TRANSFORMATIONS OF SYNGAS DERIVED FROM LANDFILLED WASTES USING THE GASPLASMA® PROCESS

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Abstract

The Gasplasma® advanced conversion technology is able to efficiently produce a clean syngas and an environmentally stable vitrified product from historically landfilled materials. The syngas is rich in hydrogen and carbon monoxide and possesses high calorific value, and low residual tar levels. While this syngas has traditionally been considered only as a fuel source for power generation, it can also be transformed into fuel gases.

The Gasplasma® technology developed by Advanced Plasma Power consists of a bubbling fluidised bed gasifier (BFBG) followed by a single carbon electrode plasma converter. This ATC technology allows processing of a broad range of wastes, including, amongst others, MSW-sourced and landfill-derived Refuse Derived Fuel (RDF), Automobile Shredder Residue (ASR), and biomass. The process provides high conversion efficiencies using waste feed, and is designed specifically to cope with ash components and problem species (e.g. PVC found in ASR). The syngas generated by the process is of sufficient quality, both in terms of calorific value and cleanliness, to permit use of the gas in high efficiency power generation equipment; whereas gasification alone has traditionally produced a syngas with high residual tar levels limiting its applications to lower efficiency steam-based power generation.

Additionally, the properties of the syngas generated within the Gasplasma® process are ideally suited for transformation into a fuel gas, such as substitute natural gas (SNG) or hydrogen. While the decarbonisation of electrical generation is well under way, there is currently no clear similar path for the decarbonisation of domestic and industrial heating, whose greenhouse warming potential (GWP) is roughly equivalent to that of electricity generation inside the EU27. Indeed, the bulk of the 5717.3 TWh (in 2010) of natural gas consumed in the EU27 came from fossil fuel sources imported from outside the EU. The transformation of syngas into a fuel gas requires use of catalysed reactions to either enrich specific syngas components (e.g. hydrogen in the waste gas shift reaction) or combine the hydrogen and carbon monoxide together to form methane (in the methanation reaction).

Use of landfill waste-derived syngas as a source for fuel gas production has a lower carbon footprint than natural gas in addition to the carbon benefits of diverting waste from landfill, which are considerable. This technology has the potential to provide a secure and cost-effective supply of gas derived from waste; a fuel source that we have in abundance.
Introduction

Finding effective, sustainable solutions to combat the effects of anthropogenic global warming will be the greatest challenge that the global community faces in the 21st century. A major part of this endeavour will be in developing means of securing dependable sources of renewable energy and also in greatly reducing the amount of materials obtained from virgin reserves. Within Europe, the EC has set ambitious targets to increase the proportion of energy from renewable sources from around 8.5% today to 20% by 2020. However, there still exists a fundamental challenge with this approach in providing both heat and power economically, while achieving renewable targets. Technological innovation has largely centred on the ‘greening’ of the power supply, but little has happened on the decarbonation of the provision of heat. In 2010 the energy consumption of the EU27 area still centred on fossil fuels, with 35.1% coming from oil products, 25.1% from natural gas, and 15.9% from solid fuels. Furthermore, as shown in Table 2, the vast bulk (c. 70%) of the natural gas consumed was imported from outside the EU, coming principally from Russia, Norway, the Middle East, and North Africa.

Table 1: Natural gas supply and demand in EU27 in million tonnes oil equivalent

<table>
<thead>
<tr>
<th>Natural gas source</th>
<th>2010</th>
<th>2011</th>
<th>Natural gas destination</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary production</td>
<td>170.4</td>
<td>153.7</td>
<td>Exports</td>
<td>82.6</td>
<td>94.8</td>
</tr>
<tr>
<td>Imports</td>
<td>395.0</td>
<td>391.2</td>
<td>To stock</td>
<td>0.0</td>
<td>10.2</td>
</tr>
<tr>
<td>From stocks</td>
<td>8.8</td>
<td>0.0</td>
<td>Consumption</td>
<td>491.6</td>
<td>440.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>574.2</td>
<td>544.9</td>
<td>TOTAL</td>
<td>574.2</td>
<td>545.0</td>
</tr>
</tbody>
</table>

As shown in Table 2, the major portion of this gas is used for power generation, as is the majority of the solid fuel consumed by the EU27. The remaining natural gas is almost exclusively consumed for domestic and industrial heating.

