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Energy from Waste

Putting Resources to Productive Use

Prepared for the West Coast Waste
Management Working Group

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Executive Summary

The West Coast Region's municipal solid waste (MSW) is deposited in landfills in each of the District Councils' areas. The Grey landfill is the only fully engineered site meeting the present standard for a sanitary landfill with the required resource consent and discharge permit. The current plan is for Buller and Westland to reach an agreement to use the McLeans site in the near future, but other alternatives are being considered.

The total waste collection for the three Councils is approximately 15,000 tonnes per annum at present and growing, as West Coast development continues, particularly through tourism. The West Coast Regional Council, together with the three District Councils of Buller, Grey and Westland, formed the West Coast Waste Management Working Group (WCMMWG) in 1996. Initially the working group was to collectively work to dispose of hazardous wastes, but nowadays it engages in all aspects of solid waste disposal and materials recovery.

The WCMMWG commissioned the Centre for Advanced Engineering in June 2003 to report on the opportunities for Energy from Waste (EfW) technologies with particular emphasis on fast pyrolysis as a technically robust approach. This report examines the current status of thermochemical conversion of waste and its applicability for conversion of the waste streams to procure energy or other by-products.

The current average cost of waste disposal to the Councils is of the order of \$133/tonne. This figure does not include other waste management spending or the lost opportunity cost from potential economic use of the waste materials. However, the information summarised in this report suggests that pyrolysis is unlikely to be economic within the region without significant changes in the ways in which waste management is addressed. This change in approach represents the opportunity to the West Coast.

Thermochemical Conversion

The impetus to apply gasification and pyrolysis technology to MSW and other waste streams has arisen in recent times from increasing environmental concerns about conventional incineration and non-sanitary landfills. The thermochemical conversion of waste by pyrolysis produces volatiles, which can then be burnt to provide heat for on- or off-site distribution, or power production, and a solid char residue.

High heating rates used in fast pyrolysis produce relatively low char yields and high volatiles output. Some of the most modern, up-to-date technology and development work on energy from waste conversion combines pyrolysis with hydro-forming technology to produce a chemical feedstock or syngas and minimal residues. Modern, fast-pyrolysis EfW plants can achieve ultra low emissions capable of meeting the most rigorous environmental standards.

Technology Assessment

An "energy from waste" pyrolysis plant, regardless of scale, will be a complex engineering project involving a significant level of investment for the scale of operation. If a decision was made to undertake a pre-feasibility study on a pyrolysis plant (or another waste processing process e.g. Refuse Derived Fuel production), there are significant risk factors that will need to be examined in detail alongside the selection of the preferred technology. Most important of these are the technical maturity and operating flexibility of the processing route selected.

As an indication, at best, of the level of investment required, published data for plants of this type indicate an investment cost of the order of \$15M to \$40M (footnote 6). A report in 2000 by Juniper Consultancy Services ("Worldwide Technology and Business Review of Pyrolysis and Gasification of Waste"), identified capital cost levels ranging from US\$50 to over US\$1,000/tpa depending on scale and complexity. Capacity of plants ranged from as little as 4 ktpa to 250 ktpa, although not all plants were suited to mixed waste (MSW) feedstock as will be the requirement for the West Coast.

Operating costs were similarly reported by Juniper, but can only be taken as a guide as up-to-date project specific investigations are needed to quantify such figures and largely depend on the country of operation

and site conditions. These “treatment” costs ranged from US\$10/t to over US\$200/t, with costs of over US\$100/t reported for projects in the European Union (mainly Germany and Switzerland) where the costs for all waste disposal is higher than other parts of the world.

The MSW volume of the West Coast region is relatively small to the volume that would generally be required to make a business case for an EfW plant and thus ensure economic feasibility. However, in this report we identify other waste producers in the Region, and in Canterbury, which in combination with an EfW facility could make the difference to the economic viability of such a project.

Regional Betterment

An energy from waste project which draws on a wider base than just regional MSW has the potential to bring additional revenues into the region, creating employment and spin-off job opportunities. An EfW plant could supply heat and electricity for an “Energy Park”, for example, for new start-up or relocated businesses. The improved resource efficiency offered by cleaner disposal with energy recovery will achieve flow-on environmental benefits to the West Coast community.

The proposed Canterbury landfill site will be setting tight standards on “waste quality”, therefore there is the opportunity for an EfW plant to take the “unacceptable” waste not able to be taken to Kate Valley and supplement available waste streams on the West Coast.

Recommendations

The report highlights there are opportunities to bring MSW disposal for the Region together with other waste resources from within and outside the Region, which together have the potential to make an economic case for a modern EfW plant using fast pyrolysis techniques. However, before any commercial scale facility could be considered a full analysis needs to be undertaken of the different options available and a more robust economic analysis undertaken. The recommendation, therefore, is that:

- 1) interested parties with waste disposal issues are brought together to establish what common ground there is for an EfW type plant,
- 2) if sufficient interest is established, a preliminary process scheme and waste management strategy be developed
- 3) preliminary engineering studies and economic assessments be completed, and
- 4) based upon this evaluation further consideration be given on what project, if any, should proceed as the basis for Request For Proposal tenders from selected vendors and detailed feasibility assessment.

Location Map



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Project Brief

The total solid waste generated annually on the West Coast is about 25,000 tonnes, distributed over a wide area and range of sites. The West Coast scenic attractions bring increasing numbers of tourists, who also contribute to waste disposal problems at key scenic locations.

The West Coast has other un- or under-utilised waste resources in the form of coal fines, coal-bed methane and wood processing residues. Ways and means to include their use to generate electricity, liquid fuels for both road and rail (such as methanol, ethanol and biodiesel), and other high-value end products need to be considered.

There are technology options available to enable energy and valuable by-product production from otherwise neglected or problem waste resources. The West Coast Waste Management Working Group (WCMMWG) has taken particular interest in the pyrolysis route.

Three important considerations for the WCMMWG and the wider community are:

- I. the cost effectiveness of any proposed scheme
- II. whether investment in such a facility will avoid the need for land filling and have other positive outcomes, and
- III. the potential economic spin-off and job creation opportunities.

The project sought a preliminary review of all these resource streams and their potential suitability for pyrolysis conversion. Waste pyrolysis technologies were to be reviewed (in conjunction with other opportunities to be identified) in order to establish a preferred approach for maximum economic and environmental benefit for the region. Other opportunities worth investigating further are also to be identified where possible. The study scope included:

- Examination of the potential for pyrolysis conversion of the waste resource (most likely in conjunction with other material resources of the West Coast).
- Identification of any possible business case for further investigation including site requirements, technology evaluation, capital costs and employment numbers.
- Contact with a wide range of potential stakeholders to determine any common ground and potential for merging projects.
- Technical overview of the technologies for energy from waste conversion, in a form suitable as a public document.

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1 Introduction

“Nothing is created, nothing is lost, all is transformed” (Lavoisier 1743-1794)

Public opinion on environmental issues and resource utilisation is progressively reaching an informed consensus on the need to protect the environment within an ethos of sustainability. Policy makers all over the world are recognising the stress induced on the planet by air pollution and greenhouse gases resulting from the unconstrained use of fossil fuels. Deregulation of energy markets as well as the emergence of novel technologies are also opening the world of energy to greener and to smaller, nimbler and cleaner plants that are closer to the end-user.

Within this context, the West Coast Waste Management Working Group (WCMMWG) commissioned the Centre for Advanced Engineering (CAE) to look into the opportunities for energy from waste (EfW), particularly reporting on pyrolysis methods, yet looking beyond the immediate confines of solid waste disposal to develop a broader picture of what might be achievable with the participation of others.

An important consideration was that the opportunities so identified, desirably, would enhance economic and employment opportunities for the region.

2 Current Situation

The West Coast Regional Council, together with the three District Councils of Buller, Grey and Westland, formed WCMMWG in 1996 to collectively face the issue of hazardous waste disposal. This group has continued in existence and now acts as a forum for all waste matters concerning the Councils. In this regard we distinguish three waste streams as potential feedstock for a thermochemical facility:

- 1) Municipal solid waste (MSW)
- 2) Hazardous waste
- 3) Recovered materials

MSW

Municipal solid waste (MSW) is deposited in landfills in each of the District Councils' areas. The landfill sites in Buller and Westland are close in time to closure (2-3 years), as they will not meet the required standard for sanitary landfills. The Grey landfill (McLeans) is an engineered site and does meet the required standard for sanitary landfills with required resource consents and discharge permits held by Council. The Buller and Westland Councils propose to reach an agreement to use the McLeans site. Negotiations begun two years ago are continuing with this objective, with Buller considering the alternative of buying land and opening its own sanitary landfill.

The McLeans landfill receives some 6,000 m³ (5,000 t) of MSW annually, and at this waste level the site has a potential life of 40 years. Neighbouring land has been purchased by the Grey Council that will double this lifetime. The waste from Buller and Westland will more than double the volumes if diverted to the McLeans site, in effect reducing the lifetime to between half or one third. These figures are based on current population and development levels. The figures are also based on current levels of waste minimisation activity which are considered to be only moderate, (see additional comments below). This, and the inevitable high transport costs, will be the biggest difficulty faced in coming to a decision on future disposal of the Buller and Westland waste streams. The total waste collection for the three Councils is approximately 15,000 tonnes per annum at present and growing, as West Coast development continues, particularly through tourism¹.

