible. Unlike conventional waste incineration processes, neither ash nor flue gas emerge.
Input: Feed materials (waste) and additional materials (e.g. coke, limestone) at normal temperature and pressure

100 to 200°C:
Drying of input; elimination of physical water

250°C:
Deoxidation; desulphuration; elimination of constitution water and CO₂; depolymerisation

340°C:
Cracking of aliphatical bonds; beginning separation of CH₄ and other aliphates

380°C:
Carbonization

400°C:
Break-up of C-O and C-N bonds; separation of heteroatoms

400-600°C:
Conversion of bitumen into smoldering oil and smoldering tar

>600°C:
Cracking of bitumen into thermally stable substances (short chained, gaseous hydrocarbons); synthesis of aromatic hydrocarbons

800-1,200°C
Gasification: Synthesis of N₂/NH₃ and H₂S/COS; halogens are completely in the vapour state (as alkalichloride or HCl)
Melts: Synthesis of mineral melting phases

1,200-2,000°C
Complete decomposition of aromatic hydrocarbons, HCN and organic chlorine compounds; formation of carbon black
Melts: Synthesis of iron metallic melting phases

2,000°C-2,700°C
Beginning of molecular dissociation; lower plasma region
“Zero Waste” becomes Reality

Value Products

These are typical of processing by gasification at temperatures up to 2,500°Celsius. Depending on the feed materials content:

- A high quality fuel synthesis gas, usable for production of electricity, heat or methanol or diesel
- A non leaching mineral slag containing minimal heavy metal oxides, usable as road aggregate, flux for construction or with further processing as an insulation material
- A castable metal, alloyed with heavy metals, usable as ingots/pig iron for steel foundries
- Heat, usable in various ways

The only other output of the HTCW process is a concentrate from the gas cleaning, 1 - 3% of the initial charge volume (compared to about 30 % in waste incineration plants). It will be deposited.

Gas

The gas produced in the reduction zone of the HTCW gasification furnace is called raw gas. It is fed into the gas treatment and cleaning system. This gas is almost free from hydrocarbons. Chlorine, sulphur, other unwanted compounds and dust components are separated out by the gas treatment and cleaning process, by which the raw gas becomes a synthesis gas.

These residues also contain sublimates of the low-melting heavy metals. Such residues are further reduced by multiple circulating with the input material and discharged from the process depending on their concentration. Also the filter dust is added to this circulation process several times.

Gas Cleaning

Design of the gas cleaning equipment depends on the use of the gas (see below). Each plant is bespoke designed according to customer needs.

Gas Utilization options

- Electricity generation and heat by a steam turbine
- Electricity generation and heat by Combined Heat and Power Units or Gas Turbines
- Methanol, gasoline & diesel generation
- Supply of clean gas to an external user

Raw gas (prior to cleaning) has a high calorific value of about 2,0 to 3,0 kWh/Nm³
Gas Utilization & Gas Cleaning Design

1st option: 
Electricity and heat generation by steam turbine

2nd option: 
Electricity and heat by CHP Units (Combined Heat & Power)

3rd option: 
Methanol or Diesel Synthesis

4th option: 
Supply to external user
Meltings

With the high temperatures and oxygen injection, partial oxidation occurs and so a complete melting of all mineral and metal components is achieved. The amount of minerals and metals in the waste determines the quantity of melting which descends within the reactor by gravity.

The removal of these molten materials at the bottom of the reactor is called tapping. Mineral slag and metal meltings accumulate at the reactor hearth and separate themselves due to different densities.

**Mineral Slag**

The mineral slag is basically free from heavy metal oxides. These are almost completely removed while passing through the coke bed. The molten slag is continuously discharged (tapped) and with optional fast or slow cooling, is turned into a hard crystallised stone. By customer preference, it can be processed into any other form of useful material like coarse road aggregate or (with further processing) into insulation or isolation materials by foaming, defibration(*), rolling or centrifugation as flux material for the construction industry.

(*breaking into fibres)

**Metal**

The molten iron contained in the cast is alloyed with heavy metal. It is tapped and can be used for further processing in the steel and foundry industry.

**Heat**

Heat emerges at different stages in the HTCW gasification furnace: from the surface of the reactor, from the hot raw gas produced and as output from a Combined Heat and Power unit (CHP).

The heat can be used for the production of steam for industrial use, as district heating or in water desalination plants to produce drinking water. It can also be used for the pre-treatment of waste with high moisture content when drying is needed before processing.
Plant Capacity Designs

Available Reactor sizes:

- **HTCW 70** with a throughput of waste of about 1.8 tons per hours (t/h)
- **HTCW 100** with a throughput of waste of about 3.6 t/h

Dependent on the annual operation hours of the HTCW Plant, this leads to the following annual throughputs (t/a):

**HTCW 70:** 10,000—15,000 t/a

**HTCW 100:** 20,000—30,000 t/a

A gasification line consists of 2 reactors, so the waste can still be processed in the event of one of the reactors being closed due to necessary maintenance. Therefore the sizes of gasification lines are 20,000 - 30,000 t/a and 40,000 - 60,000 t/a.

