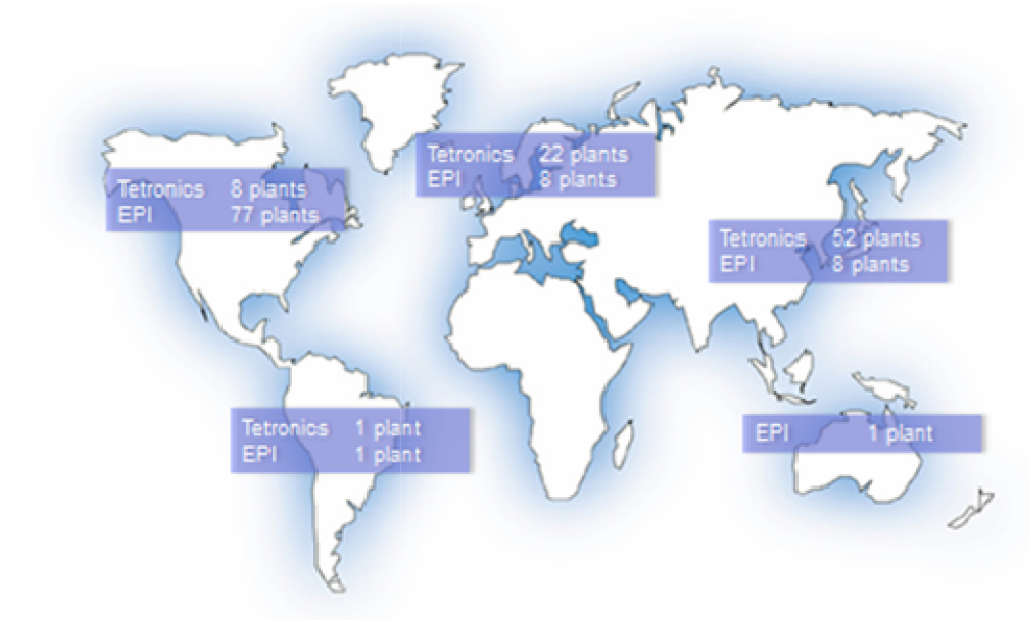
ADVANCED PLASMA POWER PLASMA ARC FLUIDISED BED GASIFICATION PLANT



Zero waste

- No residual ash
- Plasmarok® – product not waste (e.g. rock wool substitute)

Proven gateway technology

- Syngas - multiple applications (fuel cells, SNG, GTL)
- Proven equipment & validated
- Patented globally

Resource optimisation

- High net electrical efficiency
- Heat recovery
- Complementary to recycling

Local low impact solution

- Standard industrial warehouse
- Low stack
- Reduced waste miles
- CHP potential

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Comparison with MBI

Gasplasma®	Mass Burn Incineration
High electrical efficiency (30%)	Lower electrical efficiency (20-25%)
Zero waste – no residual ash	Incinerator bottom ash (20%)
Complementary to recycling (RDF)	Black bag waste
Local low impact solution - Standard industrial building (15m) - Low stack (+10m) - Low emissions (well inside WID) - Reduced waste miles - CHP potential	Located away from population centres - Large buildings (40m) - High stack (70m+) - Increased transport impacts - CHP more difficult
Lower cost	Higher capital cost, higher gate fees
Syngas with multiple applications (fuel cells, SNG, GTL etc.)	Little versatility

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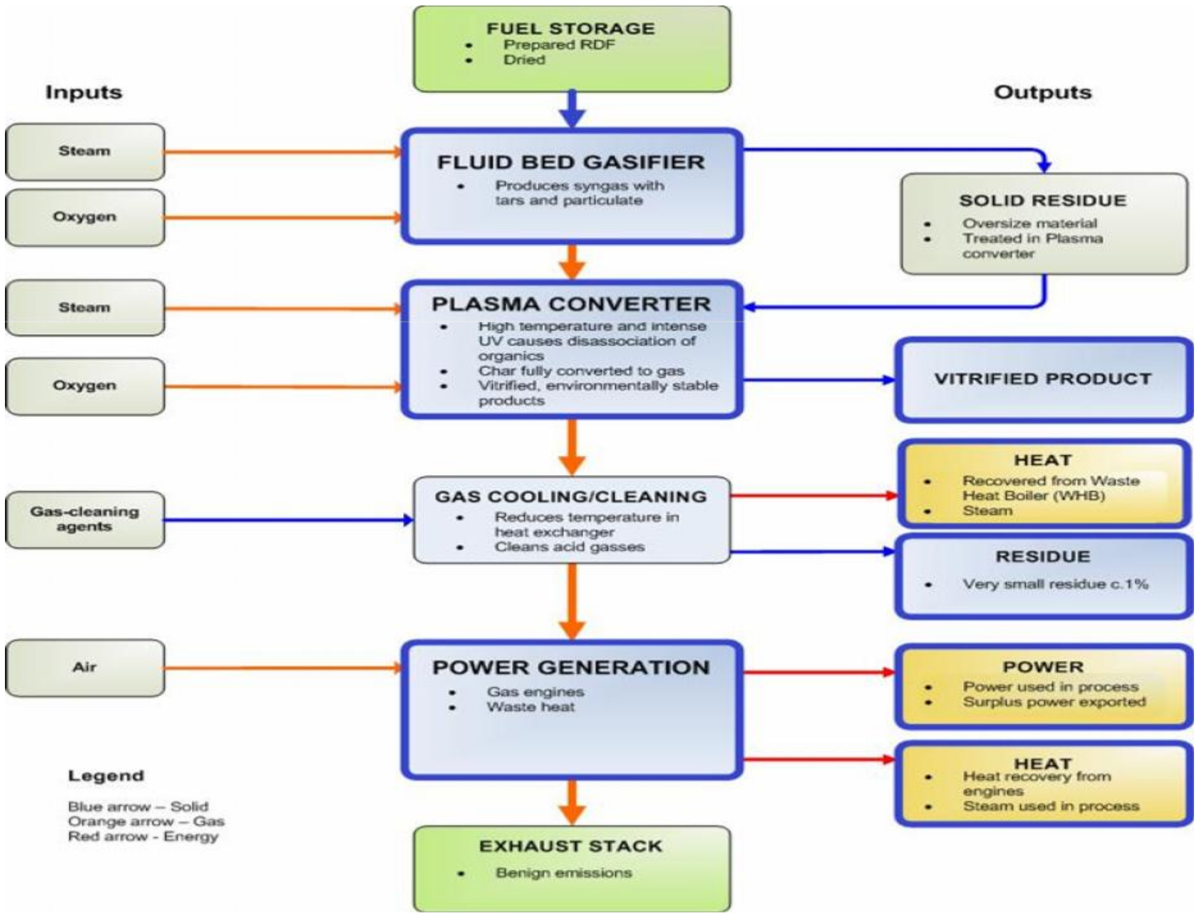
Plasma Arc Gasification Plants are economical in size compared to Mass Burn Incinerators