Table 2: Gas consumption in EU27 in 2010

<table>
<thead>
<tr>
<th>Sector</th>
<th>Gas consumption by sector (%)</th>
<th>Million tonnes of oil equivalent</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation</td>
<td>37.0</td>
<td>212.5</td>
<td>2115.4</td>
</tr>
<tr>
<td>Industry</td>
<td>21.1</td>
<td>121.2</td>
<td>1206.4</td>
</tr>
<tr>
<td>Transport</td>
<td>0.6</td>
<td>3.4</td>
<td>34.3</td>
</tr>
<tr>
<td>Services</td>
<td>11.7</td>
<td>67.2</td>
<td>668.9</td>
</tr>
<tr>
<td>Household</td>
<td>29.6</td>
<td>170.0</td>
<td>1692.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0</td>
<td>574.2</td>
<td>5717.3</td>
</tr>
</tbody>
</table>
Increasing global demand and dwindling resource availability are reflected in the gas price trends, as shown in Figure 1. Generally, gas prices in the EU and Japan have risen, recovering after the sharp decline following the 2008 global economic downturn. By comparison, the gas price in the USA has remained low, chiefly due to the availability of low-cost shale gas.

It is against this background that Advanced Plasma Power has developed the Gasplasma® technology. This advanced thermal conversion (ATC) technology uses waste materials, currently destined for landfill or incineration, and is able to either produce a synthetic gas (syngas), that can be transformed into a fuel gas for direct injection into national distribution networks, or efficiently generate electrical power. Invariably, the waste material used as a fuel source will contain a significant proportion of biogenic carbon, with RDF containing as much as 60-65%, thus effectively permitting both the power and the fuel gas generated to be sourced from largely renewable sources.

**Gasplasma® process**

The Advanced Plasma Power Gasplasma® process is centred on a two-stage thermal treatment process, as shown in Figure 2. The process comprises a bubbling fluidised bed gasifier (BFBG), designed specifically for steam/oxygen gasification, that is closely coupled to a plasma converter.
The gasifier contains a bed of nominally 1 mm mullite particles, and is fed with a supply of steam and oxygen as the gasification medium. The fluidised bed is maintained at a temperature of between 700 and 850°C, with the actual operating condition depending on fuel characteristics and desired reaction profiles (see Figure 3). The flows of steam and oxygen are finely controlled to maintain the bed temperature, good fluidisation of the gasifier bed and also to obtain the required syngas quality.

Figure 3: Typical gasification temperature for various feedstock and influence of temperature change on some critical factors

Figure 4 shows the effects of oxygen availability within the gasification reactions on the syngas calorific value, with a maximum achieved at a stoichiometric ratio (the ratio between the oxygen available and that required for complete combustion) of around 0.35, a value that depends on the composition of the RDF/waste being utilised as a feedstock. At lower
stoichiometric ratios the reactions tend towards pyrolysis reactions with more volatile organic compound generation and lower temperatures, while at higher stoichiometric ratios the reactions tend towards the more exothermic combustion (full oxidation) reaction pathways.

**Figure 4: Theoretical variation in RDF gasification system conditions with stoichiometric ratio using pure oxygen as the oxidant source**

The fluidised bed gasifier permits the process to accept a broader range of feedstock types and physical properties (both in terms of particle size and density). Fluid bed systems allow a more efficient gasification due to a homogeneous temperature, good flow mixing inside the reactor, and rapid heating of the feedstock, leading to a more consistent syngas generation and high conversion efficiencies.

The waste is thermally decomposed within the gasifier to produce a crude syngas, containing residual tars, unconverted char and entrained ash particles. This crude syngas enters the side of the converter chamber above the slag level and circulating around the periphery of the chamber allowing the gas to increase in temperature while receiving maximum exposure to the intense ultra violet light within the converter, aiding cracking of tar substances, conversion of the residual char, and promoting the separation of particulates from the syngas. The converter is also designed to capture the particulate materials entrained in the gas flow from the gasifier and convert these into slag. The base of the converter chamber contains a layer of molten slag. The plasma power is controlled to provide a uniform syngas temperature and destruction of the residual tars and chars contained within the crude syngas (see Figure 5).
Figure 5: Destruction of tar-like materials within the Plasma Converter

APP has a demonstration Gasplasma® plant in Swindon, UK, which is in constant use for research and development purposes and testing of new materials. The core principal of the gasifier and the plasma converter described above is applicable for both full scale and demonstration plant.