The McLean landfill's first cell will reach its capacity in under two years time when it will be finally capped and capable of re-circulating leachate. There are no plans at present to tap this cell for biogas. Grey Council is embarking on building a sewage treatment plant and therefore there will be sewage sludge to

¹ Lincoln University has undertaken a study of the effects of tourism on infrastructure in the Westland District, which may provide a guide to the expected increase in waste volumes from this activity.

dispose of in future. This will be permitted in the sanitary landfill at McLeans but other beneficial uses might be found for it. Westland Council's sewage treatment ponds at Hokitika have 36 years of accumulated solids. The Council is not permitted to dispose of this on site, and other means of disposal are currently under investigation.

Empty fluid bags and other non-hazardous clinical waste from the Greymouth hospital are also permitted to be landfilled. The region's hospital has an incinerator but is likely to discontinue its use and transport material to Christchurch for disposal.

There are the major commercial operators, Blue Bins and Trans West skips, for household and commercial waste collection and both these companies also provide "wheelie" bin services. Smaller, private operators are found at Whataroa, Franz, Fox and Haast (Westland DC) and at Westport (Buller DC).

Construction/demolition waste is increasing rapidly in the area although the quantities are uncertain. Should alternative treatment options be considered, it will be necessary to conduct more thorough enquiries into other trade wastes in the area through the Timber Millers Association, Solid Energy, Timberlands West Coast, Holcim and Westland Milk Products, etc. As an indication of the likely quantities that might amass, a brief survey of available waste streams is included in Chapter 5 and 6.

Grey District Council has recently released (June 2003) a draft solid waste management plan for public consultation and submissions closed on the 1 September 2003. This follows Westland DC, which adopted a plan in March 2002 as did Buller DC in 2000.

Hazardous waste

The quantities of hazardous waste are not easy to specify because collection is sporadic and dispersed. Hazardous waste collections are advertised from time to time, encouraging the public to bring into safe custody any non-commercial quantities of hazardous chemicals and other unwanted items. After a region-wide hazardous waste survey about two years ago, each district held a trial collection. For the Grey District the material is held in storage at the landfill site at McLeans, just north of Greymouth. Tredi New Zealand Ltd is used to remove collected material for ultimate disposal offshore.

Tredi New Zealand Ltd is the international logistics division of TREDI SA with the responsibility for recovery and shipping for disposal of hazardous and intractable wastes outside the European region. The service it offers encompasses all aspects of handling hazardous and intractable wastes, such as polychlorinated biphenyls, from site assessment, identification and formulation of a plan to manage the hazard through to decommissioning, packing, transportation, shipping and disposal of the waste.

Recovered Materials

None of the Councils at present practice kerb-side recycling. Grey District provides two "heavy trash" days each year and Westland one. The site operator at McLeans Landfill recovers any recyclable material. The public is encouraged to keep green waste separate and this is utilized as cover material at McLeans (approximately 600 tpa). Glass is accepted at a crushing site because it is used locally for "sand" blasting but within the last six months bottle banks have been abandoned because of nuisance dumping in the bins of other rubbish and also because not enough use could be made of all the glass collected.²

Recycling by sport and charity groups has declined. There is one operator in Greymouth and one in Hokitika who collect and bundle cardboard, sending about 800 tpa to Christchurch. Similarly, plastics are collected at Hokitika (about 100–120 tpa) but not in Greymouth or Westport at present. Excepting the smaller township sites, the bulk of cleanfill is taken to the old landfill site in Greymouth for land re-contouring and landscaping purposes. Cleanfill is not carried between centres as there are dedicated cleanfill sites 2 km south of Hokitika (Westland) and at Westport (Buller).

The sparse population of the region, making relatively low total wastes of mainstream materials such as

² There are also three small cleanfill-greenfill-skip and recycling centres located near outer lying townships (Moana, Blackball, Nelson Creek).

A grant of £150,000 has been awarded in Scotland to a pilot scheme for recycling farm plastics. The Royal Scottish Agricultural Benevolent Institution (RSABI) which has been operating an existing scheme received the grant.

RSABI arranges bags for plastics to be delivered to farmers, collected when full, and sent for recycling into items such as garden furniture at a plant in Dumfries. Funding has now been granted to keep the scheme in operation until the end of March 2004, which will allow a full evaluation of its effectiveness and success.

Under the scheme two operators, one each in the north and south of Scotland, receives instructions from a co-ordinator on the basis of requests from farmers, through local volunteer organisers. Farmers receive bags which they fill with black polythene silage film, and which are then collected and baled by the operators. The cost to farmers is £15 per bag. A bag holds, on average, 250 kg of plastics.

The bales are delivered to British Polythene Industries' plant in Dumfries. At Dumfries the plastic is washed, shredded and heat-treated. The material is used for "Plaswood" products, such as garden furniture.

So far the scheme has dealt with some 800 tonnes of plastics. In the next phase until end March 2004, which is being supported by the Scottish Executive, an estimated further 800 tonnes should be recycled. This is about 5% of the arisings of this form of waste in Scotland.

The agricultural industry has often been overlooked as a source of waste, though the volumes involved are significant. This is a project which demonstrates a positive attitude to dealing with waste plastics in a farmer-friendly, inexpensive way.

cardboard, paper, glass and plastics compared to major metropolitan centres, means there is generally insufficient scale to economically collect these materials for national or world markets. The isolation of the Coast only compounds the transportation cost issue.

One solution to this paradox could be to import more waste from other areas. There exists nearly 2 million tonnes per annum empty rail car capacity arising from the coal export trade through Lyttelton, which might be utilised. More MSW and high value waste would provide a sounder business case for an EFW plant, and a bigger economic opportunity to current recycling efforts. The economics of doing so will depend on the value of the waste received.

In the time available for the study it has not been possible to complete a regional survey of all the waste resources. One study of the Hokitika area was made in 1983 (NZERDC report LF2030). The aim of that report was to consider the availability and type of waste in a number of localities with the view to converting these to liquid fuels since they consisted mainly of organic materials³. Even so, today the waste resources of the West Coast are predominately MSW and sewage sludge, coal mining wastes, wood processing wastes, fish and milk processing wastes (representing the main activities of the region). Modern life styles also generate particular waste items such as tyres, inks and paints, photocopy and printer cartridges, insecticides and pesticides, dry cleaning fluid and marine anti-fouling coating. Contaminated soils are another material that infrequently need attention⁴.

³ Average daily available dry matter (tonnes) for the area then was estimated to be: orchard prunings, 3 t in May, 4 t in June and 3 t in July; paper 2 t from domestic and 2 t from non-domestic sources; putrescible domestic waste 2 t; wood manufacturing 2 t. The key factors in assessing the viability of a waste to fuel plant using these wastes would be the purity, cost of separation, extraction and processing. The degree of consistency and homogeneity was not studied. Crop residues were not seen as an attractive feedstock for fuel production because of season variation in supply and high transport costs because of their wide distribution. The study did not consider sewage, dairy or meat processing wastes.

⁴ The former Fruitgrowers Chemical Company's site at Mapua in Nelson District has the highest organo-chlorine insecticides residue level found in New Zealand. It was recently announced this would be mechano-chemically de-halogenated by Thiess Services Group and Environment Decontamination Ltd by a new pulverisation technique in a drum reactor using steel balls with added catalysts. Contract cost of \$1,000 per cu. metre.

Current estimates of the quantities that are annually recycled or reused in the Region are:

- Paper and cardboard 400 m³
- Glass 2,000 kg
- Plastics 55 kg
- Green waste 2,600 m³

The Councils have undertaken no landfill surveys although landfill waste records have been kept at McLeans since 1999. This record estimates the volume and records the source of the waste, but not the composition. However, it is possible to derive estimates using the national waste composition figures from MFE's Environment Waste Analysis Protocol.

The result of applying these statistics to the three Council districts is shown in Table 1.

	ktpa	Paper	Plastic	Glass	Metal	Organic	Haz.	Clean	Other
Buller	7.464	1493	448	149	448	3733	37	858	298
Grey	10.653	2131	639	213	639	5327	53	1225	426
Westland	6.608	1322	396	132	396	3305	33	760	264
total	24.725	4946	1483	494	1483	12365	123	2843	988

Table 1: Estimate of the West Coast Councils solid waste generated

By subtracting the cleanfill and hazardous components and halving the quantities of paper, glass and organic fractions available through recycling and other losses, gives an approximate analysis of the waste components that are likely to be presented to sanitary landfill. This total is 3,880 tpa from Buller, 5,540 tpa (close to the estimated quantity received) for Grey and 3,435 tpa from Westland, a total close to 13,000 tpa.

The analysis is shown in Table 2.

	ktpa	Paper	Plastic	Glass	Metal	Organics	Other
Buller	3.881	746	448	75	448	1866	298
Grey	5.539	1065	639	106	639	2664	426
Westland	3.435	661	396	66	396	1652	264
total	12.855	2472	1483	247	1483	6182	988

Table 2: Estimate of the West Coast Councils solid waste presented to landfill

3 Energy from Waste by Thermochemical Conversion

The thermal decomposition or destruction of organic waste can be accomplished in a number of ways usually with a release of more energy than is consumed. The following definitions are therefore worth establishing to clarify the differences between different types of energy from waste processes. No process is entirely independent as there is usually a continuum from one process type to the next depending on the extent of conversion desired. However, these definitions do establish a broad categorisation for comparing EfW processes.