The Gasplasma® Process

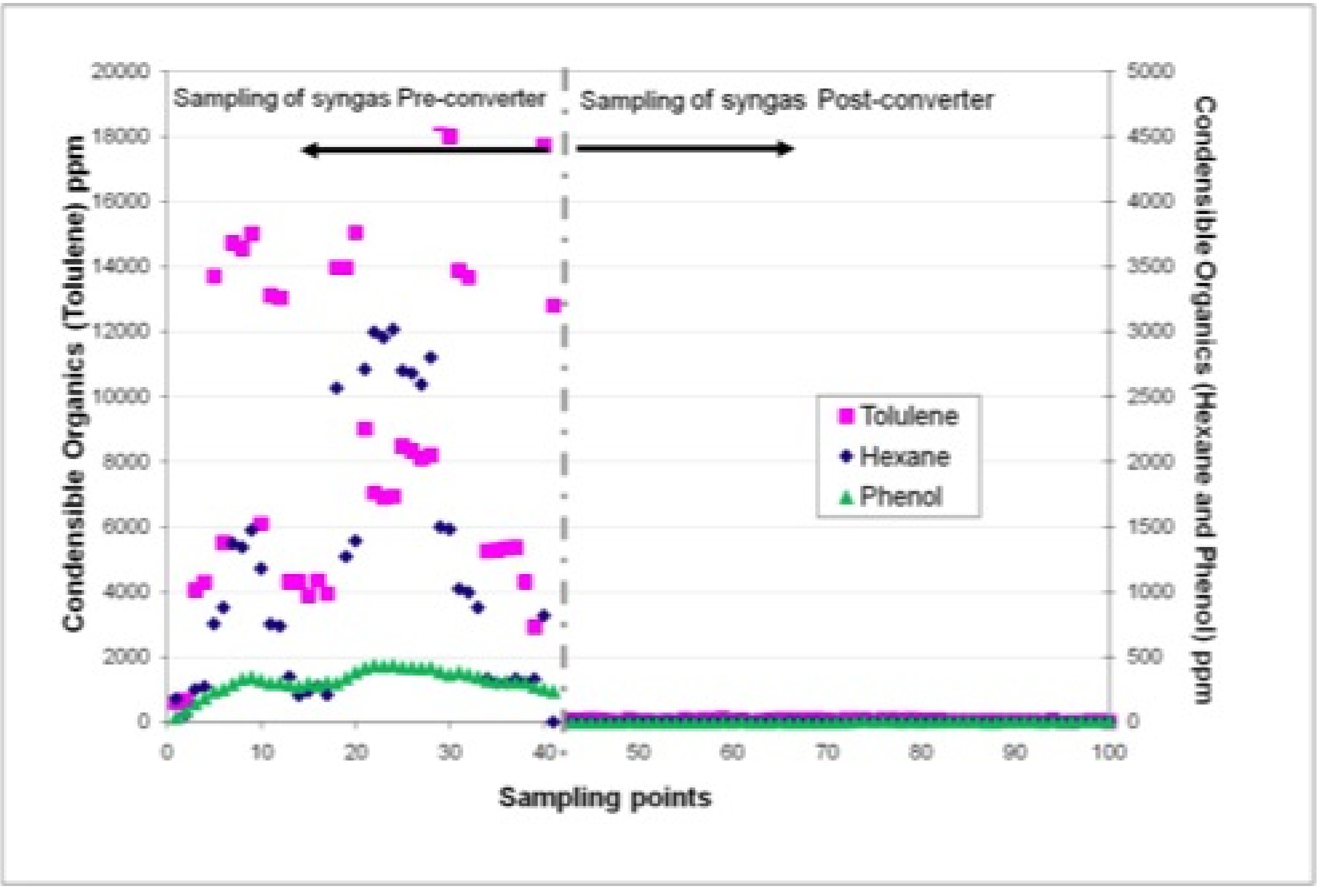


Converts RDF feedstock into:

- Converts 97% of the waste fuel
  - Very clean hydrogen-rich gas
  - Recyclable aggregate
- Minimal emissions / low environmental impact
- Negative carbon footprint
- Potential CHP Energy efficiencies of >70%
- Exporting up to 82% of electricity generated
- Local waste, power and heat solution

Fundamentals: Cracking of organics in plasma converter

The effect of plasma treatment on the reduction of organic species in the syngas



Syngas Composition

H_2	36%
CO	37%
CO_2	17%
N_2	3.7%
H_2O	4.2%
CH_4	1.4%

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ADVANCED PLASMA POWER

General Description
Gasplasma® Process

INTRODUCTION

This document describes the process for a Gasplasma® facility that converts circa 150,000 tonnes per annum of Municipal Solid Waste (MSW) and commercial waste into electrical power and heat energy, exporting renewable electrical power to the national or local grid.

This document also describes the core Gasplasma® process equipment and reviews how energy is produced from a waste feedstock.

The Gasplasma® system is designed to be a part of an integrated waste processing system and is at the heart of a dedicated system that includes waste processing, drying, gasification, power and heat generation.

FACILITY OVERVIEW

The whole process can be viewed as three distinct operations (see Figure 1):

• **Fuel Preparation**	The reception of waste and preparation of a Refuse Derived Fuel (RDF)
• **Gas Production**	The conversion of the RDF to a syngas and inert solid aggregate product
• **Power Generation**	Converting syngas to electricity and heat

Fuel Preparation of RDF is based on a maximum design capacity of 150,000tpa of municipal and commercial wastes which, following processing to remove recyclate, moisture and reject materials, produces approximately 90,000 of RDF as feedstock for the Gasplasma® process.

Syngas Production converts the RDF into a synthesis gas (syngas) through the Gasplasma® process which includes cooling, cleaning and conditioning of the syngas. During the syngas cooling stage, steam is produced and is used in the drying process and for power generation.

Power Generation is achieved by converting the syngas into electrical power through reciprocating gas engines. Exhaust gases from the engines produce steam allowing further power generation to take place using a high efficiency steam turbine.

