# Pyrolysis and Gasification

# Briefing (Draft 2)

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## Contents



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## Briefing Objectives

This briefing is intended to assist waste campaigners in mounting confident, robust, professional and effective campaigns that dissuade Local Authorities (LAs) from adopting waste gasification or pyrolysis processes for waste disposal or agreeing planning applications for plants to accept Commercial and Industrial (C&I) waste.

These processes:

- Are inconsistent with reducing consumption, maximising reuse, and then recycling.
- Are inconsistent with changing patterns of consumption and reduction so as to minimise residual waste through high recycling and the gradual withdrawal of materials that cannot be reused, recycled or composted.
- Emit large quantities of carbon dioxide thereby contributing to global warming

and

- Produce toxic emissions.

It should be noted that gasification and pyrolysis are long established technologies with many industrial applications but which have only recently been applied in the waste processing field.

Links to Appendices to this briefing and to Associated Briefings are listed at the end of this briefing, and are available at

http://ukwin.org.uk/knowledge-bank/

Endnotes appear in section 10.

# 1. Pyrolysis and Gasification – the principles

Pyrolysis and gasification are ‘Advanced Thermal Technologies that’, using high temperatures, can convert combustible materials into gas. Whilst these process differ from traditional mass-burn incineration, they are still classified, in the context of waste disposal, as incineration in the European Union‘s Waste Incineration Directive (see **section 10** for links) and have to meet the mandatory emissions limits that it sets.

Pyrolysis and gasification, which can also be known collectively as  (ACTs) or Alternative Conversion Technologies, are not new technologies and have been used with a variety of feedstocks (including coal) for industrial purposes for many years. Their adoption in the UK for waste disposal purposes is, however, a new departure, and experience to date, other than in Japan, has been less than encouraging.

For waste disposal purposes, ATTs typically rely on materials with significant carbon content such as paper, petroleum-based wastes like plastics, and dry organic materials with a high carbon content.

Whilst they have much in common, pyrolysis and gasification have, in principle, differing primary objectives.

In the gasification process, materials are exposed to some oxygen, enough to allow partial, but not complete combustion to occur.  The process is geared to producing a synthetic gas (‘syngas’), which is composed mainly of carbon monoxide and hydrogen with small quantities of other hydrocarbon gases including carbon dioxide and methane.

The pyrolysis process, in which waste is heated in the absence of air (and oxygen), is geared to producing oil and / or char (carbon). Syngas is usually a secondary consideration. The syngas created may only be enough to meet the heating demands of the process itself.

In the waste context, waste contractors appear to see the benefits of syngas for power generation as offering greater benefit than char or oil. However, pyrolysis offers the opportunity to intercept carbon and sequester it (ie effectively remove it from the carbon cycle). See below under **Climate Change.**

Process temperatures vary greatly. Quality syngas production is best served by high temperatures (>1000C), oil and char production by relatively low temperatures (c 400C).

Gasification can be operated as either a batch or continuous flow process or, using multiple gasification chambers, a number of overlapping batch processes. A batch process involves loading a gasification chamber with a consignment of waste, gasifying the waste, emptying the ash and then repeating the process.

Pyrolysis is run as a batch process or a number of overlapping batch processes.

The extent to which ash will be produced, and the nature of the ash, depends on the feedstock and upon the details of the process.

(Section 1 continued)

A recent variant of gasification and pyrolysis technology utilises a plasma (electric) arc at very high temperature (up to 12 000$^{o}$C) to gasify the waste. In a sub variant, the plasma stage may follow on from a conventional gasification stage. The advantage gained from these very high temperatures is in the higher quality (including reduced contaminants) of the syngas.

Whilst it would appear to offer some advantages over conventional gasification, this technology is, in the waste processing context, still at an early stage. Two plants using the sub variant process with biomass feedstock are planned in the UK, but this briefing will not extend to its details, and potential implications.

For plant layout schematic plans see **appendix B**

## 2. Stages in the ATT processes

In the waste disposal context, gasification and pyrolysis processes have three principal stages. Please see **Appendix B** for more a more detailed description.