Incineration

Incineration is the rapid conversion of the chemical energy contained in waste materials into heat by burning the material with excess air or introduced oxygen. The organic compounds present in the waste

are broken down by excess heat and then oxidised by reaction with air and released oxygen. Carbon is converted to carbon dioxide and hydrogen to water. Other elements, like nitrogen and sulphur will also oxidise into gases. Inert materials will form the residue ash. Other common terms used to describe incineration are *combustion*, *thermal oxidation* and *direct firing*.

Further sub-divisions can be made for the incineration process. These options include “mass burn”, “modular”, and “refuse-derived fuel” (RDF). Of these three technology options, modular systems are most likely to be best suited to the volume of waste that is generated on the West Coast. Modular systems are also commercially available from a number of vendors. Furthermore, capital and operating costs, and air emission standards are well documented and can provide a “benchmark” performance standard for a pyrolysis plant.

Mass burn and RDF options are generally applied to much larger waste streams from larger cities. However, the RDF option deserves further consideration as it can reduce transportation costs and is a potential fuel for co-firing with coal in a power station or for fuel at a cement plant.

Gasification

Gasification is a partial oxidation process in which organic compounds again are thermally decomposed and converted to a mixture of gases and char. The gases are typically fuel gases such as carbon monoxide, hydrogen and methane, collectively called syngas or producer gas. Another term used is *partial oxidation*. Usually the gases are then burnt to release further heat energy, or they could be stored for later use.

For power production the Integrated Gasification Combined Cycle (IGCC) process is one where a gasifier's output is used to fuel a gas turbine generator, then the exhaust heat from the gas turbine raises steam which is used in a steam turbine generator to produce more electrical power. If water is injected in the gasification process this is known as steam reforming. The water molecule is split into hydrogen and oxygen, the oxygen combining with the hot char from the gasification process to form carbon monoxide. The water shift reaction, or hydroforming, is mainly used in the petroleum industry to convert petroleum fractions into more volatile compounds.

Pyrolysis

Pyrolysis is the thermal decomposition of organic material in the absence of any air or introduced oxygen. Depending on the operating conditions of temperature and residence time (slow, fast, ultra-fast or ablative pyrolysis), varying quantities of syngas, pyrolysis oils and char are formed. Other terms used are *thermolysis*, *thermal distillation*, *thermal gasification*, *destructive distillation*, *retorting* and *carbonisation*.

Since pyrolysis is a necessary stage for both gasification and combustion processes, there is in fact a

The International Solid Waste Association (ISWA) is a key worldwide organization that produces state-of-the-art reports on energy from waste processes. The 1997 report (ISBN 87-90402-04-9) gave a review of the incineration plants of several European countries. France (95) had the largest number, followed by Germany (36), Denmark (34), Switzerland (28) and Sweden (21). Note these are countries that make use of surplus heat for district heating. Because of their nature, all incineration plants have some kind of flue gas cleaning treatment.

The amounts treated per plant ranged from 50,000 tpa to over 300,000 tpa. Waste incineration per capita averaged 120kg/annum. In Europe, while energy from waste continues to be more common than sanitary landfills, the use of incineration methods gives way to cleaner, more technically efficient plant designs. These newer plants use gasification and/or pyrolysis techniques to achieve this superior performance. One such example is the incineration plant once owned by the Avon County Council at Avonmouth, near Bristol. It was one of ten plants situated throughout the U.K. established during the 1970s (Selchp Ltd, built in London in 1994, is the only other one built since then). The Avonmouth plant is now decommissioned and beside it is located the advanced pyrolysis plant of Compact Power, only a fraction the size of its defunct neighbour.

continuum between pyrolysis, gasification and combustion.

Plasma

Plasma is a highly ionised gas with free negative and positive charges, often referred to as the fourth state of matter after solids, liquids and gases. Plasmas occur at very high temperatures and the high heat flux can be used to decompose material to its elemental forms. It is a technique usually reserved for hazardous waste disposal, see box and appendix A. The technology is included here for completeness, but it is not a serious option for consideration for the purposes of extracting energy from solid waste alone.

Plasma technology (Plasma Arc Heater) was developed and employed in the metal industry during the late 1800s to provide extremely high heat. During the early 1900s, plasma heaters were used in the chemical industry to manufacture acetylene fuel from natural gas.

Plasma arc heaters received renewed attention when the USA NASA space programme, during the early 1960s, evaluated and selected plasma arc heating technology for simulating and recreating the high heat encountered by spacecraft on re-entry into the earth's atmosphere.

Utilising the same plasma technology, scientists, some of whom previously worked for NASA, have refined and improved the plasma arc technology in both efficiency and expanding user applications; including municipal solid waste, all toxic and hazardous waste streams, medical waste and low level radioactive waste.

Plasma arc heaters use electricity as a source of energy and convert it into a clean, low mass heat. Low mass heat means that very little gas is used to generate the "plasma", the 4th state of matter (after the other states, e.g., 1st-solid, 2nd-liquid, 3rd-gas). A plasma conducts electricity like a metal wire and, like a metal wire, a plasma resists the flow of electrical current. The resistance to the flow of electrical current is the mechanism for converting electricity into heat.

General Overview

Incineration (combustion) is an age-old means of waste destruction and is still used at present to dispose of clinical and quarantine wastes in Christchurch (Nuplex Industries) although this is soon to be replaced with steam sterilisation and consigning to sanitary landfill.

Early in the last century, Christchurch had a waste incineration boiler that produced electric power from a steam turbine and heated the public swimming baths. However, the composition of the waste stream nowadays is markedly different from a century ago, and certain products of combustion are hazardous in themselves. Largely because of the emissions emanating from such plants, incineration for mixed waste disposal understandably is now being superseded by gasification and/or pyrolysis methods because of the inherent technical superiority to mass burning, see box.

Gasification of coal and wood has been used in industry for the production of chemical feedstocks for a long time. Wood gasifiers were built during WWII for vehicles, to compensate for limited supplies of petroleum products and, of course, jet and aviation fuels were produced from coal. There is a large body of knowledge of industrial practice in thermochemical conversion of materials, including mixed solid waste. A summary of known technology providers is provided in Appendix A. The summary is presented in a simplified form so as to enable easy comparison between the different technology types.

It should be recognised that much of the modern technology options described are at a pre-commercial stage with even commercial plant still in the early stages of development. In other words, once you move from mass burn or incineration processes there are few mature suppliers. An example of leading edge technology is demonstrated by the case history of Compact Power, see Appendix B.

The impetus to apply thermochemical technology to MSW and other wastes has grown from increasing

environmental concerns about conventional incineration and non-sanitary land fills. Even sanitary landfills must be well engineered and maintained for a very long lifetime. The impervious membrane lining must remain intact; the leachate must be retained and not allowed to escape to possibly contaminate ground water supplies. Biogas, a mixture mainly of methane, carbon dioxide and carbon monoxide, generated by the natural anaerobic decomposition process, will migrate to the surface and dissipate into the atmosphere. Alternatively, it is better to collect and use this biogas for a purpose like power production⁵, and already several landfills in New Zealand are operated in this way.

Most of the emerging, up-to-date technology development work on energy from waste conversion combines pyrolysis and syngas manufacture. This entails pyrolysis conditions volatilising the organic components of the raw material, followed by partial oxidation of the gases, liquid tars and solid char to form a syngas. Inert material and unconverted char is left behind as ash.

Both incineration and gasification are “auto-thermic” processes, i.e. the heat required by the process is supplied from burning produced syngas from the reactions. In contrast, pyrolysis is an “endothermic reaction”, i.e. heat must be supplied, usually through the walls of a containment vessel sealed off from atmosphere. High heating rates used in fast pyrolysis produce relatively low char yields and high volatiles output. Conversely, slow heating rates and long time intervals will produce high char yields. A prime example of slow pyrolysis is charcoal production from wood.

The energy from waste process is best applied after a separation of any recovered materials has been made. Recovered materials are subject to commodity price fluctuations so if it is uneconomic to store organic types these can, at times, be disposed of in the EfW plant. Moisture content of the feed materials is an important operational cost factor.

All thermochemical processing of mixed wastes carries some potential for dioxin production and other unwanted releases of contaminants to the atmosphere. In general terms pyrolysis is better performing than gasification and gasification is better performing than incineration. There is no perfect “black box” solution to solve waste disposal issues, but some pyrolysis plants are achieving extremely impressive pollution control records. For example, in the case of Compact Power, the combined effect of pyrolysis, gasification, high temperature oxidation and advanced NO_x and acid gas abatement minimises pollution to extremely low levels. The system may be regarded as the Best Practical Environmental Option (BPEO) for the thermochemical destruction of waste. The design also meets the more general objective of promoting the best environmental options for waste disposal.

Gaseous emissions from Compact Power plant processing MSW are well within all integrated pollution control standards and compare much more favourably to typical results from modern incineration plant (see Table 3, over).