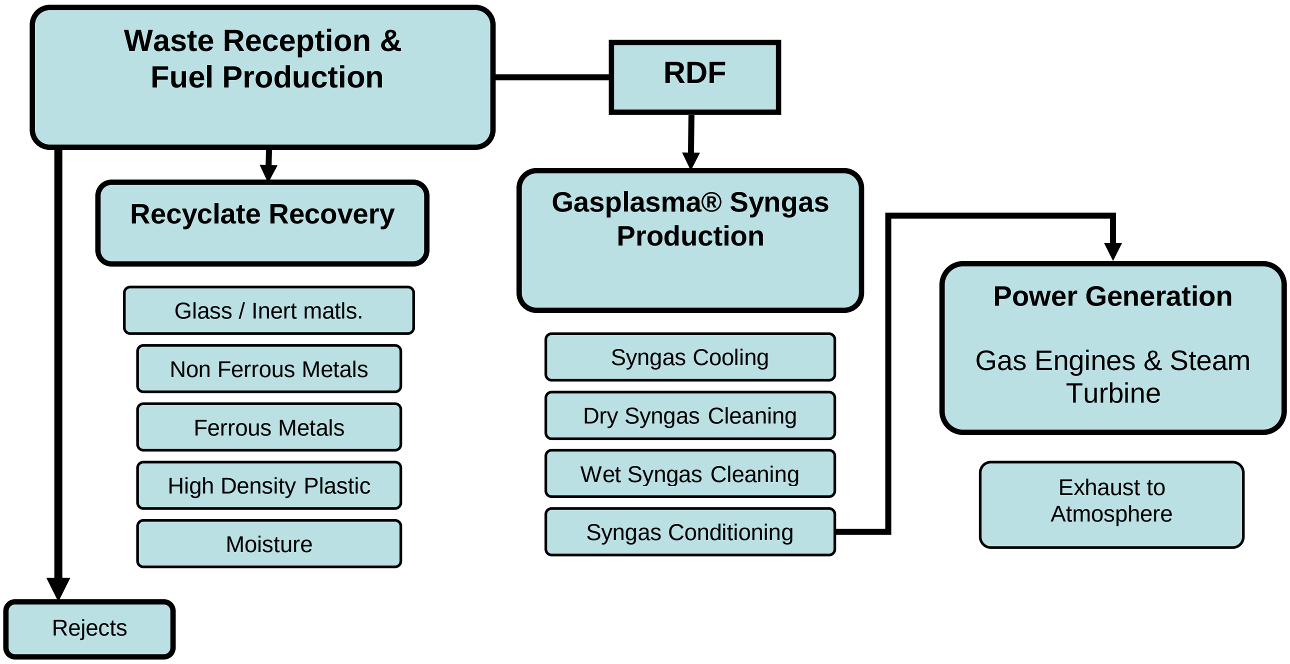

Figure 1 - Facility Overview

FUEL PREPARATION

Waste Reception

The waste reception area receives waste deliveries during the agreed operating hours for the facility. All waste is deposited onto a tipping floor for initial visual screening. To allow for fluctuations in delivery volumes the waste reception area is designed to accommodate more than a days' storage of waste while still leaving manoeuvring space for loading waste into the plant.

The reception area accepts different waste types and incorporates options for pre-sorting and shredding of waste before feeding to the fuel preparation process. Suitable equipment including wheeled front end loaders and a 360 degree "excavator" moves the waste and carries out the stockpiling of materials within the reception area.

Fuel Preparation

The facility is a single line plant with a nominal design processing rate of up to 25tph allowing up to 150,000tpa of material to be processed. The fuel preparation process operates for up to 24 hrs a day, 6 days per week, depending on the waste deliveries. The first stage of the fuel preparation system is the size classification of material through a rotary screen. The rotary screen then splits the materials into three size categories most suitable for the down stream equipment as follows (see Figure 2):

- **Stream 1** Materials less than 15mm
- **Stream 2** Materials from 15mm to 80mm
- **Stream 3** Oversize

Stream 1 is mainly dirt, grits, glass, stone and putrescibles. This material stream is transferred directly to containers and is then available for further processing or disposal.

Stream 2 is the correct size range for the Gasplasma® process. Material which can be recycled is removed automatically to leave a feedstock with a high biodegradable content. Materials removed are glass, ferrous metals, non-ferrous metals and dense plastics. Following their removal the remaining materials are conveyed directly to the “wet” fuel store. This store acts as a process buffer store between fuel production and gas production.

Stream 3 is oversize material which, as with Stream 2, is refined by removing recyclable material. The remainder is then passed through a shredder producing a particle size of less than 80mm. It is then combined with Stream 2 in the wet fuel store.

Drying

To improve the consistency of the fuel the material is dried using steam recovered from the Gasplasma® process. The design point of the final dry RDF is 12 -16 MJ/kg, 10-14% moisture and 14-18% ash. Approximately 90,000tpa of RDF is produced from the input tonnage of 150,000tpa. The moisture laden air removed from the RDF is treated to remove odour before release.

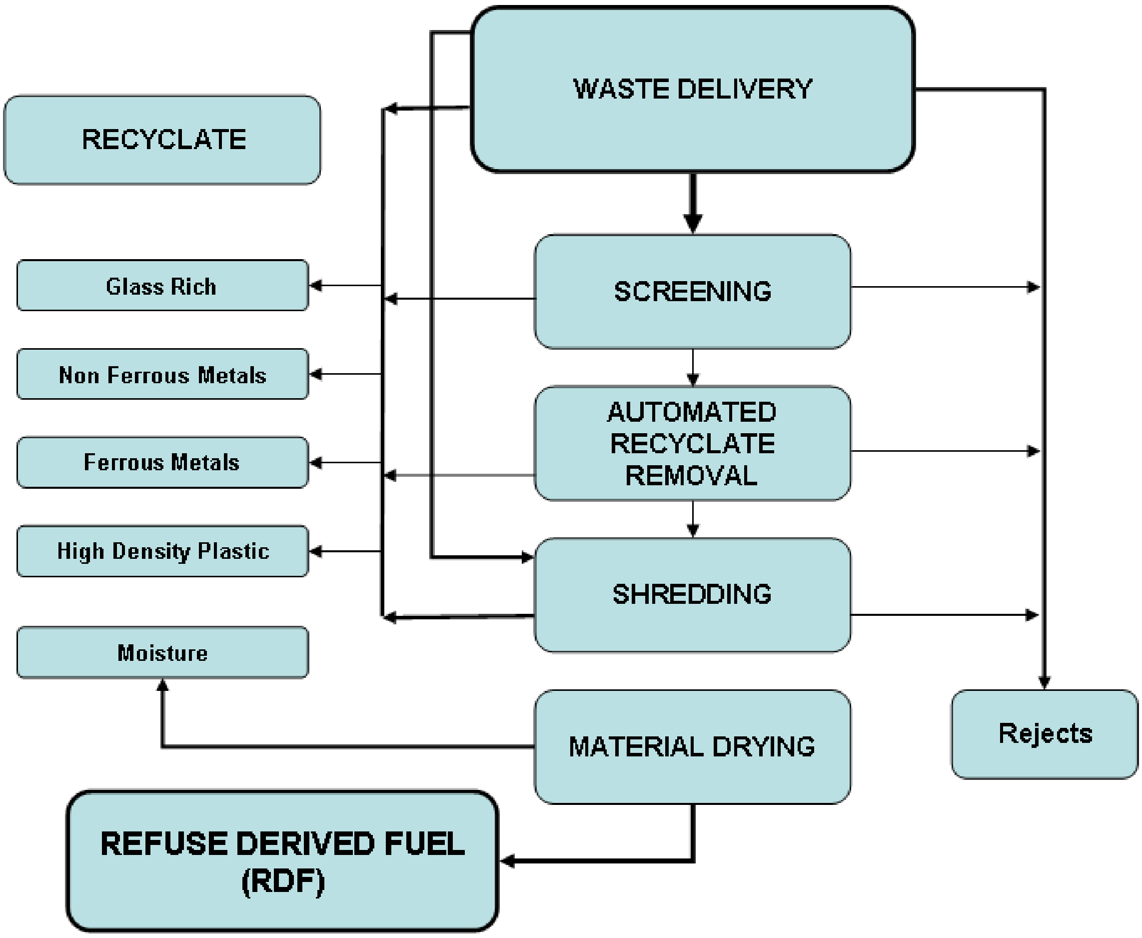

Figure 2 - Fuel Preparation

GAS PRODUCTION

The Gasplasma® system operates on a 24 hour/7 day week basis. At the heart of the facility is an advanced Gasplasma® thermal process that produces a syngas with a calorific value of between 10 and 14MJ/Nm^3. The process produces a crude syngas which is treated to remove particulate matter, acid gases and volatile metal vapours. The cool, stable hydrogen-rich syngas which is produced can be used for power generation. Within this section of the facility there are four main process groups (see Figure 4):