1. **Preparation of the waste feedstock**: The feedstock may be in the form of a refuse derived fuel, produced by a Mechanical Biological Treatment plant or an autoclave (see links in **section 10** to other briefings on MBT and Autoclaving). Alternatively, the plant may take mixed waste and process it first through a materials recycling facility which will remove recyclables and non combustible materials that have no calorific value and / or are likely to be harmful to the plant.

   The feedstock may then require to be dried and 'homogenised' (to ensure a near as constant calorific value), before it is loaded into the gasification or pyrolysis chamber...

2. **Partially combusting the waste** in a low oxygen atmosphere (gasification), or heating it in a zero oxygen atmosphere (pyrolysis), to produce syngas and other products (see below). The ash, which may be in the form of a solid mass, collects at the bottom of the gasification chamber. Note that with gasification, the heat comes from the partial combustion of the feedstock, whereas with pyrolysis the heat comes from an external source.

   There are several different designs for gasifiers and pyrolysis chambers. See **Appendix B**

3. **Cleaning the syngas** to remove, as far as possible, the particulates, hydrocarbons (tars) and soluble matter (see **Appendix A**) as appropriate to its intended use. Note that if the syngas is to be combusted in a boiler, (normally the situation with waste disposal plants) cleaning may not be considered necessary.

4. **Cleaning the flue gases:** if the syngas has been combusted, the resulting flue gases must be processed, before release to atmosphere, to remove toxic pollutants, such as to meet the limits set by the EU Waste Incineration Directive (WID). See **Section 10** for links to **Health and Safety** briefing.

## 3. Uses for syngas

There are a number of different ways in which scrubbed syngas can be used depending on the extent to which it has been scrubbed.

- To feed gas engines or gas turbines that drive electricity generators.
- It can be burned in a boiler to create steam for a turbine driving an alternator producing electricity. It may not, for this purpose, be considered to require cleaning.
- (Potentially, and subject to ongoing research) to feed fuel cells. (See **Appendix C**).

Trials are also in progress to establish the practicalities of feeding diesel engines with a syngas / air mixture and, at the same time, reducing the quantities of diesel injected.

Syngas can be converted into other gases and / or liquid fuels such as ethanol or diesel substitute.

## 4. The status of ATT for waste in the UK

At this point in time (2010) gasification and pyrolysis have yet, within the UK, to become established as reliable, or otherwise acceptable, solutions for waste disposal. Two waste gasification plants are understood to be operational, one on the Isle of Wight, the other at Dargavel near Dumfries. In addition, a number of planning applications for other MSW gasification plants have been received.

A full list of gasification and incineration plants appears on the UKWIN website. See section 10 for the link.

There is one MSW waste pyrolysis processor in the UK, installed on a testing basis, at Mitcham. Planning permission has been given for 4 additional processors. See **Appendix B** for more details.

## 5. Claimed advantages of ATT for waste

The companies developing ATTs claim that their technology has significant advantages over traditional mass-burn incineration, for example:

- By using less oxygen, air emissions can be reduced. (Note, however, if the gases and oils coming off the process are then burnt, this will also generate emissions; sometimes technology promoters do not make this clear.)
- The plants are modular. They are made up of small units which can be added to or taken away as waste streams or volumes change (e.g. with increased recycling) and are therefore more flexible and can operate at a smaller scale than mass-burn incinerators, and be quicker to build.

(Section 5, Claimed advantages of ATT for Waste – continued)

- The processes recover useful energy which can be used either on site, or, following further processing or conversion, elsewhere. The energy recovered by mass burn incineration can only be used on site.
- The syngas may be used to generate energy more efficiently, if a gas engine (and potentially a fuel cell) is used, whilst incineration can only generate energy less efficiently via steam turbines
- The energy produced may be eligible for more Renewables Obligation Certificates (ROCs) than incineration, increasing the potential income from any power generated.

Such data as is available on the performance of these technologies comes from the supplying companies themselves and much of this data appears to be aspirational rather than factual. See **section 6** and elsewhere in this briefing.

