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Friends of the Earth

Briefing

Pyrolysis, gasification and plasma

Introduction

In the past, almost all residual municipal waste in the UK - the waste left after recycling and composting - has been landfilled untreated. The European Landfill Directive means we must now reduce the biodegradable waste we send to landfill. Until recently, the main alternative to landfill which has been considered in the UK is mass-burn incineration. Friends of the Earth has long opposed incineration of residual waste because it destroys natural resources; it undermines recycling by demanding a steady stream of waste; it adds to climate change; and it causes pollution from air emissions and toxic ash. Local authorities have started considering other options for dealing with residual waste, including pyrolysis, gasification and plasma arc technologies. This briefing explains how these processes work and what their benefits and disadvantages are.

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Pyrolysis and gasification – how it works

Like incineration, pyrolysis, gasification and plasma technologies are thermal processes that use high temperatures to break down waste. The main difference is that they use less oxygen than traditional mass-burn incineration. However, they are still classified as incineration in the European Union (EU)'s Waste Incineration Directive, and have to meet the mandatory emissions limits that it sets.

These technologies are sometimes are known as Advanced Thermal Technologies or Alternative Conversion Technologies. They typically rely on carbon-based waste such as paper, petroleum-based wastes like plastics, and organic materials such as food scraps.

The waste is broken down to create gas, solid and liquid residues. The gases can then be combusted in a secondary process. The pyrolysis process thermally degrades waste in the absence of air (and oxygen). Gasification is a process in which materials are exposed to some oxygen, but not enough to allow combustion to occur. Temperatures are usually above 750^{o}C. In some systems the pyrolysis phase is followed by a second gasification stage, in order that more of the energy carrying gases are liberated from the waste.

The main product of gasification and pyrolysis is syngas, which is composed mainly of carbon monoxide and hydrogen (85 per cent), with smaller quantities of carbon dioxide, nitrogen, methane and various other hydrocarbon gases.

Syngas has a calorific value, so it can be used as a fuel to generate electricity or steam or as a basic chemical feedstock in the petrochemical and refining industries. The calorific value of this syngas will depend upon the composition of the input waste to the gasifier.

Most gasification and pyrolysis processes have four stages:

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 to briefings on MBT and autoclaving on page 6). Alternatively, the plant may take mixed waste and process it first through some sort of materials recycling facility, to remove some recyclables and materials that have no calorific value (e.g. grit)

2) **Heating the waste** in a low-oxygen atmosphere to produce a gas, oils and char (ash)

3) **'Scrubbing' (cleaning) the gas** to remove some of the particulates, hydrocarbons and soluble matter

4) Using the scrubbed gas to **generate electricity** and, in some cases, heat (through combined heat and power – CHP). There are different ways of generating the electricity from the scrubbed gas – steam turbine, gas engine and maybe some time in the future, hydrogen fuel cells (see page 4).

In plasma technologies the waste is heated with a plasma arc (6,000º to 10,000º Celsius) to create gases and vitrified slag. In some cases the plasma stage may follow on from a gasification stage.

Unfortunately, most of the available data on the performance of these technologies comes from the companies themselves. This makes it difficult to establish their real performance[1].

Comparing pyrolysis, gasification and mass-burn incineration

The companies developing advanced thermal processes ***claim*** that their technology has significant **advantages** over traditional mass-burn incineration:

- By using less oxygen, fewer air emissions may be produced. However, if the gases and oils coming off the process are then burnt, this may 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.
- They are quicker to build.
- The processes are claimed to produce a more useful product than standard incineration – gases, oils and solid char can be used as a fuel, or purified and used as a feedstock for petro-chemicals and other applications.
- 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[1].
- The energy produced may be eligible for more Renewables Obligation Certificates (ROCs) than incineration, increasing the potential income from any power generated.

However, gasification and pyrolysis share some of the same **disadvantages** as mass-burn incineration:

- Unless they only deal with truly residual waste (what is left once maximum recycling and composting has happened) the processes will undermine recycling and composting.
- They are unlikely to be able to deal with truly residual waste, as plants need a certain amount of particular types of materials in order to work effectively e.g. plastic, paper, and food waste. However this conflicts with recycling and composting as these materials are often the most valuable parts of the waste stream for these processes.
- Any fuel produced will not make up for the energy spent in manufacturing new products – re-use and recycling are still better (like incineration and landfill, energy savings from waste prevention and recycling are likely to be greater than the energy produced).
- Disposal of ash and other by-products may be required, though some companies claim that their process makes this easier than for incineration ash.