- Gasification
- Gas Cooling
- Dry Gas Cleaning
- Wet Gas Cleaning

Gasification

The Gasplasma® process is made up of two closely coupled but separate operations:

- Gasification of RDF
- Plasma Conversion of Gas

Gasification of RDF

RDF is fed into the gasifier under strictly controlled conditions. The process environment is maintained by control of oxygen, steam and RDF feed rate. This process provides sufficient heat to maintain the fluid bed temperature and produce a "crude syngas". The syngas contains significant quantities of long chain hydrocarbons which would condense as tars and residues. The ash component of the RDF is removed from the base of the gasifier through the bed screening process and conveyed to a hopper where it is metered into the plasma converter. There are no residues, chars or ash removed at this stage of the process.

Plasma Conversion of Gas

The raw syngas is transferred from the gasifier to the plasma converter via a refractory lined duct. In the centre of the plasma converter is a graphite electrode from which a thermal plasma arc is generated (see Figure 3). The syngas is exposed to elevated temperatures and intense ultra violet light. The effect is to "crack" and reform the tars and chars contained in the syngas into its basic composition of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2) and water (H_20).

Figure 3 - Image of a Thermal Plasma Arc

The syngas is then drawn via a refractory lined duct to the inlet of the gas cooling system. At all times the gasifier and plasma converter operate at a negative pressure of <-5 to -10 mbar.

The plasma converter has been designed using computerised flow and modelling techniques to obtain maximum dwell time for the syngas within the converter whilst allowing time for ash and dust particles to drop out of gas stream. These particles are then incorporated into a molten melt which builds up in the base of the converter. The molten material is tapped from the converter and cooled for use as a vitrified and stable material. This material has been approved by the Environment Agency as a product and is trademarked under the name Plasmarok®.

Gas Cooling System

The gas cooling system comprises a heat recovery boiler designed to reduce syngas temperatures from circa 1200ºC to 200ºC and generates steam at 10bar pressure. The basis of the design is a water tube boiler, incorporating robust features as used throughout heavy industry with specific attention given to the materials of construction for long service life and to minimise down time caused by fouling and corrosion. The steam generated is used in the process at the drying and Gasplasma® stage.

Dry Gas Cleaning System

The gas cleaning system, operating at 180-220ºC, removes fine particulate materials from the gas stream, neutralises acidic gas and removes heavy metal vapour.

The syngas passes to the ceramic particulate filter via an insulated duct into which sodium bicarbonate and activated carbon is injected. The duct provides sufficient residence time and turbulence to allow good reaction and collection, providing high capture rates for acidic components. Particulate matter is trapped on the ceramic filter elements and periodically removed using a nitrogen reverse pulse system.

Wet Gas Cleaning System

The syngas enters a quench vessel where the temperature is reduced using water sprays. It then enters a scrubber chamber and flows through two packed beds before being exposed to bio liquor that absorbs the hydrogen sulphide in the syngas.

The bio liquor is passed to a bioreactor where it is aerated and dosed with small quantities of sodium hydroxide to maintain the pH and nutrients for the organisms. Sulphur is filtered out continuously from the circulating solution and recovered. The condensate from the syngas is treated to capture dissolved hydrogen sulphide before being discharged to sewer (meeting the local trade effluent discharge authorisation).

Thermal Oxidiser

A thermal oxidiser is provided to treat all products of combustion, as well as the syngas during the start up phase of the process. This ensures that all emissions to air from the Gasplasma® process meet the requirements of the Waste Incineration Directive. This legislation covers all emissions to air from the treatment of waste in the EU and is regulated in the UK by the Environment Agency via the Environmental Permitting process.

The thermal oxidiser is configured to remain on hot stand-by at all times the Gasplasma® equipment is operational. This ensures that in the event of an emergency shutdown of the process there is no release of un-combusted gas to atmosphere.

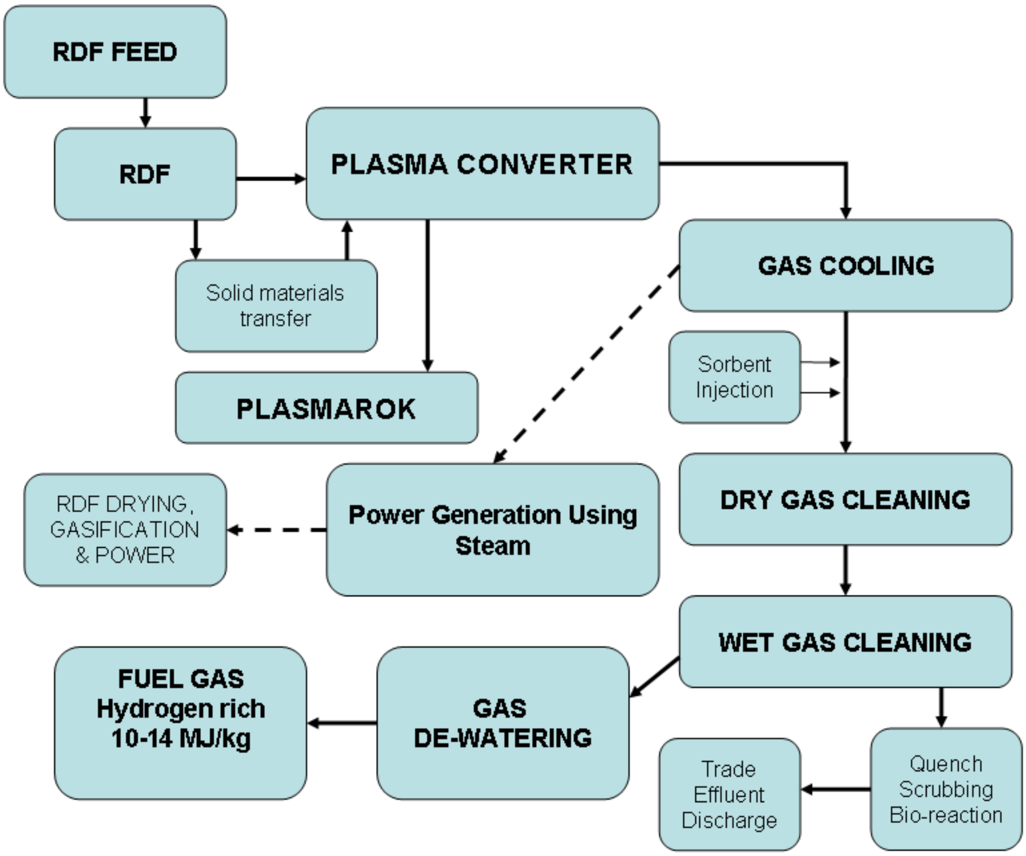

Figure 4 - Gas Production

POWER GENERATION (see Figure 5)

Gas Engines

Dependent upon the manufacture selected, a number of gas engines are installed with the exhaust emissions controlled by efficient combustion control and a system of catalysts and oxidisers. The final engine exhaust emissions also comply with Waste Incineration Directive limits (WID).