Syngas quality from landfilled waste

The qualities of RDF derived from fresh waste or landfilled waste may have very different properties, predominantly due to the degradation of biogenic materials and the evolution of volatile components. This change is reflected in the change in ultimate and proximate analyses presented in Table 3, where volatile matter content is less in the landfill-derived RDF. The degradation of biogenic components (e.g. paper, wood, fabrics) is reported in the literature.\(^8\)
Table 3: Comparison of fresh and landfill-derived RDF (dry basis, with oxygen by difference)

<table>
<thead>
<tr>
<th>Component</th>
<th>Units</th>
<th>Fresh RDF</th>
<th>Landfilled RDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>wt%</td>
<td>43.92</td>
<td>47.40</td>
</tr>
<tr>
<td>H</td>
<td>wt%</td>
<td>6.36</td>
<td>6.15</td>
</tr>
<tr>
<td>N</td>
<td>wt%</td>
<td>0.77</td>
<td>1.20</td>
</tr>
<tr>
<td>O</td>
<td>wt%</td>
<td>33.48</td>
<td>19.78</td>
</tr>
<tr>
<td>S</td>
<td>wt%</td>
<td>0.29</td>
<td>0.22</td>
</tr>
<tr>
<td>Cl</td>
<td>wt%</td>
<td>0.48</td>
<td>1.50</td>
</tr>
<tr>
<td>Ash</td>
<td>wt%</td>
<td>14.70</td>
<td>23.75</td>
</tr>
<tr>
<td>Total</td>
<td>wt%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Proximate analysis (dry basis)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Fresh RDF</th>
<th>Landfilled RDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed carbon</td>
<td>wt%</td>
<td>12.34</td>
<td>10.38</td>
</tr>
<tr>
<td>Volatile material</td>
<td>wt%</td>
<td>72.96</td>
<td>65.87</td>
</tr>
<tr>
<td>Ash</td>
<td>wt%</td>
<td>14.70</td>
<td>23.75</td>
</tr>
<tr>
<td>Total</td>
<td>wt%</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Energy content (dry basis)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Fresh RDF</th>
<th>Landfilled RDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Heating Value</td>
<td>MJ/kg</td>
<td>19.54</td>
<td>22.55</td>
</tr>
</tbody>
</table>

Table 4 gives the measured gas composition for the Gasplasma® processing of the wastes outlined in Table 3. In this study, the conversion of solid wastes to syngas was undertaken at a stoichiometric ratio of 0.30-0.35. The syngas compositions measured during the gasification of these wastes are in close agreement with thermodynamic equilibrium prediction presented in Figure 4. However, it is clear that the differences in waste feed quality are conveyed into differences in the gas composition, with the higher calorific value landfill-recovered RDF producing a higher calorific gas with elevated levels of hydrogen and carbon monoxide.

Table 4: Syngas qualities derived from wastes

<table>
<thead>
<tr>
<th>Syngas parameter</th>
<th>Units</th>
<th>Syngas from fresh RDF</th>
<th>Syngas from landfilled RDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO/CO₂</td>
<td></td>
<td>2.22</td>
<td>2.71</td>
</tr>
<tr>
<td>H₂/CO</td>
<td></td>
<td>1.14</td>
<td>1.44</td>
</tr>
<tr>
<td>Stoichiometric ratio</td>
<td></td>
<td>0.31</td>
<td>0.33</td>
</tr>
<tr>
<td>Calorific value</td>
<td>MJ/m³</td>
<td>9.521</td>
<td>10.16</td>
</tr>
</tbody>
</table>
Gasplasma® products

This two-stage approach physically separates the principal unit operations of gasification and final syngas conversion into separate zones, providing longer residence time whilst making a more efficient use of the oxygen required to support the endothermic steam reactions. This results in a higher yield of synthesis gas than is possible by single stage partial oxidation. The properties of the syngas lend itself to consideration for use in many applications from power generation through to chemical precursor. The principal products from syngas generated from waste are given below in Figure 6.