There are also considerable **uncertainties** about these technologies:

- Much of the data on the performance of these plants comes from the individual companies, and is contradictory if comparisions are made between approaches. For example, advocates of incinerators will claim that they are more energy efficient,[2] whilst advocates of these alternative technologies will claim they are more efficient.
- It is often unclear exactly what emissions will be involved, and what sort of ash or other residue will be produced (again, in most cases this information comes from the company).

- Many of these technologies have been mainly used on more defined waste streams (e.g. particular industrial wastes), so their reliability and effectiveness on mixed municipal waste is often questioned.
- There is often uncertainty about the real practical and financial performance of these plants, which can lead to more established technologies (e.g. incineration) being selected.

A report by consultancy company Juniper[3] states that "*the recovery routes that have the highest energy recovery efficiencies are the least proven.*" It explains the complications of assessing the energy recovery potential of these technologies: "*unlike incineration, gasification can be used in conjunction with higher efficiency energy recovery technologies … but, because the higher efficiency modes of energy recovery are less proven, the financial and environmental benefits are offset by the increased risk. Partly because of this greater risk, many projects actually choose to use less efficient technologies for energy recovery. So it is important to judge each project on its own merits, when assessing the actual performance. Proponents … may 'talk-up' the energy efficiency, based on theoretical capabilities of this family of technology. Yet, because the specific project uses more conventional, low efficiency energy recovery it may actually have a lower net recovery than equivalent incinerators.*"

The report goes on to explain "*Most commercial processes use combinations of technologies. It is important to note that nearly all of the commercial "gasification" systems actually follow the gasification with combustion. In doing so many of the key theoretical differences between pyrolysis, gasification and incineration become blurred. While gasification is not the same as incineration, the actual practical differences between some commercial gasification systems (that incorporate combustion to produce electricity) with incineration are relatively modest. Similarly, if pyrolysis is followed by combustion, there is relatively little difference from incineration*."

The impact on climate change

These processes will release fossil-fuel derived CO2 from plastics, synthetic textiles etc. They will also release biologically derived CO2 from biological materials. This is why the phrase 'renewable energy' is not accurate when describing the energy produced from such plants.

A study by Eunomia[1] compared the greenhouse gas emissions of residual waste management technologies including gasification and plasma gasification. The scenarios involving gasification and those involving MBT (including with MBT residue to landfill, which scored best overall) performed much better than those involving incineration. However this study did not consider how these technologies would perform in practice, with the data being provided by the companies concerned.

The Eunomia study demonstrated that maximising the removal and recycling of materials, particularly of plastics avoids emissions from virgin manufacturing processes and so significantly reduces climate impacts. It may not be possible to maximise recycling prior to treatment by gasification and pyrolysis, due to the requirement for a fairly specific composition of waste, including combustibles, in order for the process to work effectively.

Juniper's report[3] says "*where pyrolysis and gasification (P&G) processes are integrated with more efficient energy recovery, significant greenhouse gas savings per kW of electricity generated relative to incineration are possible*", however pyrolysis and gasification plants that directly combust the raw syngas to produce electricity in a steam boiler (called 'close-coupled') "*are quite similar to incineration in the way energy can be recovered and in greenhouse gas terms this type of P&G is arguably little different from incineration.*"

Hydrogen fuel cells

Syngas can be used in either a gas engine or hydrogen fuel cell to generate energy.

In Eunomia's study, scenarios involving hydrogen fuel cell technologies (export of syngas for conversion to H2 for use in vehicles and plastics reprocessing) performed better than CHP, in terms of their greenhouse gas impact. This is because of greater conversion efficiencies of fuel cells when compared to other energy generation technologies.

Although this suggests that there is potential for fuel cells to generate energy from hydrogen converted from syngas, in reality very little research has been carried out on the use of syngas derived from municipal solid waste in hydrogen applications and they are presently unlikely to attract commercial finance.[1]

Given the current uncertainties about this technology, claims should be treated with caution.

The impact on human health

Human toxicity is a measure of the potential risk to health from a plant. Like incineration, pyrolysis and gasification are likely to produce emissions, for example:

- Air emissions include acid gases, dioxins and furans, nitrogen oxides, sulphur dioxide, particulates, cadmium, mercury, lead and hydrogen sulphide;
- Solid residues include inert mineral ash, inorganic compounds, and any remaining unreformed carbon (which is also inert) – these can be between 8 and 15 per cent of the original volume of waste;
- Other emissions include treated water – used to wash the waste in the pre-treatment stage, and clean the gas.