Each engine is provided with an acoustic enclosure that also houses the fire suppressant systems. Exhaust from the engines is routed via a heat exchanger which generates steam for use in a high efficiency steam turbine or for process use.

Off Gas Treatment

During start up, as well as during conditions where the syngas may not meet the required specification for the engines, all syngas is diverted to the thermal oxidiser to allow these gases to be fully oxidised. Emissions from the thermal oxidiser are compliant with the WID regulation. The thermal oxidiser is rated for up to half the design output of the syngas and will be used as a control during normal operation of the Gasplasma® process. At times of normal operating conditions it will be held on hot standby.

Heat Recovery

Heat is recovered from the syngas cooling system and from the gas engine exhausts, which is used in additional power generation or process heating. The normal scheme allows for a high efficiency steam turbine to be used to convert the recovered energy from the gas engine exhaust to electricity. The facility is able to divert steam for use elsewhere in the process (RDF Drying) or for export if there is a suitable third party requirement. Hot water is also available from the engine cooling water systems and is suitable for use in district heating systems and other applications.

Oxygen and Nitrogen Provision

Oxygen and nitrogen supply are provided for use in the Gasplasma® process.

SITE INFRASTRUCTURE

Buildings and Process Areas

The Gasplasma® process can be housed in a building of conventional portal frame design. The building incorporates specific features which make it suitable for processing waste feedstock with significant emphasis placed on odour and noise control.

Waste reception, fuel processing and RDF fuel storage is carried out inside the building which is held under slight negative pressure to prevent odour escape. An exhaust air treatment plant extracts air from the reception area, the fuel preparation equipment and the wet fuel storage area before exhausting via a dry filter and carbon filter system to atmosphere.

The gasifier and plasma converter are also housed within the building whilst the gas cooling, gas cleaning, gas compression and storage systems are all located outside on a suitable concrete pad foundation. The gas engine module is located inside the building with all heat exchangers mounted on the roof of the building.

The main building includes a reception area at the front entrance of the facility adjacent to a site control office. There is a staircase/lift pod giving access to a high level pedestrian route to the integral offices, control rooms and staff accommodation. Included within this area are educational facilities and viewing access across the process.

Fire Protection

The building and process are protected with sprinkler and/or water cannons systems where required. This includes the waste and RDF storage areas.

Process equipment is protected by a specialist fire control system and all are interlinked to the site wide fire alarm system.

Provision is made for the collection and storage of fire fighting water within the design of the site and buildings.