As mentioned before, one solid waste treatment strategy is to produce refuse-derived fuel (RDF). Any such action should be worked in with pre-sorting for materials recovery. RDF processing would separate out non-combustible material (which may have a value or can be sent to a clean land fill). The remaining material is then shredded, dried and pelletised. RDF pellets are stable, reasonably consistent in nature and more readily transportable and disposable as an industrial grade fuel (e.g. a cement kiln or a co-fired power station).

Economics

The key question is: ‘how do the capital and operating costs of pyrolysis compare with other methods of disposal when all factors are taken into account?’ Because of the preliminary nature of the study, it has only been possible to examine data available in the public domain. Thus, care must be taken in interpreting this economic data as the published information reflects specific case studies or operating circumstances. Such information is not directly transferable to the West Coast situation. The only way of gaining a robust analysis is through direct discussion and consultation with vendor organisations.

Nevertheless, despite the above caveat, examination of the available data shows that an energy from

⁵ Methane is a greenhouse gas 21 times more potent than carbon dioxide

	Daily Average	Daily Permitted	Peak Half-hour	Peak Half-hour permitted
HCl (mg/m ³)	0.16	10.00	0.79	60
CO (mg/m ³)	0.79	50.00	4.41	100
SO ₂ (mg/m ³)	4.77	50.00	6.66	200
NO ₂ (mg/m ³)	4.32	-	6.03	-
NO (mg/m ³)	27.59	-	50.73	-
N ₂ O (mg/m ³)	1.25	-	1.60	-
NO _x (mg/m ³)	46.59	200.00	83.15	400
H ₂ O (%)	23.82	-	30.53	-
CO ₂ (mg/m ³)	9.05	-	10.00	-
VOC (mg/m ³)	0.27	10.00	0.58	20
NH ₃ (mg/m ³)	4.34	10.00	6.78	20
O ₂ (%)	14.98	-	13.24	-
Particulate (mg/m ³)	2.45	10.00	3.34	30

Table 3: Emission data for 1 December 2003⁶.

waste plant (or district RDF plants) represents a high capital investment proposal⁷. Clearly from the case studies reported in Appendix A, much of the economics for waste to energy conversion investment overseas is driven by waste subsidies, renewable energy support and by-product values. These same conditions do not necessarily apply to New Zealand.

Table 4 sets out a summary of the best available capital and operating cost costs obtainable at present for some of the suppliers listed in Appendix A.

	Plant Size Range ktpa	Capital Cost US\$/tpa	Operating Cost US\$/t
Pyrolysis			
Compact Power	30 - 100	250 - 100	n/a
Ensyn	50	320	n/a
Pyrovac	150	190	n/a
Serpac-Pyroflam	8	500	60 - 75
Thermoselect	80 - 250	680 - 550	45 - 145
Von Roll	45	400 - 450	125 - 190
Gasification			
Enerkem	30	350	n/a
Foster Wheeler	85	150 - 200	n/a
Organic Power	6	380	n/a
PRM Energy	50	80	n/a

Table 4: Range of available capital and operating costs for thermochemical conversion plant (source Juniper 2000)

Further technology assessment will be a critical step in refining the operating and capital cost components presented above. Until that exercise is carried out there remains a high investment risk associated

⁶ All Figures are corrected to 11% O₂ Dry (STP). Figures are for 1 December 2003.

<http://www.batneec.com/emissions/redirect.asp?View=Normal&Day=01&Month=Dec&Year=2003&DV=&MV=&YV=>

⁷ For example, a 25,000 tpa plant with power generation supplied by Thide may cost in the region of \$38 M, plus civil works. A 6,000 tpa plant to dispose of clinical waste (average cv of 15 MJ/kg, generating 330 kW), supplied by Compact Power might have a capital cost of \$12M plus site works.

with the technology, particularly with a technology company for which there are few commercial scale plants in operation. An EfW plant will also require a site close to a sanitary landfill because of the need to dispose safely of the process residues (ash and fly ash) if no other safe use for this can be found. A sanitary landfill will also be needed to accept the waste stream in the event of the EfW plant not being able to operate for any reason at some time.

For an EfW project to be commercially successful it must therefore demonstrate all of the following attributes:

- Guaranteed waste supplies
- A “high-end” waste stream of known quality and variability (e.g. hazardous waste) attracting a high disposal fee
- Competitive energy production costs and an energy sales contract for both power and heat
- Guaranteed sales of ash byproduct (e.g. cement additive) or agreed landfill disposal.

Based upon the costs shown in Table 4 and discussions with plant operators in Europe, we can estimate that the required gate charge on MSW *without* any extra feedstock from outside the region would be in the order of \$300 per tonne (30c/kg). With supplementary high-value feedstocks found or imported to the region, such as tyres, coal fines, medical and quarantine items, industrial waste and agri-plastics, this price would come down. The influence of carbon credits and renewable energy pricing on the required economic gate fee requires further analysis. In Europe these factors are significant.

In comparison, the current costs for each Council to provide a MSW management service to its ratepayers are as given in Table 5.

		\$	tpa	\$/tonne
Buller	Landfill Operation	\$397,310		
	Landfill Resource Consent Monitoring	\$53,264		
	Total	\$450,574	3,881	\$116
Grey	Landfill loan repayments and depreciation	\$133,243		
	All other costs	\$658,026		
	Total	\$791,269	5,539	\$143
Westland	Hokitika refuse operations	\$196,715		
	All other sites	\$266,617		
	Total	\$463,332	3,435	\$135
Grand total		\$1,705,175	12,855	\$133

Table 5: Present MSW cost structure

The above costs do not include expenditure on waste minimisation (Buller \$45,044, Grey \$31,000, Westland \$66,900) or solid waste planning (Buller \$205,851). Without these costs, the analysis shows the average cost to the three Councils is around \$133/tonne of waste. Clearly, on this basis, there is a significant economic shortfall from the gate fee that would be required to support a pyrolysis facility.

4 Technology Evaluation

An “energy from waste” pyrolysis plant, regardless of scale, will be a complex engineering project involving a significant level of investment. Apart from the economic risk, this complexity also presents other risk elements that would need to be addressed in any project evaluation process. The risk can be categorised into technological, project completion and operational areas.

Technological Risk

The technological risk factors are dependent on the technology and process configuration, but include:

- maturity of the technology;
- scale-up issues;
- specialised skills, materials and equipment needed;
- health, safety, environmental hazard management; and
- vendor capability.

If a decision was made to proceed with further feasibility assessment of a pyrolysis EfW plant (or other waste processing plant e.g. RDF production), these risk factors will need to be examined with each identified plant vendor. Most worldwide vendors are identified in Appendix A. There are, in addition to these companies, a number of local firms who have stated an objective of developing commercial pyrolysis facilities. In the absence of any operating history, it is difficult to imagine any bankable proposition from a technological risk perspective.

A measure of the importance of technology maturity can be got from examining the information on product offerings contained in Appendix A. The number of EfW pyrolysis plants worldwide is small and many of the vendor firms, like Compact Power, have taken a long time to bring the technology to the market (refer to Appendix B). Compact Power, for example, acknowledge it has taken it ten years to get through its development stage. Again, taking it as an example, the fact Compact Power has run its demonstration plant on commercial terms year round, places this company at a lower risk level compared to one that has no demonstration plant or one that had a limited plant operating history⁸. Some other “due diligence” factors which would be investigated at a pre-feasibility report stage are:

- technical studies critical/environmental assessments completed;
- compatibility with intended waste stream compositions and volumes; and
- independent review of equipment reliability and manufacturing and assembly requirements.

Project Completion Risk

Looking beyond the primary technology selection process, the likelihood of the project being completed satisfactorily must also be assessed. Since no integrated energy from waste pyrolysis plant exists in New Zealand, this adds a “first of its kind” element to the risk profile, i.e. there is no other project from which construction history and environmental approvals can provide a helpful guide. The risk factors are numerous:

Direct Project Risks

- shop manufactured/field fabrication;
- local technology capability;
- technology ownership/licensing/vendor security;
- engineering/construction specifications; and
- engineering details/vendor manuals/supplier documentation.

Indirect Project Risks

- environmental approvals;
- regulatory authority attitude and capability;
- likelihood of non-performance and its consequences;

⁸ EDL in Australia are a recent illustration of long development times and high development costs for an energy from waste process which has not proved successful. Orion New Zealand invested in the company. EDL has since halted all development work on the process to concentrate its business on landfill gas projects.

- political risks; and
- training/vendor assistance.

Again, because the technology is first-of-a-kind, it can be anticipated that there will be significant regulatory and political uncertainty in respect of any project. Regulating authorities are unlikely to have the competency to assess the project which will require the vendor to make available to the project the necessary environmental and technical (health and safety) documentation to satisfy these risk factors.

Operating Risk

Although the operational risks are associated with the plant once it is built and operating, the following factors will also need to be taken into consideration at the project planning stage:

- reliability record/maintenance requirements;
- technical support/vendor commitment;
- product distribution and supply requirements;
- supplies of consumables and other materials;
- security of supply/consequence of shutdown/hazards that can occur from improper operation, etc; and
- environmental regulations.

Many of these issues actually form the basis for negotiation with the technology supplier.