The actual quantity and nature of emissions will be different from different technologies, but (as with other issues) most of the information available comes from the companies themselves. It is therefore very difficult to make general statements about the emissions of these technologies.

Juniper's report[3] states "*it is possible, due to certain technical features of P&G, that their emissions performance can be considered to be better than incineration. However, in practice, the project specific nature of process implementation means that it is inappropriate to generalise and not correct to say that gasification is better than incineration in terms of its emissions performance of vice versa…Though some developers of plasma gasification technologies have claimed that their process does not produce dioxins, solid commercial data is not yet available to back-up such claims.*"

Evidence about these processes?

Although these technologies have received a lot of attention as a possible alternative to municipal waste incineration, so far few have been proposed in the UK, and "*many of the most actively promoted processes have never been operated on a commercial basis on MSW at a significant scale*."[3]

There are a handful of commercial-scale gasification facilities operating within the EU, although not all treat mixed waste. Japan has many high-temperature facilities.

Performance data for these technologies may therefore be less reliable than that for incineration.[1] Companies suggest that it makes sense to extrapolate the data obtained from pilot scale plants to full scale facilities; but of course such results cannot be guaranteed.

As well as concerns over the technical feasibility, there is also a lack of evidence that these technologies are financially viable. Concerns about operational reliability have been raised by recent problems at various projects worldwide.[4]

Juniper's report[3] warns that "*technology risks for many P&G processes targeting municipal solid waste (MSW) can be significant. One reason for this is that P&G processes do not yet have an established track record in the UK. This is compounded by the fact that variants that are being widely marketed here (close-coupled, gasification to gas engines and plasma gasification) have limited relevant track record anywhere else in the world. The lack of relevant track record means that the robustness of guarantees given on factors that may include process availability, maintenance costs and energy output, all of which are necessary to underpin financial models and contract terms, are often called into question in technical due diligence.*"

Juniper still see the integration of gasification with gas engines as very risky. Their report also says "*integration issues will have an impact on factors that include project deliverability, performance guarantees and costs and therefore are seen as having a significant risk potential for P&G projects. The main issue is syngas cleaning. Gas engines and turbines typically have low-tolerances to impurities in the syngas and therefore cleanup of this gas product when processing a heterogenous input such as MSW is challenging. Thus, the cleaning of syngas from this type of feedstock to within narrow tolerances is seen as difficult to achieve and considered a major technical risk factor in integrating MSW gasification with high efficiency energy recovery.*"

Conclusion – a solution to the waste crisis?

There is a lack of independent data to demonstrate how well these technologies perform, so they cannot be compared to alternative treatment technologies in terms of overall impact on the climate, overall energy balance or financial viability.

Pyrolysis and gasification of municipal waste has the potential to be more flexible than incineration because it can be more modular. They may have some advantages in terms of emissions, although firm conclusions are impossible to draw because toxicity is notoriously difficult to measure.

However, three conclusions are clear:

- Most local authorities 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;
- Pyrolysis and gasification 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 pyrolysis and gasification plants to operate profitably.
- Pyrolysis and gasification of municipal waste is not a 100 per cent renewable energy technology, and analysis has shown that it can be better in climate terms to landfill stabilised waste than to burn it, even with the claimed efficiencies of these technologies. Friends of the Earth's view is that investment should be focussed on 100 per cent renewable energy technologies, for example anaerobic digestion, or wind and wave energy.

Further information

Autoclaving briefing www.foe.co.uk/resource/briefings/autoclaving.pdf

Mechanical biological treatment briefing
www.foe.co.uk/resource/briefings/mchnical_biolo_treatmnt.pdf

Defra (2007), *Advanced thermal treatment of municipal solid waste*
www.defra.gov.uk/environment/waste/wip/newtech/pdf/att.pdf

References

[1] Eunomia Research and Consulting (2008), *Greenhouse gas balances of waste management scenarios - report for the Greater London Authority*, www.london.gov.uk/mayor/environment/waste/climate-change/greenhousegas.jsp

[2] Fichtner Consulting Engineers Limited (2004), *The viability of advanced thermal treatment of MSW in the UK,* www.esauk.org/publications/reports/thermal%20treatment%20report.pdf

[3] Juniper (2008), *Briefing document on the pyrolysis and gasification of MSW*

[4] Juniper, "Pyrolysis and Gasification Factsheet", http://www.wastereports.com/information_sheets/Pyrolysis%20and%20Gasification%20Factsheet.pdf