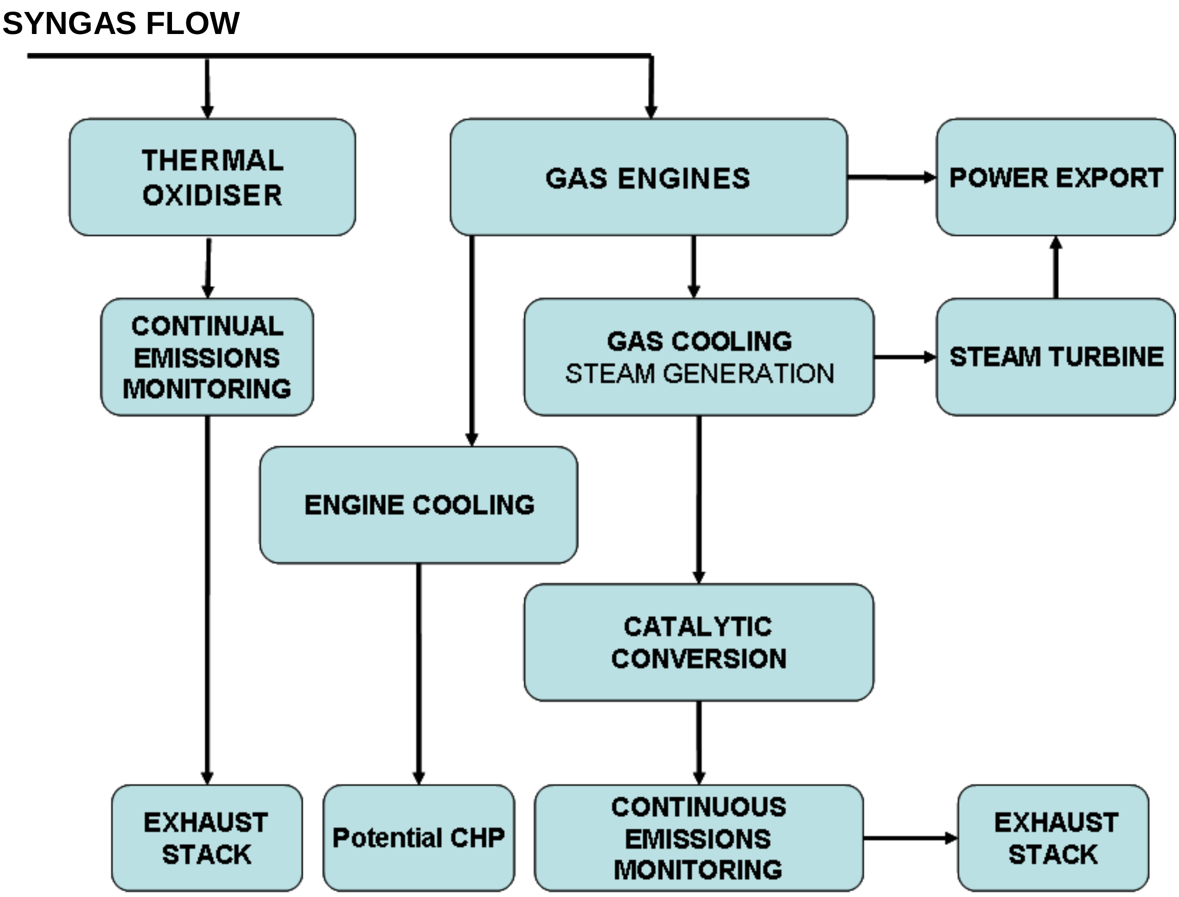

Figure 5 - Power Generation

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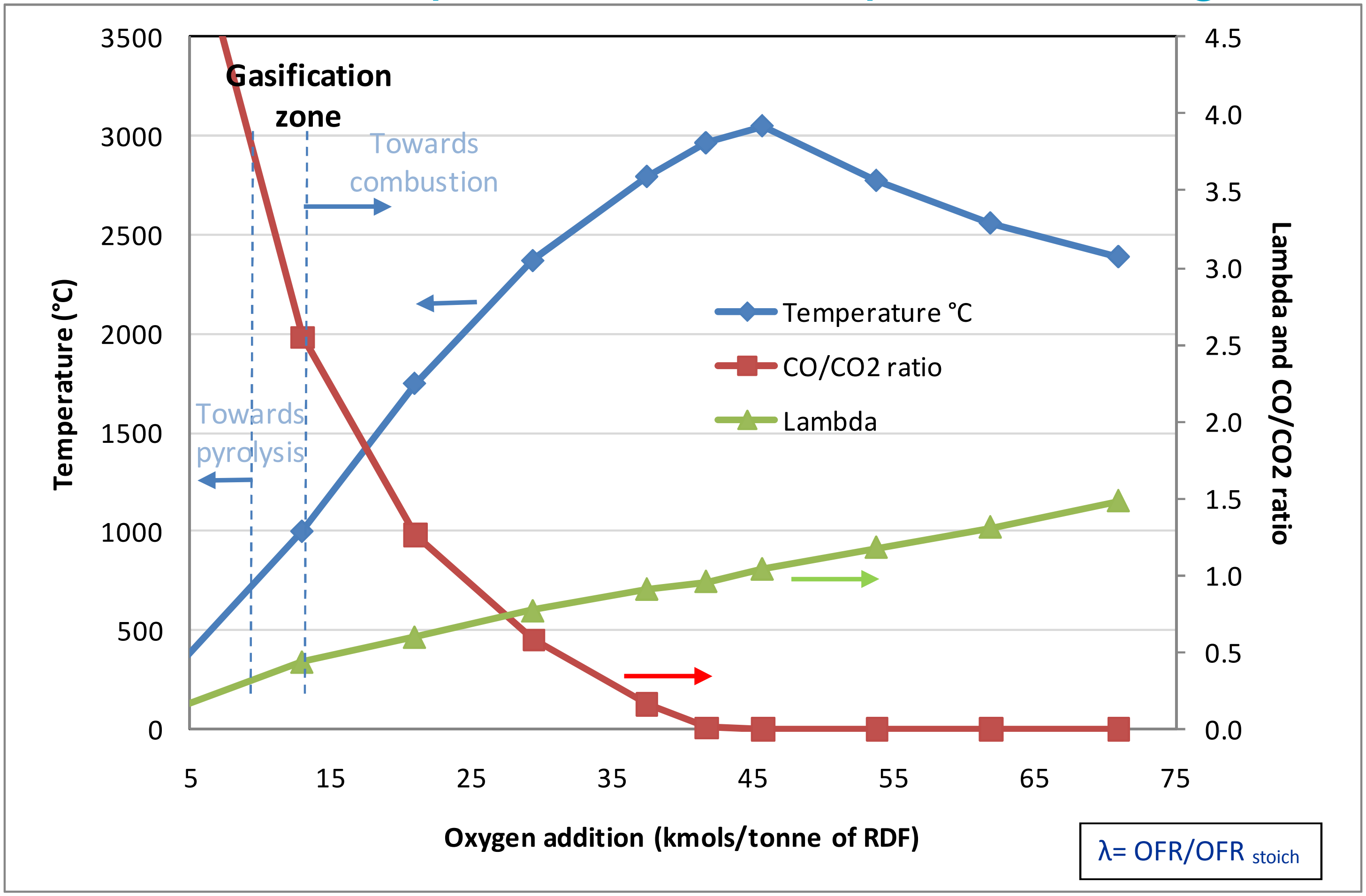
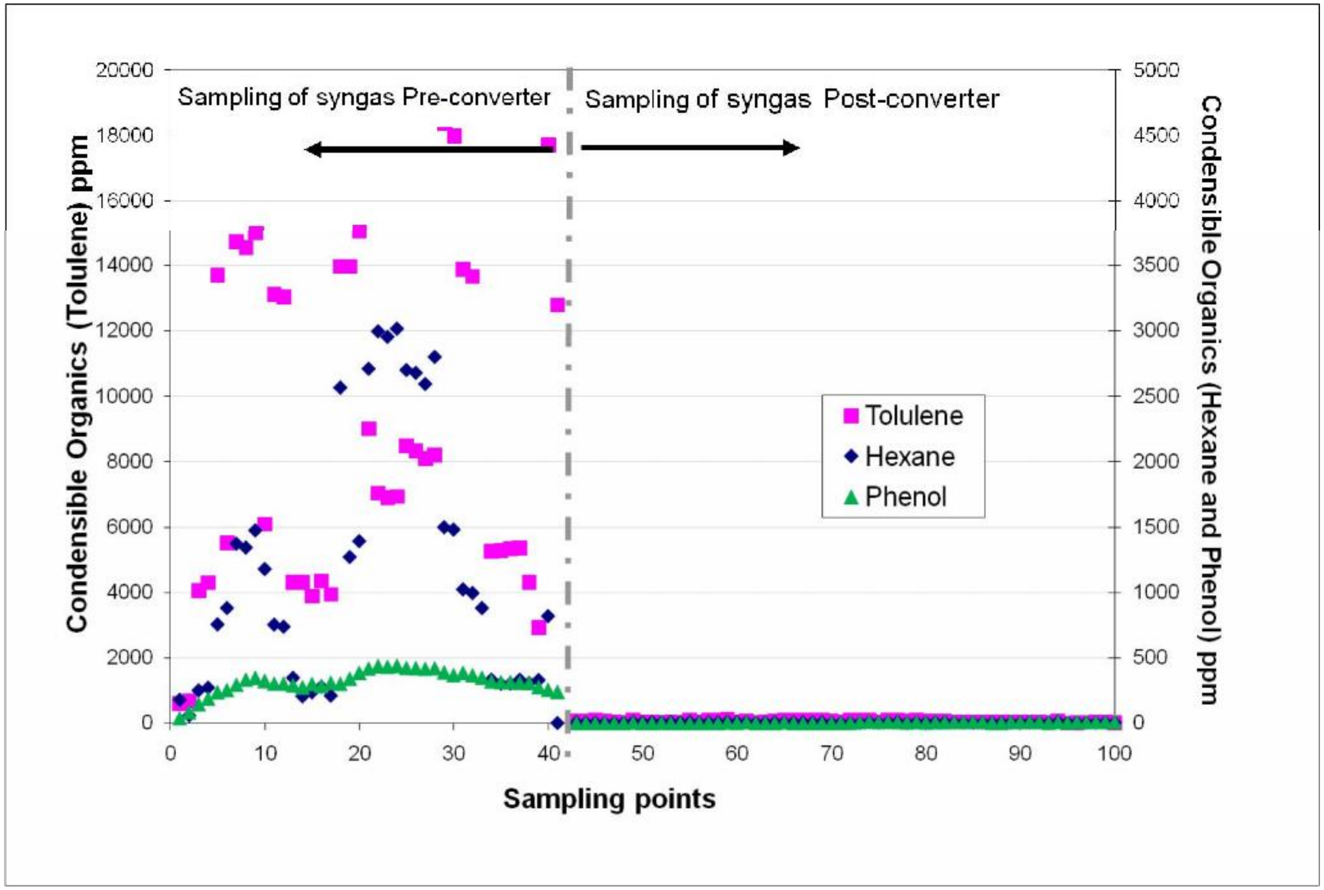
Fundamentals of Gasplasma® : Principles behind gasification