![Syngas transformations and products](image)

Waste materials may contain minor levels of sulphur- or chlorine-containing components derived from such articles as PVC or rubber. During gasification these components can generate trace quantities gas phase species, such as sulphur dioxide, hydrogen sulphide, hydrogen chloride, etc. All of the applications outlined in Figure 6 will have tolerances to these components, whether in terms of potential emissions or degradation of catalyst materials. It is an essential part of these processes that these potential contaminants are removed from the gas prior to use. Permissible levels of these contaminants depend on the application, with removal to negligibly low levels of the contaminant being the obvious mitigation technique, but this can be commercially unacceptable or technically impossible.
As such, a compromise must be reached between the cost of the removal process, the process downtime in removing spent adsorbents, any regulatory threshold limits, and the cost of the replacement catalyst or hardware being protected. Therefore, prior to establishing the contaminant removal processes it is essential that a complete analysis of the waste feedstock be performed.

Power generation

Furthermore, the two-stage Gasplasma® process produces a syngas that is both low in residual tars and possesses high calorific values, and is of sufficient quality to meet the requirements of high efficiency power generation equipment. The product of air-based gasification, with a syngas calorific value of 4-5 MJ/Nm³, would not be suitable for a gas engine, where strict requirements on gas quality are imposed by the high efficiency power generation equipment. Such syngas is usually combusted in a steam boiler, with a thermal efficiency of 80%, the steam generated being used for electrical power generation in a steam turbine, with an efficiency of 33%, giving a system power conversion efficiency of 26.4%. Whereas the higher calorific values associated with oxygen-based gasifying agents, however, would be permitted for power generation in gas engines with a system power conversion efficiency of greater than 35%, or potentially significantly more than 40% if run in combined cycle. In these single-stage gasification processes, residual char is heterogeneously reacted, via slow and endothermic pathways, with steam and carbon dioxide; processes that are usually enhanced by use of elevated temperatures achieved through use of additional oxygen.

Plasmarok®

Plasmarok® is produced in the plasma converter from the vitrification of captured fly ash and excess bed materials generated from the fluidised bed gasifier. The high energy density of the plasma arc, which is transferred directly to the molten slag phase in the plasma converter, ensures a high degree of fluidity of the slag so that any solid particle that contacts the melt surface is readily captured and assimilated. The calcia–alumina–silica rich slag is, on cooling, both mechanically strong and highly resistant to leaching. In comparison, the bottom ash residues produced from gasifiers and incinerators are subject to heavy metal leaching and may prove to be a liability in the future. Indeed, the vitrification of such ashes is already commercially practiced in Japan, to offset this potential liability using dedicated plasma vitrification furnaces. Independent environmental testing of the Plasmarok® product following the two stage BS EN 12457-2 leaching test for granular materials for a wide number of prescribed organic and heavy metal pollutants have demonstrated that the vitrified material was not harmful to the environment or human health, showing that for all the pollutant species analysed, the actual levels recorded were greatly below the compliance limits as set for inert (landfill) material. Indeed, this material
has been demonstrated as suitable for a number of aggregates applications and could be specified for use as an unbound aggregate for civil engineering.

**Figure 7:** Summary of results for inert Waste Acceptance Criteria compliance (BS EN 12457-3 Leaching tests on vitrified sample at particle size <4mm)

While such immobilisation of potentially harmful heavy metals into a dense, vitrified non-leachable material has obvious immediate benefits, it would also allow industries with specific recycling and recovery targets (such as the EU automotive industry) to achieve these goals with the additional benefits of producing a renewable energy source. In addition to the use of Plasmarok® as an aggregate material it also has potential for use in other applications where technological requirements require some combination of strength and/or particle size, such as pipe bedding and fill materials. Plasmarok® can also be a raw material source for more technically demanding applications, such as insulation wool manufacture where the molten state of the Plasmarok® at point of generation could be spun on high speed spinning wheels generating a mass of fine, intertwined fibres with a typical diameter of 6 to 10 micrometers. However, the properties of the molten Plasmarok® need to meet the demanding chemical and viscosity requirements of the manufacturing process. In addition, the final spun product may have to meet technical requirements for heat transfer, sound absorption, and fire resistance.