This makes it difficult to establish their real performance and some waste companies are now arguing that, in practical terms, they offer no advantages over incineration.

## 6. ATT of waste - Disadvantages and why it should be resisted

ATT plants appear to share all of the same disadvantages as mass-burn incineration and to be less reliable. These disadvantages are listed in more detail in **Appendix F** under headings:

- Impact on Recycling
- Impact on LA finances and Council Taxes
- Reliability
- Emissions
- Climate, GHG and Energy Efficiency.

In summary:

ATTs, like incineration, rely on high calorific value material that should be recycled.

Any electrical energy produced will be far less than the energy spent in manufacturing new products, to replace those destroyed instead of recycled.

Mixed Waste gasification has a very limited track record of success in Europe.

The ATTs, as proposed to date and for waste processing, are very inefficient in terms of the conversion of energy in waste to electrical energy both in absolute terms and by comparison with a gas fired power station. They also emit large quantities of $CO_2$ in addition to toxic materials. The income from the inefficiently produced electricity, however, supplements the gate fees. See **Appendix E**

A report by Juniper consultants enlarges on the issues set out in this section and presents a wider picture of the risks that waste gasification presents. Extracts are available in **Appendix D**. There are links to the full report in **section 10.**

## 7. Climate Change

ATTs will release syngas which, when burnt, will create $CO_2$ and other Greenhouse Gas (GHG) pollutants. Whilst the combustion will release biologically derived $CO_2$ from biological materials in the feedstock, some of which may be renewable, it will also release fossil-fuel derived $CO_2$ from plastics, synthetic textiles etc.

This is why the phrase "renewable energy" is not accurate when describing the energy produced from such plants. The extent to which the combustion of mixed waste, in particular when it includes plastics, in conventional incinerators or by ATTs, contributes to GHGs cannot be over emphasised. In this context, it is actually less damaging if plastics are put to landfill.

All waste disposal processes, recycling not excepted, result, directly or indirectly, to a greater or lesser extent, in the emission of GHG's in some form. The interests of minimising climate change are, in the waste management context, best served according to the Waste Hierarchy

More specific details are available in **Appendix G.**

A version of Pyrolysis has been proposed that will capture carbon (biochar) from organic material and thereby enable it to be 'sequestered' from the carbon cycle. The biochar can then be used for agricultural purposes, or for other purposes that prevent, or substantially delay, its return to the carbon cycle.

However, there has been no progress in the UK with the installation of this concept, although research work proceeds into the implications of adding the biochar to soil.

See **section 10** for links to more information on **carbon capture**.

## 8. The impact on human health

Human toxicity is a measure of the potential risk to health from a plant. Whilst this section gives brief details, please see associated briefing: **Health and Safety (emissions related)**. Like incineration, pyrolysis and gasification are likely to produce emissions in gaseous and particulate forms, for example:

- Air emissions, which should be controlled to limits set out in the EU WID or such lower limits as the EA may prescribe, can be expected to include acid gases, dioxins and furans, nitrogen oxides, carbon monoxide, sulphur dioxide, particulates, cadmium, mercury, lead and hydrogen sulphide. The WID limits are not applicable in all operating circumstances, for example during start up and shut down phases when higher emission levels are inevitable.

- Solid residues include inert mineral ash, inorganic compounds, and any remaining unreformed carbon– these can be between 8 and 15 per cent of the original volume of waste;

(Section 8 continued)

- Other emissions may include treated water – used to wash the waste in the pre-treatment stage, and clean the gas – but this water should be recycled within the plant.

See **appendix D** for further comments extracted from a report by Juniper Consulting Limited.

See **section 10** for links to associated briefing **Health and Safety (emissions related)**

## 9. Local Authorities (LAs), MSW and C&I waste

LAs are concerned with waste disposal in two aspects:

Some have a responsibility for MSW disposal, some for MSW collection and some for both. Those with disposal responsibilities may seek to discharge these via a Private Finance Initiative (PFI).

LAs with planning responsibilities have to decide whether to grant planning permission for waste disposal plants when planning applications are made. These applications may be made as the result of a PFI or (particularly in the case of C&I waste) an investment decision by a waste management company, or waste disposal ('energy recovery') plant manufacturer or licensee.