The relationship with the vendor, their

commitment to the project and their long-term reputation and financial security are critical to the success of emergent projects such as being described here. By understanding these risk components, and working with them, will ultimately improve the chance of commercial success.

The European Commission has presented a proposal for a Directive to regulate the management of waste from the extractive industries (mining and quarrying). Because of its composition or volume, this waste can constitute a serious threat to the environment and human health if not properly managed. This proposal seeks to improve the ways in which waste from the extractive industries is managed by setting minimum requirements and specifically addressing the environmental and human health risks that may arise from the treatment and disposal of such waste.

It covers waste from all sectors of the extractive industry and specifically focuses on operational issues connected with waste management, prevention of soil and water pollution, and the stability of waste management facilities (in particular tailings ponds).

In addition, the proposal contains an obligation to provide for an appropriate level of financial security to reinforce the “polluter-pays” principle. This entails ensuring that sufficient funds are available to leave waste sites in a satisfactory state after closure, for example, if a company goes into administration, becomes insolvent or even engages in asset-stripping (the so-called “walk away” practices). Extractive operations often generate large volumes of waste. These wastes, which may be major sources of pollution, include topsoil, overburden, waste rock and tailings.

5 Review of other Waste Resources within the Region

Solid Energy

Solid Energy, New Zealand’s leading producer and distributor of coal, operates underground and opencast mines on the West Coast. It currently extracts, processes, markets and distributes about 2 million tonnes of coal a year from its Spring Creek opencast mine, and Stockton and Reefton underground mines. This coal is destined primarily for the export trade through Lyttelton.

Graded sized products from on-shore markets create coal fines which are blended with the export and other products to satisfy customer specifications. Currently, coal fines accumulated from past operations are in the process of being reintroduced into delivered product, so there is not a large quantity of fines currently available, unless a major change occurs to the customer base. However, with a planned

increase in production (expansions on the Stockton plateau and at the Spring Creek Mine near Greymouth) there is likely to be an increasing volume of fines in future. A new water processing system will mean that much of the fine coal currently trapped in sedimentation ponds will become more "available" as a product (a dryish sludge from lamellar separation devices). Solid Energy is in the preliminary stages of investigating this as a marketable product for the future.

Coal bed methane (CBM) is the naturally occurring gas in coal seams and the West Coast has definite potential to drill and tap this resource although it has not been well defined so far. One well has been drilled at Dobson and there are other prospects at Lake Brunner, and in the Greymouth and Reefton areas. The Westport area is too shallow to have retained commercial quantities of CBM. Solid Energy intend to undertake exploration surveys for CBM during 2004.

Timberlands West Coast

By the year 2010 forestry could be the leading earner of foreign exchange for New Zealand, one of the few nations in the world with the strategic advantage of harvesting a sustainable forestry resource. Timberlands West Coast Limited (Timberlands) manages an expanding exotic forest estate on the West Coast (28,100 ha of exotic forest, including 1,070 ha of cutting rights on Department of Conservation land). Timberlands is not involved in timber processing itself but produces high quality exotic plantation logs for a range of customers. New Zealand radiata pine accounts for 80 percent of Timberlands estate with the balance made up primarily of Douglas fir and special purposes species such as Tasmanian blackwood and cypress species.

Exotic trees are the mainstay of the West Coast forestry industry. Timberlands current production of around 260,000 cubic metres per annum is forecast to increase by the year 2003 to a sustainable level of 270,000 cubic metres per annum. This accounts for about 90% of local production. Approximately 60-70 percent of these logs are processed on the West Coast⁹, the exceptions being log grades such as chipwood which are currently unable to be processed locally.

The West Coast Timber Association represents the seven major timber millers and processors based on the West Coast. The members are Inangahua Sawmills; Coast Pine, Reefton; Westimber, Ngahere; Stillwater Lumber; IPL, Gladstone; W E Whiley & Company, Hokitika, and WestCo Lagan, Ruatapu.

A recent survey of current practice at each site found that there were few who were stockpiling residues. The majority of residues (sawdust, shavings or bark) are burnt to provide on-site energy requirements. The only sites where stockpiling is occurring at present are: Inangahua (sawdust, although this is taken away by farmers when needed for stock pads); Ngahere (sawdust and bark); Stillwater (bark). Sawdust is also used in landfill cover and mixed with fish offal for making saleable garden compost, while bark is used for mulch and for other landscape uses. The amount of present-day stockpiling is quite minimal.

Before mills began using their own waste residues for heat production all waste was put in a waste pit. These landfill sites contain stored material that has lain there for many years, and in some cases this material is also being extracted for off-site uses mentioned above. There is no estimate of the stored quantity at these pits.

Westland Milk Products

Westland Milk Products (Westland Co-operative Dairy Company Ltd) is an independent, co-operative dairy company, owned by its 370 farmer shareholders. It has a history of over 60 years of dairy production. The company currently processes more than 350 million litres of milk, with daily milk intake reaching 2 million litres at the peak of the season while its vehicle fleet travels many thousands of kilometres each day.

The company has been established on the present Hokitika site since 1967. Existing onsite activities

⁹ As a major industry of the region, it would be instructive to know what amount of energy is used in processing. The recent Major Energy Users Audit scheme from EECA can be a source of funding to undertake such an assessment.

include butter production; milk powder and milk protein concentrate manufacture; milk transportation; site laboratory and research and development facility; engineering and mechanical services; retail store and bulk product stores. The energy centre houses a 25 MW boiler which uses coal. An effluent treatment plant processes the waste stream from the processing operations, removing total solids, chemical oxygen demand (COD), milk fat and adjusting the pH prior to discharge to the Hokitika River.

Wastes sent to local landfill – approximately 300 m³ per week at the height of the season (August to the end of May) includes general waste from all areas; the majority being used packing material – paper and plastic not suitable for recycling; ash from the boiler (1300 tpa); dissolved aeration floatation sludge – removed as part of the effluent treatment process.

Recycling is practised: cardboard, paper, glass, scrap metal and used engine oil (Oil Recovery Company). Chemical laboratory waste is transported to Christchurch on an infrequent basis for disposal and worn tyres are returned to the supplier.

Holcim (New Zealand) Ltd (Holcim)

The cement works at Cape Foulwind, near Westport is potentially significant in developing opportunities for waste disposal in the region as well as beyond. At present the site burns a relatively large¹⁰ amount of used oil, including ships' slops¹¹, as a supplementary fuel to coal. This source is back-loaded by a Holcim bulk carrier ship visiting main ports around the country. Waste oil currently provides about 17% of the heat energy required by the plant with the volumes burnt representing approximately 50% of the available used oil in New Zealand.

A resource consent was obtained in 1994 from the West Coast Regional Council to burn used oil for 20 years, subject to conditions. The conditions include limits on the lead, cadmium, mercury, PCB, sulphur and total organic halogen¹² content of the oil. Holcim is required to test a sample from every load of incoming oil for these contaminants.

Holcim Switzerland is one of the most prominent examples of good AFR business development in the global cement industry. In the early 1990s, driven by the financial and environmental benefits of using waste as a fuel, and a temporary shortage of landfill and incineration capacity in Switzerland, stakeholders came together to address the use of alternative fuels and raw materials in the cement industry. Together they developed an agreed framework of clear rules for regulation of the environmental and societal aspects of the use of alternative fuels and raw materials.

Today, the company's five cement plants in Switzerland have thermal substitution rates of between 10 and 60%, using wastes including solvents, waste oil, plastic and used tyres. Continuing engagement with stakeholders has enabled Holcim Switzerland to use a variety of other alternative fuels and raw materials. These include dried sludge from sewage treatment and animal meal from the preventive slaughtering of cattle potentially infected with BSE ("mad cow disease").

Holcim has set a target date for achieving zero energy cost of production. Similarly, it has also set a date by when cement production will have the lowest possible carbon dioxide emissions.¹³ For the last decade, Holcim (New Zealand) Ltd has had some success in reducing its carbon dioxide emissions. However, early results from further improvements towards achieving these targets suggests that it will be a difficult task given the isolation of the site, and hence the waste transportation issues.

Emphasis, therefore, is likely to concentrate on destruction of selected nuisance and hazardous wastes to provide fuel and raw material offsets against currently used non-renewables (coal, as described in the box).

¹⁰ The latest figure available is 12.5 million litres of used oil per year, excluding ships' slops.

¹¹ An oil and water mix containing predominantly bunker fuel and some lubricant drainage and drippings.

¹² Halogens: any of a group of reactive, non-metallic elements (chlorine, fluorine, bromine, iodine) which form strongly acidic compounds with hydrogen, from which simple salts can be made (Concise Oxford Dictionary).

¹³ Apart from the production process the release of carbon dioxide is a natural consequence of cement production which calcines forms of calcium carbonate).

Cement kilns operate at very high temperatures (peak gas temperatures up to 2000°C) and the gases in the kiln are kept at high temperatures (over 1200°C) over a long residence time. Because complete combustion occurs at these temperatures, organic contaminants are destroyed. Metallic compounds in fuel, whether coal or used oil, are broken down by the intense heat, but the metals are not destroyed. Most metals (generally as their oxides) are incorporated into the kiln products, cement clinker and kiln dust, with much of the remainder attached to the surface of dust particles. Over 99 percent of kiln dust is collected before combustion gases are discharged to the atmosphere.