Other applications, such as alumino-silicate geopolymers, would utilise the alkali-rich activated alumino-silicate content of the Plasmarok®. However, such functionality must also be combined with the need to achieve final product hardness where chemical reaction of geopolymer precursors with alkali polysilicates is required to promote polymeric Si–O–Al bonds. With a global cement production of 3084 Mt in 2010, which, according to the EPA, creates between 900 and 1100 kg of CO₂ for every tonne produced (the equivalent to 7% of
the total global CO₂ emission to atmosphere), the potential for such geopolymers is considerable. Geopolymer binder technology offers a “green” replacement to Portland cement, with a reduction of 85% in carbon footprint and 90% in energy consumption¹⁷.

**Hydrogen Production**

Around 50% of hydrogen is currently produced from the nickel-catalysed steam-methane reforming process¹⁸ operating at temperatures of 700-1100°C, thus:

\[
\text{CH}_4 (g) + \text{H}_2\text{O (g)} \rightleftharpoons \text{CO (g)} + 3\text{H}_2 (g) \quad \Delta H = 206.2 \text{ MJ/kmol}
\]

The reaction is strongly endothermic, requiring substantial energy input to drive the reaction. To achieve this energy input a portion of the natural gas or methane is actually burned to generate heat producing the high quality steam required for the reaction. The relatively high calorific value of the syngas and the high contents of hydrogen and carbon monoxide also allow consideration of the syngas generated from the Gasplasma® process for use in applications other than power generation. For example, the syngas can be transformed using water/gas shift to generate a hydrogen-rich stream that can then be separated from other components to produce a high purity hydrogen product. This transformation is undertaken using the reversible exothermic Water Gas Shift reaction pathway within a catalytic reaction matrix where carbon monoxide is reacted with steam to produce hydrogen and carbon dioxide:

\[
\text{H}_2\text{O (g)} + \text{CO (g)} \rightleftharpoons \text{H}_2 (g) + \text{CO}_2 (g) \quad \Delta H = -40.9 \text{ MJ/kmol}
\]

The mildly exothermic nature of the reaction makes the reaction less thermodynamically favourable at elevated temperatures, while the reaction kinetics is obviously favoured as the reaction temperature rises. In order to overcome the thermodynamic limitation while maintaining high reaction rates, the water-gas shift is normally conducted in multiple adiabatic stages with inter-stage cooling to obtain higher conversions overall. Often this involves combination of a high temperature shift (HTS), operating at temperatures in the range 350 to 600°C and using iron-based catalysts, followed by a low temperature shift (LTS), with temperatures in the range of 150 to 300°C and using copper-based catalysts¹⁹. As the reaction progresses along the reactor length, the temperature rises and the reaction approaches thermodynamic equilibrium. The shape of this temperature profile is initially an exponential rise, but eventually reaching an asymptotic value as shown in Figure 8, reflecting the change in gas component composition as shown in Figure 9.
The high importance of the water-gas shift reaction pathways has led to numerous researchers producing models to describe the reaction\textsuperscript{20}.

**Methane Production**

As for hydrogen production, the qualities of the syngas generated from the Gasplasma\textsuperscript{®} process also make it suitable for transformation into methane. In order to achieve this transformation, it is first necessary to adjust the chemistry of the syngas by using the water-gas shift reaction. However, it is necessary to control the water-gas shift reaction profile so
as to produce a stoichiometric ratio of hydrogen to carbon monoxide of around 3:1 by controlling the addition of steam to the catalytic reactor. This modified syngas can then be further transformed using a catalysed methanation reactor to generate a substitute natural gas (SNG), which meets the specifications for injection it into the gas networks.\textsuperscript{21}

The methanation reaction is highly exothermic and may involve the reaction of either carbon monoxide or carbon dioxide with hydrogen to form methane and water, thus:

\[
\begin{align*}
3H_2 (g) + CO (g) &\rightleftharpoons CH_4 (g) + H_2O (g) & \Delta H = -206.2 \text{ MJ/kmol} \\
4H_2 (g) + CO_2 (g) &\rightleftharpoons CH_4 (g) + 2H_2O (g) & \Delta H = -15.2 \text{ MJ/kmol}
\end{align*}
\]

These reactions, in combination with the water gas shift, as shown in Figure 10 are governed by kinetic and thermodynamic equilibria parameters.\textsuperscript{22, 23}

![Figure 10: Reaction pathways for methanation reaction](image)