The smallest HTCW Plant is a 20,000 - 30,000 t/a plant with 2 reactors of 10,000 - 15,000 t/a each. Due to this modular system, bigger plants by adding further gasification lines are possible. By means of an appropriate configuration of several modules, any upwards capacity may be reached, achieving significant economic advantages.

Therefore centralized, as well as decentralized waste management systems can be established with the HTCW Technology.

Examples of Plant Configurations

The HTCW modular gasification system allows plant design to client specifications. Possibility of initial 2 reactors of 10,000 - 15,000 t/a and later extend to any capacity.
Gasifiers have an intrinsic process advantage over incineration, in that they use distinct stages to:

1. Process the feed to make a highly energetic gas
2. To clean the gas before its use
3. To burn the gas in an efficient engine to generate electricity or steam
4. Alternatively, synthesize the gas into diesel, gasoline or methanol

The quality of a gasification process can be measured by its syngas. A good syngas has a high CV and is effectively free of tars. Tars are eliminated by high temperature operation and by ensuring sufficient air or oxygen are supplied to complete the gasification reactions.

A high CV syngas is created by not adding excessive air or oxygen. Good control is needed for optimal performance. The computer controlled multiple injection of oxygen in the HTCW furnace allows this optimization.

Gasifiers come in many forms, they can be divided into those such as HTCW that use oxygen or enriched air and those using air. Air is cheaper than oxygen, so an air gasifier should be cheaper, but is it better?

- The nitrogen in the air used in an air gasifier ensures a greater volume of syngas is formed per tonne of feed. Consequently an air blown gasifier has to be physically bigger than an equivalent oxygen blown gasifier.
- The nitrogen in the air gasification process' syngas of typically 45% creates problems with maintaining engine efficiency and avoiding a substantial de-rating of the engines.
- The excessive nitrogen has to be heated to gasification temperature. The bulk or all of this energy is normally lost as the gas is cooled on leaving the gasifier.

Gasification Efficiency Graph

This illustration compares an air-blown to an oxygen-blown gasifier (HTCW). It shows
- a) HTCW has a better efficiency
- b) that in both cases the efficiency of a gasification process decreases as the temperature is raised.

Source: I.P.S. Ltd
As can be seen at the graph on the previous page, at 1,400°C (2,550F) the HTCW operates with the same efficiency as an air blown gasifier operating at 850°C (1,550F). However, in the range of 1,400-1,600°C (2,550-2,900F) considerable advantages are achieved, e.g.:

- Effective destruction of toxic substances at molecular level, which are still stable at 1,000°C (1,830F) - for instance PCB’s
- Formation of metallic and mineral meltings which encapsulate dangerous substances (at this level, we are not talking about ash anymore)
- Conversion of dangerous substances into a harmless or considerably less harmful states, e.g. tars, dioxins, Cr 6 (Chromium Carbonyl)
- Almost complete mass reduction of residual substances — at the end of the process 1 - 3% of the original volume remains for disposal, consisting of dusts and salts mixed in non-toxic slurry

**HTCW efficiency is measured by:**

\[
\frac{\text{Total Electrical Power Generated - Own Need + Total Heat Sold to Customers}}{\text{Total Energy contained in the entire Input}}
\]

**Efficiency vs Calorific Value**

The efficiency of any gasification process is always a function of the CV of the feed. Good use of HTCW internal heat will increase the net electrical efficiency by at least another 10% than shown below. This, together with the illustration on the next page, shows HTCW superiority in generating higher energy yields than incinerators/air blown gasifiers, as the CV ratio rises.

In this illustration wood is considered as the fuel and the moisture content is altered to vary the CV of the waste. The HTCW is operating at 1,400°C, the oxygen is assumed to have been supplied as liquid. The Plasma operates at 1,050°C and the plasma torch power is 0.4 MWh/t of feed.

**Electrical Efficiency Graph**

Comparison of the electrical efficiency of an HTCW to that of an air blown plasma unit. As the CV ratio rises, HTCW has superior qualities in generating higher energy yields over incinerators/air blown gasifiers/plasma assisted gasifiers.

Source: I.P.S. Ltd
**Efficiency compared**

MSW (Municipal Solid Waste) has a CV of 9 - 11 MJ/kg. When using MSW the Plasma gasifier efficiency is considerably low. Plasma gasifiers normally operate as two stage operations. The first stage is a conventional air blown gasifier. The dirty syngas from this unit passes into a separate chamber containing an electrically powered plasma torch and additional air is added and the torch raises the temperature. With this, a tar free gas can be produced. The final syngas has a low CV typical of air blown units because of 45% nitrogen content.

The plasma torches are big users of electricity, 0.4 MWh/ton of feed is typical. Simply put, to express the net process efficiency this power needs to be subtracted from the gross amount of energy contained in the input feed material (the waste). This reduces the process efficiency further, resulting in a low efficiency and thus a significant lower profitability.