The cement kiln is one of the most environmentally efficient means to deal with wastes. The main reasons are the extremely high temperatures (1450 to 1900 Celsius ensuring complete combustion and ash combination for most substances) and the elimination of any residues. However it does not necessarily strike the optimum balance between environment, economy and community (job creation). Therefore other processes can be sustainable and a broader look at the options is pertinent.

In Europe, the cement industry has many years experience in treating wastes and the process is highly developed. There exists a waste fuel specification which covers many characteristics. Cement plants are prohibited from using wastes that fall outside this specification. The more important constraints are the concentrations of halogens, sulphur, nitrogen, barium, chromium, lead, zinc, vanadium, PCB + PBB, and benzene.

Some typical waste fuels and their approximate characteristics are listed here:

	Ash %	Moisture %	Gross heat value (kcal/kg)
animal fats	-	-	9,500
corn cobs	3	5	4,500
paint	-	-	4,500
paper	1	5	4,000
rubber	20	30	5,500
municipal waste	5-10	10-70	1,500-4,500
pathological waste	3	85	550
wood	3	10	5,000

When the full impact on the cement process is analysed, the use of certain wastes can become non viable. For instance, the burning of whole motor car tyres at a level of 15 % replacement of firing heat, commands a cement plant to charge in the region of NZ\$80 per delivered ton.

6 Other Potential Resource Players

Tranz Rail

Tranz Rail has a fifteen year contract with Solid Energy to transport export coal to Lyttelton although the rail link is close to capacity, which makes any increase in exports hard to deliver¹⁴. Close to 2 million tonnes are railed to Lyttelton each year, mainly for export to Japan. The coal wagons are specially designed for bottom unloading, and return empty to the Coast. Depending on volumes, handling requirement and turn around times, back-loading to bring raw waste as feedstock to a West Coast treatment facility may offer a useful economic opportunity.

¹⁴ The limitation in rail capacity and an expected increase in exports from the Stockton open-cast mine has given fresh impetus to a possible deep-sea jetty at Granity.

Transwaste Canterbury

Transwaste Canterbury Ltd is a Local Authority Trading Enterprise owned 50/50 by the local authorities (detailed below) and by Canterbury Waste Services Ltd. Canterbury Waste Services Ltd is owned 50/50 by Waste Management New Zealand Ltd and Envirowaste Services Ltd. The Local Authority participation in the process is via the Canterbury Waste Subcommittee. The split of capital funding for the Canterbury Waste Subcommittee is as follows:

Council	Population (1996 census)	%
Christchurch	314,000	75.70
Waimakariri	32,100	7.74
Hurunui	10,000	2.40
Selwyn	25,000	6.03
Ashburton	25,000	6.03
Banks Peninsula	8,700	2.10
Total	414,800	100.00

The Christchurch City Council has budgeted a total of \$8.25M as its contribution to Transwaste Canterbury Ltd to enable Transwaste to acquire a landfill site subject to appropriate resource consents. Of this, the 2002/03 capital contribution from the Christchurch City Council is projected to be \$400,000. The full operational budget of the Company will not be known until a landfill site has been consented.

The objectives for Transwaste Canterbury are to undertake activities related to:

- 1 Selection of a site for a new Canterbury Regional non-hazardous landfill, including site purchase and ownership, obtaining Resource Consents, developing the landfill and site operation.
- 2 Haulage of waste from refuse/transfer stations throughout the Canterbury region to the landfill in due course.
- 3 Offer waste management facilities and solutions at all levels in the Canterbury Region and beyond, including investment in alternatives to landfilling should those alternatives be more environmentally sustainable and cost effective methods of disposal (in due course).

The overall service objective is to operate as a successful business that owns and operates a Canterbury Regional Landfill, which accepts waste from contributing Territorial Local Authorities and makes a fair rate of return on shareholders investment.

Nuplex

The Nuplex Environmental Services division comprises of four Nuplex subsidiaries collectively known as Nuplex Environmental. The group companies, and Nuplex's ownership share of them, are United Environmental Ltd (100%), Nuplex Medismart Ltd (100%), Medical Waste Wellington Ltd (50%) and Nuplex Special Waste Pty Ltd (100%).

United Environmental Ltd, trading as Nuplex Environmental, operates waste processing plants in Wellington and Auckland, servicing the requirements of customers throughout the North Island of New Zealand. The waste processed covers the entire range of industrial and municipal wastes commonly generated in New Zealand.

Nuplex Medismart with Medical Waste Wellington, supply services throughout New Zealand and operate disposal facilities in the four major cities. Medismart offers a fully integrated specialist collection and disposal service for clinical and quarantine wastes from waste assessments, to the supply of specialised containment, to the safe collection and disposal of hazardous wastes.

The Christchurch facility resource consent requires more stringent conditions beyond 2004. Incineration will not be able to meet these conditions so it is planned to change to steam sterilisation followed by

sanitary landfill. Steam sterilisation is already taking place at the Auckland, Wellington and Dunedin sites.

Sims Pacific Metals

Auto shredder residue (ASR) is generated from processing of old car bodies and a limited supply of whiteware appliances (washing machines and refrigerators) to recover the metals. The process is a large consumer of electrical power. The annual throughput produces 6,000 tonnes of ASR in Christchurch and 15,000 tonnes in Auckland. At present this is taken to land fills and is a high cost of disposal for the company.

The company is investigating better methods of disposal rather than sending ASR to landfill. It is undertaking a chemical composition analysis with a view towards taking advantage of EfW opportunities in the future.

7 Discussion

This review has centred on the opportunities for pyrolysis as an economic means of treating current and projected waste streams within the West Coast region. The solid waste volumes of the West Coast are relatively small against the volumes that would generally be required to make a business case for pyrolysis or other related thermal conversion technologies. It could be argued that incineration may be a viable alternative, but has not been considered.

Information that is typically required for planning thermal treatment projects includes detailed information on waste composition, including proximate analysis, ultimate analysis and heating value range. The minimum requirement is to establish the moisture content and heating value of the material for the likely range of supplier and delivery conditions. The West Coast is the wettest region in New Zealand and if the waste stream contains a high moisture content this could have an adverse impact on the viability of using any thermal conversion technologies.

From factors identified earlier, the McLeans landfill site appears at first to be the most likely site for any EfW plant. Common concerns for any project around health and safety concerns, air emissions, odours, traffic and impacts on property values are largely addressed at this site. In the event of a shut down of the plant, due to scheduled or unscheduled reasons, all waste would be able to be directed to the landfill. However, when other aspects of a proposal come to be examined, the desirability of this site may not hold true.

Set against this background, however, there are a number of issues affecting a wide range of organizations and interests that suggest several possibilities in bringing forward a systemic solution to meet the West Coast's needs. These revolve around a comprehensive review of the waste resources, an appreciation of the technologies that are applicable, and generating the willingness for separate commercial and public service interests to work together.

Organisations so far identified with either a strong or potential interest in a total systemic solution are:

- The West Coast Regional Council and the three District Councils;
- The West Coast Development Trust;
- Holcim;
- Nuplex Industries;
- Sims Pacific Metals;
- Solid Energy;
- The Canterbury Regional Council and its District Councils;
- Transwaste Canterbury; and
- Tranzrail.

The possible range of options into disposal and use of waste in the Region are so far seen as:

- 1 Base case: continue sanitary landfilling. Investigate landfill gas extraction¹⁵.
- 2 Introduce waste materials separation alongside continuation of sanitary landfill operations. Materials with little or no commercial value at present to be stored in separate cells of the landfill.
- 3 Process MSW into RDF (refuse derived fuel) at selected locations. Use as a supplementary fuel at the cement kiln at Cape Foulwind or co-fire¹⁶ in a thermal power station planned by Solid Energy, or others.
- 4 Combine MSW with other local waste resources, and/or imported waste to the region from Canterbury (utilising the empty coal wagons returning from Solid Energy's export trade through Lyttelton) to bring together sufficient waste volumes for an EfW facility to be economic. Examine EfW modular incineration or pyrolysis.
- 5 Dependent on the technology of any treatment option identified in 4 above, look to provide a disposal service to the South Island for clinical and quarantine waste.

This suggested range of opportunities requires wider discussion with the potentially affected partners and then for the feasibility assessment of the most highly-rated option(s). Bringing affected and commercial organizations together creates an opportunity to devise a plan that will have a wide benefit, socially as well as economically, for the region.

An energy from waste project which draws on a wider base than just regional MSW could supply heat and electricity for an "Energy Park". This could take various forms, either a community recreation centre or a light industrial site making use of the by-product heat and electricity. Another vision could be that of establishing algae farms nearby to utilise the carbon dioxide from the energy from waste plant¹⁷.

The final outcome, whichever concept is pursued, will be to turn what is possible into actuality for the long-term benefit of the West Coast.

8 Recommendations

To provide sufficient information for the WCMMWG to advance investigation of a pyrolytic integrated waste solution the following staged analysis is proposed:

1. Preliminary site study to determine optimum location for an integrated pyrolysis facility

As a first step the study team, in consultation with WMWG staff and local infrastructure organisations, should be established to develop an overview project scope that describes the locations of waste sources, energy plants, cement and other major manufacturing sites, plus other infrastructure facilities that might potentially have a use for the energy or byproducts produced from an integrated facility. This analysis (based on available information through WMWG or through stakeholder consultation) should seek to identify a preferred location for the facility so as to minimise transport costs and to avoid public concerns. The supply chain and location arrived at will form the basis for the following stages of investigation.