Fundamentals: Cracking of organics in plasma converter

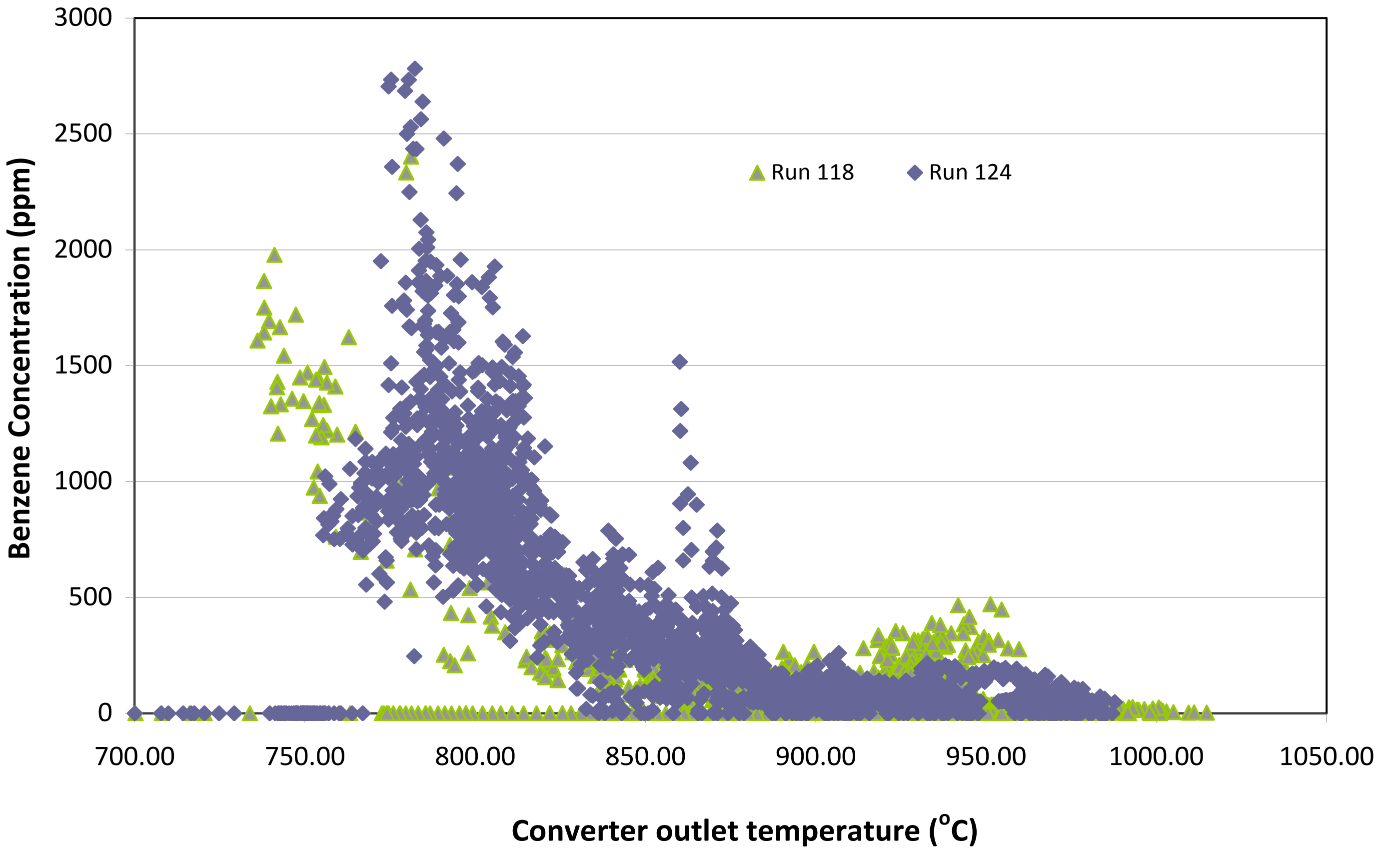
The effect of plasma treatment on the reduction of organic species in the syngas



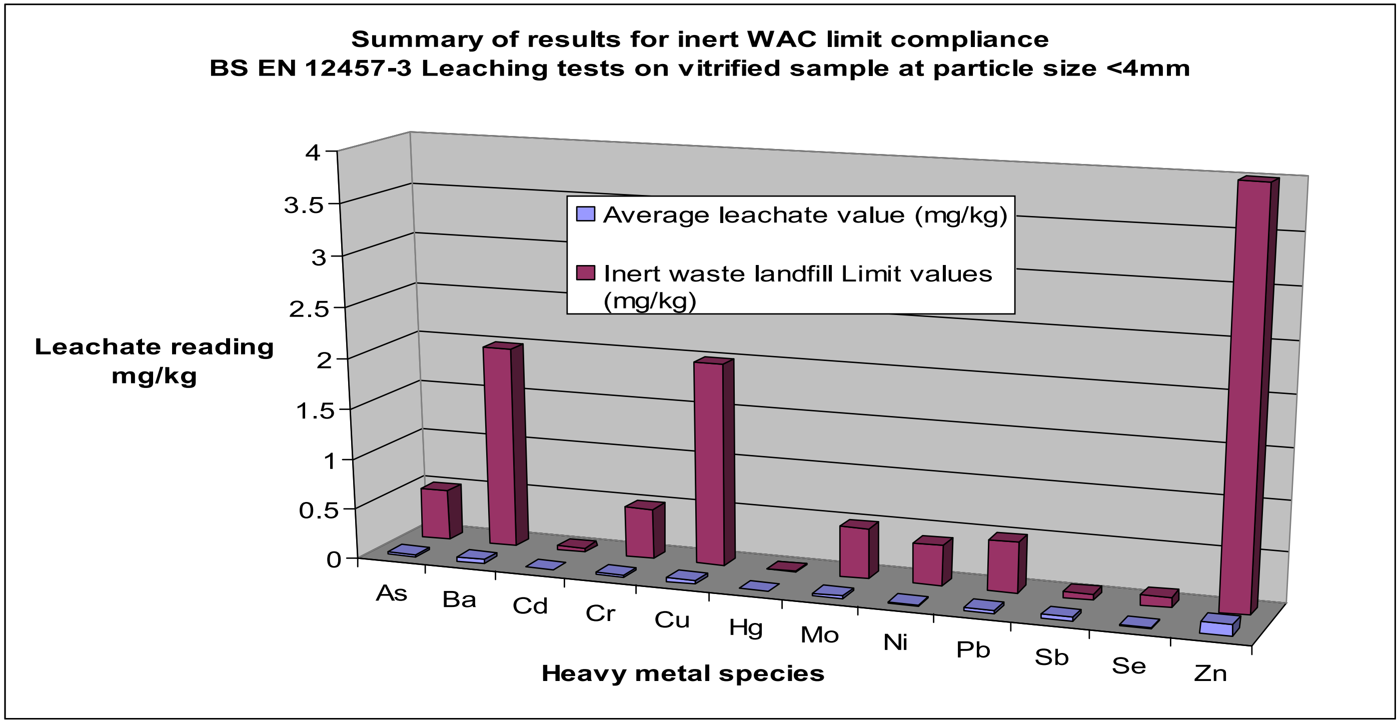
Syngas Composition

H_2	36%
CO	37%
CO_2	17%
N_2	3.7%
H_2O	4.2%
CH_4	1.4%

Fundamentals: Effect of temperature on tar levels in syngas



Gasplasma® Outputs: Plasmarok® – A Recycled Aggregate



Mechanically strong extremely leach resistant

Accepted by EA as a product –not a waste

Main constituents: Silica 37%; Lime 31% ; Alumina 16%
Others include: Iron Oxide; Titania; Magnesia; Sodium Oxide; Potash ; Phosphate