For the HTCW, the higher the CV of the feed, the greater is the efficiency advantage over an incinerator, air blown and plasma assisted gasifier. Further, well managed use of internal heat will increase net efficiency by at least 10% above that shown on the previous page.

**HTCW Modularity**

The HTCW’s modular plant size presents a better opportunity to use the waste heat arising from the engines for supply to an adjoining energy user. This combined heat and power installation further improves the process efficiency.

**HTCW = Total Disposal**

The below chart shows how the various technologies best fit into the waste treatment industry. With 80% renewables content, anaerobic process is recommendable but only up to approximately CV 38 MJ/Kg.

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100% total disposal can also be realized with HTCW alone:

With HTCW's versatility, low CV waste can be mixed with higher CV compositions (or with added coke or coal), thus achieving a viable CV range.

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Source: I.P.S. Ltd
### Technology Options

<table>
<thead>
<tr>
<th>Mixed Waste Component</th>
<th>Compost</th>
<th>AD</th>
<th>Incinerate</th>
<th>Pyrolyse</th>
<th>Gasify</th>
<th>Landfill</th>
<th>Landfill problem</th>
<th>HTCW problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and card</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>OK</td>
<td>none</td>
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<tr>
<td>Plastic film</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Persistent &amp; Leachate</td>
<td>none</td>
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<tr>
<td>Dense plastic</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Persistent &amp; Leachate</td>
<td>none</td>
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<td>Textiles</td>
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<td>No</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Persistent</td>
<td>none</td>
</tr>
<tr>
<td>Absorbent hygiene products</td>
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<td>some</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Infection</td>
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<tr>
<td>Wood</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Persistent</td>
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</tr>
<tr>
<td>Combustibles</td>
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<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Persistent</td>
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</tr>
<tr>
<td>Non-combustibles</td>
<td>No</td>
<td>No</td>
<td>Ash</td>
<td>No</td>
<td>Slag</td>
<td>Yes</td>
<td>Persistent</td>
<td>none</td>
</tr>
<tr>
<td>Glass</td>
<td>No</td>
<td>No</td>
<td>Ash</td>
<td>No</td>
<td>Slag</td>
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<td>Yes</td>
<td>Yes</td>
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<td>No</td>
<td>Ash</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Persistent</td>
<td>none</td>
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<tr>
<td>Non-ferrous metal</td>
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<td>No</td>
<td>Melts into ash</td>
<td>Melts into ash</td>
<td>Melts into ash</td>
<td>Yes</td>
<td>Persistent</td>
<td>none</td>
</tr>
<tr>
<td>Fine material</td>
<td>No</td>
<td>No</td>
<td>Ash</td>
<td>No</td>
<td>Slag</td>
<td>Yes</td>
<td>Persistent</td>
<td>none</td>
</tr>
<tr>
<td>Waste Electrical and Electronic</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes but ash</td>
<td>Yes</td>
<td>Yes but not always legal</td>
<td>Persistent &amp; Heavy metals</td>
<td>none</td>
</tr>
<tr>
<td>Hazardous Waste Items (including all batteries)</td>
<td>No</td>
<td>No</td>
<td>Yes but Temp too low</td>
<td>Yes but ash</td>
<td>Yes</td>
<td>Yes but not always legal</td>
<td>Toxic &amp; Heavy metals</td>
<td>none</td>
</tr>
</tbody>
</table>

Source: I.P.S. Ltd

With qualified independent studies and industry expert advices as source, the foregoing illustrations show that HTCW gasification encompasses the functionality of the main competing technologies, capable of processing all types of waste in mixed compositions.

Concurrently, high and low CV wastes can be combined if needed. Low CV waste can be mixed with higher CV compositions (or with added coke or coal), thus achieving a viable CV range. The opposite is also true. High CV value (e.g. car tyres) can be mixed with lower CV waste types.

Together with processing mixed waste materials which require no shredding or pre-sorting, profit targets can be controlled.
Challenging the Existing Technologies

HTCW Inspection by British Environment Agency

The Environment Agency, an organisation commissioned by the UK DEFRA Government Department, assessed 40 waste processing technologies from various countries including HTCW gasification. The resulting case study, published as shown below, corroborates HTCW suitable to processing all types of waste with an environmentally friendly process. HTCW was the only case study that got a Y (Yes) in every category!
HTCW vs Incineration

**Now:**
**Incineration**
- Sorting needed
- 100% Waste
- Emissions
- About 30%

**The Future:**
**HTCW**
- No Sorting needed
- 100% Waste
- No Emissions
- Zero Emissions!
- Higher Efficiency!
- Total Disposal!

**Produced Energy**
- About 1-3%
HTCW Research and Development Plant in Arnstadt, Germany

The HTCW technology is tested according to the European Combustion Guidelines and to the even stricter German 17th Emission Protection Law (17. BlmSchV). The corresponding EC guideline is RL 2000/76/EG. The reference plant in Arnstadt has passed these tests during continuous operation without problems and demonstrated its capability to match or surpass the necessary license standards and regulations.
Notes