However, where the activities of ATT waste disposal facilities conflict with national or regional plans for waste reduction, LAs must take account of these, as well as local environmental issues (such as odours, emissions and traffic congestion) when considering planning applications.

Most LAs are still not maximising recycling and composting. While this is the case, using pyrolysis and gasification will undermine recycling and composting – which are far better ways of saving energy and resources.

ATTs rely on a feedstock rich in paper, kitchen and garden waste and plastics. Increasing re-use, recycling and composting will dramatically alter the level of these waste streams in residual waste, and may therefore compromise the ability of ATT plants to operate profitably.

There is, currently at least, no reason to believe that the reliability of waste gasification plants will be better than, or equal to that of conventional incinerators, with implications of a build up of untreated waste or diversion to landfill if the contractor cannot meet its commitments.

Waste management contractors pressure councils to accept long term (typically 20 year) contracts with conditions that (a) conflict with recycling and (b) may contain 'get out' clauses applicable in cases of non delivery.

**Appendix F** gives more details of the disadvantages of gasification for waste as these relate to LA responsibilities and the disposal of C&I waste.

## 10. Information Links

### Appendices
**Available from**
http://www.ukwin.org.uk/files/pdf/Appendices_UKWIN_Pyrolysis_and_Gasification_Briefing_May_2010.pdf

- Appendix A: Syngas Cleaning
- Appendix B: Typical Schematic Layouts – Pyrolysis and Gasification plants
- Appendix C: Fuel Cells
- Appendix D: Juniper Report Extracts
- Appendix E: The EU approach to the Efficiency of waste recovery installations
- Appendix F: Gasification and pyrolysis disadvantages

**Details of Waste Incineration (incl. Pyrolysis & Gasification) Plants in the UK:**
http://ukwin.org.uk/knowledge-bank/incineration/sites-where-incinerators-exist-or-are-proposed/

### Associated Briefings
Anaerobic Digestion: http://ukwin.org.uk/knowledge-bank/ad-briefing/

These are also expected to include:

- MSW preferred recycling methods and disposal processes
- MBT and aerobic processes
- Waste Treatment Technologies compared.
- Carbon Sequestration
- Health and Safety (emissions related)

These will be available at: http://ukwin.org.uk/knowledge-bank/ad-briefing/

### Friend of the Earth Briefings
Friend of the Earth briefings can be found at
http://www.foe.co.uk/community/campaigns/healthy_planet/incineration_index.html

- Dirty Truths – the climate impacts of energy from waste and residual waste treatment: http://www.foe.co.uk/resource/briefings/dirty_truths.pdf
- Up in Smoke- why Friends of the Earth opposes incineration http://www.foe.co.uk/resource/media_briefing/up_in_smoke.pdf
- Pyrolysis, gasification and plasma http://www.foe.co.uk/resource/briefings/gasification_pyrolysis.pdf

The Friends of the Earth site also includes briefings on Mechanical Biological Treatment (MBT), food waste collection and the Landfill Allowance Trading Scheme (LATS).

### Other sources
Juniper Consulting Ltd: Pyrolysis and Gasification Factsheet
http://www.wastereports.com/information_sheets/Pyrolysis&gasifcation_factsheet.html

Juniper Consulting Ltd:
Briefing Document on the Pyrolysis and Gasification of MSW (pdf.)

Energos, Gasification plants and layouts
http://www.envirolinknorthwest.co.uk/envirolink/Events0.nsf/0/8025739B003AADE38025750000321B0E/$file/ENERGOS.pdf (inc. layout drawings)

Compact Power: Energy from Waste by Pyrolysis and Gasification the Experience and Performance of an Operational Plant (inc. layout drawings):
http://www.swlf.ait.ac.th/IntlConf/Data/ICSSWM%20web/FullPaper/Session%20VI-B/6_B6%20_Richard%20Hogg.pdf

EPi pyrolysis:
http://www.merton.gov.uk/living/planning/planningpolicy/mertonrule/building_a_zero_carbon_future.htm