2. Source and fuel characteristics for the various waste streams

This phase will bring together information on the waste streams identified as potential feedstock for any waste conversion plant to establish overall supply characteristics. Within the various waste streams, only

¹⁵ Landfill gas extraction is not expected to be viable from such a small site. Supplementary gas from coal seams might be a possible adjunct.

¹⁶ "Co-firing" municipal solid waste with other materials or wastes presents a number of challenges for "proven" technologies. Implementation of this strategy with developmental technologies such as gasification and pyrolysis should not be under estimated.

¹⁷ Early work on this concept has been undertaken at the Bromley sewage treatment ponds in Christchurch. The objective is to harvest the algae and, by pyrolysis, obtain biodiesel. If this technology became proven, it could ultimately be applied to CO₂ emissions from the cement kiln at Cape Foulwind.

part of the waste material such as woody biomass, paper products, some plastics and tyres are suitable for conversion. Identification of their quantity including seasonal variation and competing uses is critical to determining plant scale and operating configuration. As a waste management solution other non-pyrolytic wastes also need to be considered for further treatment such as recycling.

3. Technology choices, integration and process configuration

There are many kinds of pyrolysis technologies such as conventional and fast. Technology selection will depend on scale, reaction parameters and final product required (liquid or solid). Based upon the needs analysis described above, technologies will be evaluated related to feedstock requirements, product preference and process energy consumption. An integrated process configuration including equipment items will be established for the West Coast situation as a basis for further more detailed investigation and assessment.

4. Economic and technical viability assessment

Economic operation varies with the scale and technical complexity, which is largely determined by the availability of the feedstock from the waste sources. Technical issues may occur due to a change of the feedstock type or a change of the final product. These parameters need to be assessed and analysed based on preliminary assumptions from the earlier recommended work and indicative capital and operating costs (approximate $\pm 30\%$ accuracy) estimated. Market or end-use suitability of the products should be also be assessed, including evaluation of possible integration options.

5. Recommendation on further work

From the above analysis and project definition it will become clear the requirement for decision-making and vendor analysis, and any expression of interest would naturally follow, depending on the requirements of the West Coast Waste Management Working Group. At this stage full commercial analysis will need to happen as for any normal investment decision. The structure of these arrangements are beyond the scope of this work.

Appendices

Appendix A: Information on Commercial Companies

1 Pyrolysis

COMPANY	STATUS	FUEL	COMMENT	WWW
Alcyon	Demonstration plant	tyres	Range of technology solutions for different wastes	www.alcyon.ch/E/EIND010.HTM
BS Engineering	Demonstration plant	MSW, industrial waste		www.bseri.com/eindex.html
Compact Power	Demonstration plant	MSW, ASR, sewage sludge	Steam reforming	www.compactpower.co.uk
Cresttec AS			Microwave energy	www.cresttec.no/
Dynamotive	Pilot plant	Agri-wastes	Fast pyrolysis of materials into BioOil	www.dynamotive.com/biooil/technology.html
Ensyn	Pilot plant	Agri-wastes	Biomass	www.ensyn.com/what/rtp.htm
Entech				http://entech.net.au/ws2/process.htm
JND Energy	Pilot plant	Agri-wastes, MSW		www.jnd.co.uk/JNDThermalProcess/energyfromwaste.html
Mitsui	Commercial	MSW, ASR		www.mes.co.jp/english/product/environ/a01.html
Pyrovac	Pilot plant	Agri-wastes, MSW	Vacuum process	www.pyrovac.com
RGR Ambiente	Pilot plant	RDF, ASR, tyres		www.rgrambiente.com/english.htm
Serpac-Pyroflam	Demonstration plant	MSW, industrial waste		www.bseri.com/eserpacenv3.htm
SFT-Nexus	Pilot plant	MSW, RDF	Analytical modelling	www.irisa.fr/ProHPC/SFT_E.HTM
Thermoselect	Demonstration plant	MSW, industrial waste		www.thermoselect.com/index.cfm?fuseaction=Technologie&m=2
Thide	Semi-commercial	MSW, industrial waste	Licensed to Hitachi	www.thide.com/
Toshiba PKA		MSW		www.toshiba.co.jp/about/press/1997_12/pr1602.htm
Von Roll	Commercial	MSW, ASR		www.vonrollinc.com/tech/therm_rcp.html
Wellman	Demonstration plant	Agri-wastes		www.wellman-process.co.uk/Wellman%20Gasifier%20Page.html

Demonstration plant: a plant, not necessarily full-scale, which is able to fully demonstrate the process.

Pilot plant: a plant, less than full-scale, which demonstrates aspects of the process.

2 Incineration

COMPANY	STATUS	FUEL	COMMENT	WWW
Kvaerner Chemrec	Commercial?	MSW, black liquor		www.kvaerner.com/group/
Onyx	Commercial	MSW		http://onyx-environment.com/gb/part2/chap4/sub/0000625.htm

3 Gasification

COMPANY	STATUS	FUEL	COMMENT	WWW
Choren Industries	Pilot plant			www.choren.de/e_html/eunter_10.htm
Ebara	Commercial	MPW, ASR		www.ebara.ch/products_services.php?n=1
Enerkem	Demonstration plant	Agri-wastes, MPW, MSW		www.enerkem.com/
EPI	Demonstration plant	Agri-wastes, sewage sludge		www.energyproducts.com
Foster Wheeler	Commercial	Agri-wastes, MPW, RDF	Co-firing coal with wood	www.fwc.com/power/fuels/#anchor_05
Heuristic	Commercial	Agri-wastes	Wood waste. Rice husk.	www.heuristicengineering.com/about_us/envirocyclers/envirocyclers.html
Lurgi	Commercial	MSW, MPW, RDF		www.mg-lee.de/index.html
MTC-Thermochem	Commercial	RDF, paper sludge	Steam reforming	www.thermochem.com/
Organic Power	Pilot plant	Agri-wastes,, MSW, industrial waste		www.opas.no/company/technology.html
PRM Energy	Commercial	Agri-wastes		www.prmenergy.com/

4 Plasma

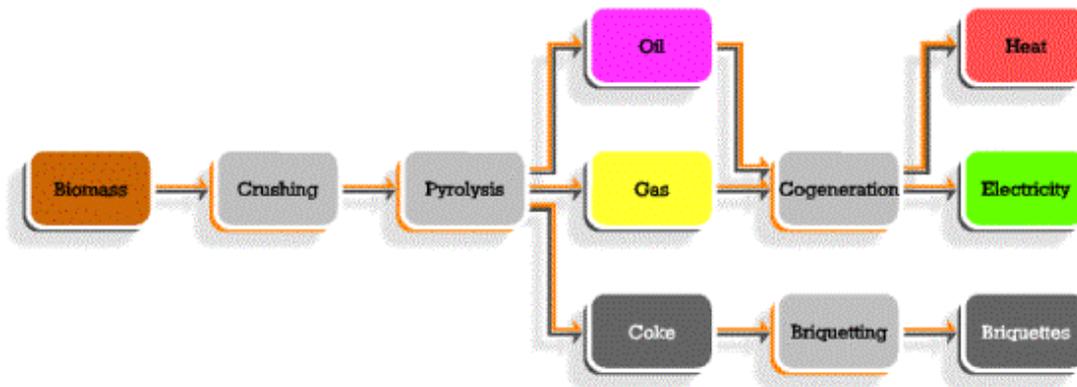
COMPANY	STATUS	FUEL	COMMENT	WWW
PEAT	Semi-commercial	Hazardous waste		www.peat.com/
Solena	Semi-commercial?	Hazardous waste		

Glossary:

- ASR Auto Shredder Residue. The residue from a car recycling process.
- MPW Mixed Plastic Waste. The residue from recycling separation of plastics.
- MSW Municipal Solid Waste. Domestic mixed solid waste (refuse), or commercial and trade waste of a similar nature.
- RDF Refuse Derived Fuel. Semi processed refuse with inorganics removed, homogenised, dried and compressed into pellets.

Alcyon® “BioRec”

Innovative, value-added recycling of biowaste by the Alcyon® BioRec process.



Biowaste is transformed by pyrolysis into charcoal, oil and combustible gas.