However, unlike the water-gas shift, which exhibits a steady exponential rise in temperature to an asymptotic value, the methanation reaction can exhibit runaway properties as shown in Figure 11. This temperature rise may be sufficient to damage the catalyst if unchecked by use of appropriate system design (e.g. cooling systems, catalyst bed geometry, etc.).
The resulting methane-rich syngas must still be upgraded to make it suitable for insertion into a national distribution network, requiring the removal of the bulk of inert gas constituents such as carbon dioxide and nitrogen. Various techniques including physical and chemical liquid absorption techniques or Pressure Swing Adsorption (PSA) are employed, some with the ability to produce a carbon capture and storage (CCS)-ready stream. The use of oxy-steam in the Gasplasma® process effectively reduces nitrogen in the syngas to a few per cent, compared to the typical 45 vol% associated with air-based gasification. This makes the process of removing residual nitrogen to meet the strict requirements for network entry using PSA much less problematic, and, as a consequence, much more economically viable. The generation of SNG from a waste stream will play a crucial role in the decarbonisation of domestic and industrial heating and will help reach binding carbon reduction targets, as these waste streams will contain significant quantities of biogenic carbon, with RDF containing as much as 60-65% biogenic carbon.

**Conclusions**

The Gasplasma® process is able to efficiently transform a wide variety of problem wastes currently destined for landfill into a clean, high calorific value syngas, rich in carbon monoxide and hydrogen. Inert components in the waste are either recovered (e.g. metals) or transformed into an environmentally stable vitrified material.

The combination of separate gasification and a plasma conversion stage provides the ability...
to process high throughputs of waste whilst simultaneously permitting the destruction of tars/chars normally found in syngas resulting from gasification processes. This destruction of tar/char residues is attributable to the conditions within the plasma converter, where an intense energy field is contained that combines both thermal and ultraviolet effects.

These same features account for the transformation of the inert components in the waste into the vitrified material. This material is termed Plasmarok®, and possesses useful physical properties including resistance to leaching, moderate-high density, and good compressive strength. Such features make the material ideally suited for use in lower technology applications (e.g. secondary aggregate, pipe bedding material, etc.). However, there is potential to valorise this material to allow its use in more demanding application where a price premium is available.

In addition, the Gasplasma® process is based on use of oxygen as the gasification agent. The use of this agent in place of air produces a syngas of considerably higher calorific value due to the avoidance of inclusion of atmospheric nitrogen as a diluent. Indeed, this work indicates that the oxygen-based gasification syngas calorific value is more than 2.5 times higher than that achievable with air-based gasification processes. The Gasplasma® process achieves a cold gas conversion efficiency of around 80-85% across a wide range of feeds of very different characteristics. The core process is able to treat problematic materials (such as the high ash bearing automotive shredder residues) due to the use of fluidised bed gasification technology, where temperatures within the gasifier are uniform and so avoid issues of slagging of bed materials.

The syngas resulting from the process possesses a high calorific value (typically > 10 MJ/Nm³) which results from the relatively high content of carbon monoxide and hydrogen, typically 10-25 and 30-40 vol%, respectively. The plasma converter treatment of the crude syngas issuing from the gasification process results in a syngas with very low residual levels of tars and chars. These factors combined make the syngas suitable for use in electrical power generation using high efficiency generation equipment, providing the process with high conversion efficiency from waste feed chemical energy (calorific value) to electrical power output. Traditionally, these high efficiency power generation technologies have not been permitted for use with syngas from gasification processes due to the high levels of tars (e.g. naphthalene or benzene) and dust contamination. Furthermore, the use of this high efficiency power generation equipment has not been possible due to low syngas calorific values or the high loads of tars/chars.

Alternatively, the syngas can be processed using catalytic transformation to generate either hydrogen or methane, or liquid fuels. These fuel gases inherit a significant biogenic content from the waste feed and so could significantly decarbonise the provision of domestic and industrial heating, currently met by use of fossil fuels. These conversion pathways involve
generation of an ‘ultra-clean’ syngas where the levels of trace species have been virtually removed so as to avoid inactivation of the catalysts used in the conversion reactors. These reactions are highly exothermic and require careful consideration of reaction geometry to maximise yields and minimise the potential for thermal degradation of the catalyst matrix. However, this exothermic nature also permits the recovery of significant quantities of high grade (>300°C) heat that can be usefully applied to drive the process. This factor leads to high conversion efficiency in these processes.

References

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