Gas Engine Emissions - compared to EU limits

Emission	Gas Engine mg/Nm^3	IED (WID) Limits mg/Nm^3
CO	31.8	50
NOx	128.9	200
HCl	2.4	10
SO2	15.8	50
Particulate	5.6	10
VOC/TOC	<1	10
Dioxins / Furans	Undetectable	< 0.1 ng / Nm^3 ITEQ

Main Exhaust Gases (by weight)
CO_2 13%; H_2O 5%; O_2 13% ; N_2 69%

Item	Unit	IED (WID) limit for Averaging period				
		10 min	30 min	0.5 – 8 hr	6-8 hr	Daily
Particulates	mg/Nm³	-	30	-	-	10
Sulphur dioxide	mg/Nm³	-	200	-	-	50
Oxides of nitrogen	mg/Nm³	-	-	-	-	200
Carbon monoxide	mg/Nm³	150	100	-	-	50
Hydrogen chloride	mg/Nm³	-	60	-	-	10
Hydrogen fluoride	mg/Nm³	-	4	-	-	-
Total organic carbon	mg/Nm³	-	20	-	-	10
Mercury	mg/Nm³	-	-	0.05	-	-
Cadmium, Thallium	mg/Nm³	-	-	0.05	-	-
Metals[11]	mg/Nm³	-	-	0.5 total	-	-
Dioxins & furans	ng ITEQ/Nm³	-	-	-	0.1	-

•Antimony, Arsenic, lead, chromium, cobalt, copper, manganese, Nickel, Vanadium and compounds associated with these metals
All pollution concentrations were corrected to WID reference conditions of dry gas, 11% oxygen (vol, dry) and 101.325kPa;

PLASMAROK® – RECOVERED FROM THE ADVANCED PLASMA POWER GASPLASMA® ENERGY FROM WASTE PROCESS

WHAT IS PLASMAROK®:

Plasmarok® is the fully vitrified, mechanically strong and environmentally stable and inert product that is recovered from the Advanced Plasma Power Gasplasma® energy from waste process. Simply put, it's a material that has been reduced to a stable and inert product by being subjected to extreme heat.

HOW IS PLASMAROK® MADE:

Plasmarok® is formed in the heart of the plasma converter where the intense heat (around 8,000°C) reduces the ash forming part of the waste feedstock into a molten vitreous material resembling volcanic lava.

The particular technique employed for treating the molten stream exiting the plasma converter can be adjusted to suit the end-use application for the product. For example, the molten material can be rapidly cooled and granulated in a water bath to form a <10mm product that would be appropriate for use as a pipe bedding material.

Alternatively, casting the material into blocks and allowing it to cool more slowly produces a high strength product that may be used as a sub-base material for a high load bearing structure.

WHY PLASMAROK® IS SAFER THAN ALTERNATIVES:

Plasmarok® is more suited to a wider range of uses than residues generated in other thermal conversion processes, such as conventional incineration. Incineration bottom ash contains leachable levels of heavy metals becoming potentially toxic, and the fly-ash contains heavy metals and other hazardous constituents and is therefore classed as hazardous waste under the European waste catalogue. Other technologies typically produce solid residues that contain high levels of chars, tars and heavy metals that may also require disposal to hazardous landfill.

UK ENVIRONMENT AGENCY APPROVED:

- **Certainty of use:** Plasmarok® has demonstrated that there is a need and a market for the recovered waste
- **Suitability for use:** Plasmarok® has been independently tested and passed BS EN 13242:2002 standards as an unbound aggregate in civil engineering construction projects. For example, in pipe bedding applications and road construction aggregate
- **No risk to the environment or human health:** Plasmarok® has undergone independent leachate testing against BS EN 12457 and has demonstrated that there is no potential to cause pollution or harm to human health when it is stored or used

APP's Gasplasma® technology economically converts waste fuels into two recyclable products;

i. A clean, hydrogen rich synthesis gas (syngas), capable of generating high electrical output

ii. An inert product (Plasmarok®) that can be reused as a building material

Advanced Plasma Power

THE Energy From Waste Solution

Plasmarok® has gone through comprehensive testing to ensure its safety against British Standard EN 1342:2002 standards.

USES FOR PLASMAROK®:

Plasmarok®'s unique combination of high mechanical strength and hardness, as well as extremely high resistance to chemical leaching make it perfect for use as a secondary aggregate material (material that has been used, then recycled and recovered) in road paving, pipe bedding or other markets. In addition, tests have proven that Plasmarok® is less vulnerable to the cracks and weakness that may reduce other materials resistance to fracture.

UK ENVIRONMENT AGENCY APPROVED:

The UK Environment Agency states that Plasmarok® meets the criteria set out in the Waste Framework Directive ("WFD") (Directive 2008/98/EC), which acknowledges Plasmarok® as a product and not a waste.

To achieve this status Plasmarok® has met the following requirements:

- **Certainty of use:** Plasmarok® has demonstrated that there is a need and a market for the recovered waste
- **Suitability for use:** Plasmarok® has been independently tested and passed BS EN 13242:2002 standards as an unbound aggregate in civil engineering construction projects. For example, in pipe bedding applications and road construction aggregate
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Advanced Plasma Power has successfully developed and operates a comprehensive Gasplasma® facility in Swindon. As a group we are experts in the use of Plasma; a clean, controllable, omnivorous technology that the group has been supplying since 1964 with 80 installations.

APP's Gasplasma® technology economically converts waste fuels into two products:

i. A clean, hydrogen rich synthesis gas (syngas), capable of generating high heat and power output

ii. An inert product (Plasmarok®) that can be reused as a building material

The technology is patented nationally and internationally.

ABOUT ADVANCED PLASMA POWER

Advanced Plasma Power (APP) Limited is the world's first waste-to-energy company using breakthrough Gasplasma® technology able to treat a wide range of feedstocks. Gasplasma® is based on proven sub-systems that offer an effective solution to two of the world's most significant environmental issues: the need for low carbon renewable energy and the need for cleaner, environmentally sustainable, waste management solutions.

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