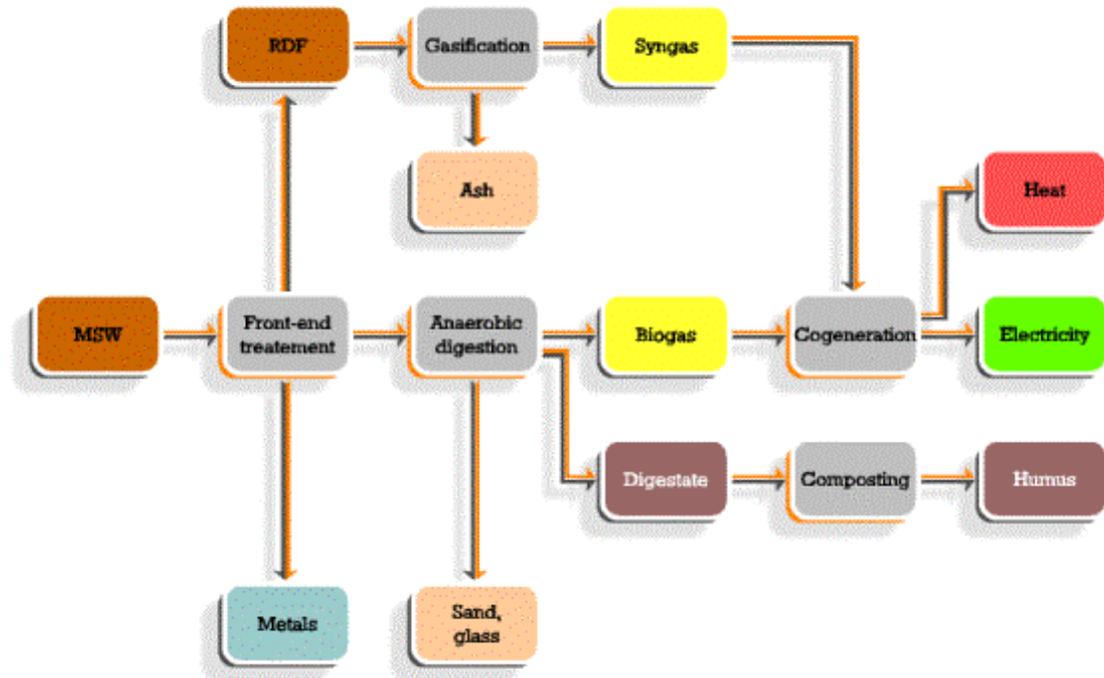
Charcoal is packed into briquettes; gas and oil are used to produce electric power.

Biowastes:

- Debris resulting from the processing of agricultural products such as: peanuts, corn, and various grains.
- Residue from food-processing industries
- Residue from timber industries
- Other organic residue

Alcyon® BioThermic Process.

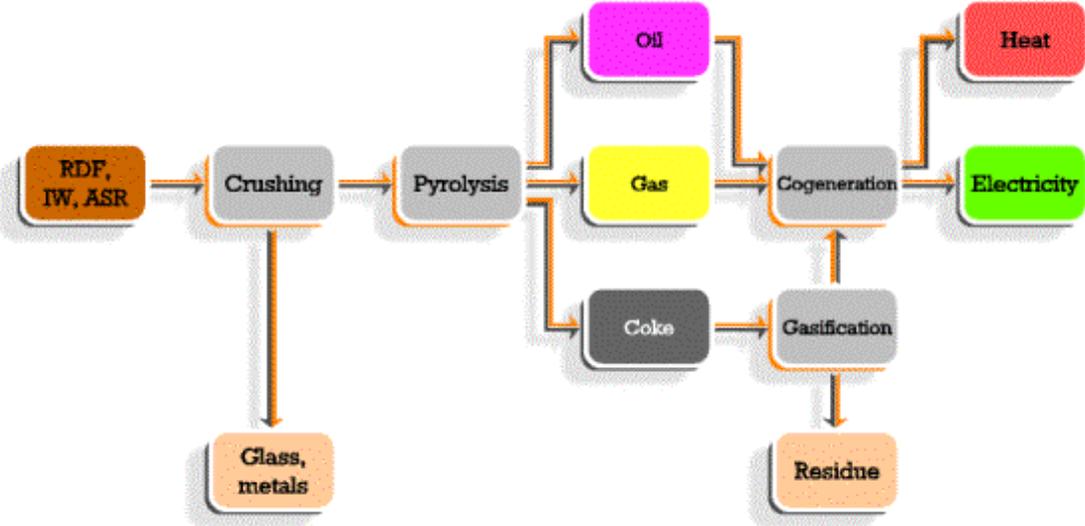
Efficient Municipal Solid Waste (MSW) treatment by the Alcyon® BioThermic Process.



This integrated process combines the MSW mechanical pretreatment for the extraction of recyclable and inert material, with biogasification of the organic fraction (WAASA™ anaerobic digestion), and thermal treatment of the combustible fraction (RDF), using gasification. Cogeneration deliver heat and electric power.

Alcyon® UrbaRec

Original, value-added disposal of RDF (Refuse Derived Fuel), IW (Industrial Waste) or ASR (Automobile Shredded Residue) by the Alcyon® UrbaRec process.

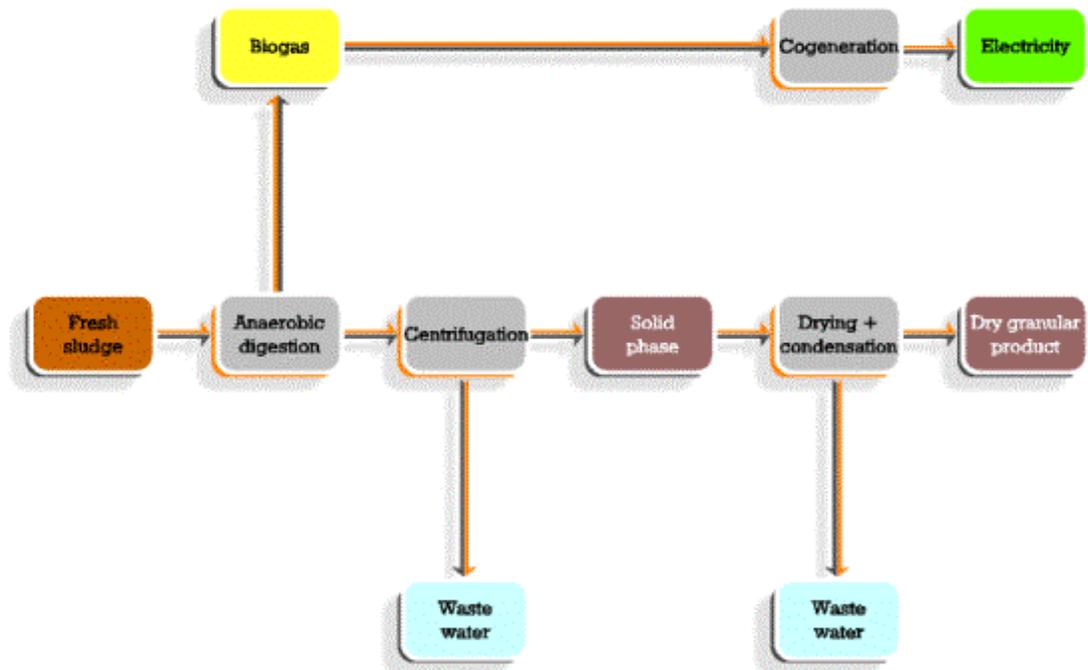


Incoming waste is transformed by pyrolysis into coal, oil and combustible gas.

Coal is gasified and combined with oil and gas to produce energy

GSTP® SLUDGE

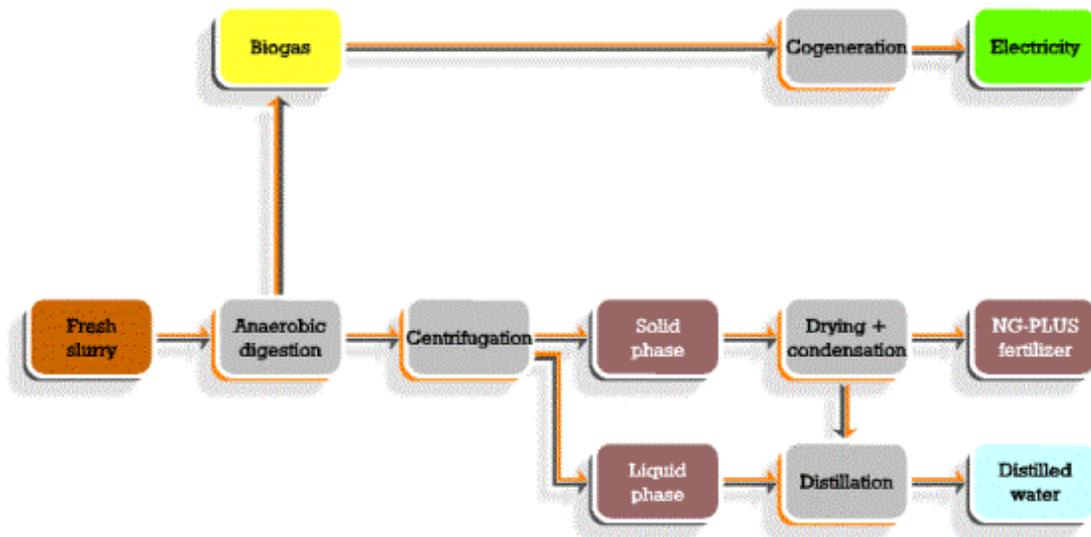
Treatment and value-added conversion of sewage sludge.



Fresh sludge is digested through an anaerobic digestion. Biogas is used for the generation of electricity and heat needed by the process. Digested sludge is centrifuged and dried. The result is a stable, granulated form product which can be used as fuel for a cement kiln. Waste water will be sent back to the WWTP.

GSTP® SLURRY

Treatment and value-added conversion of livestock manure.

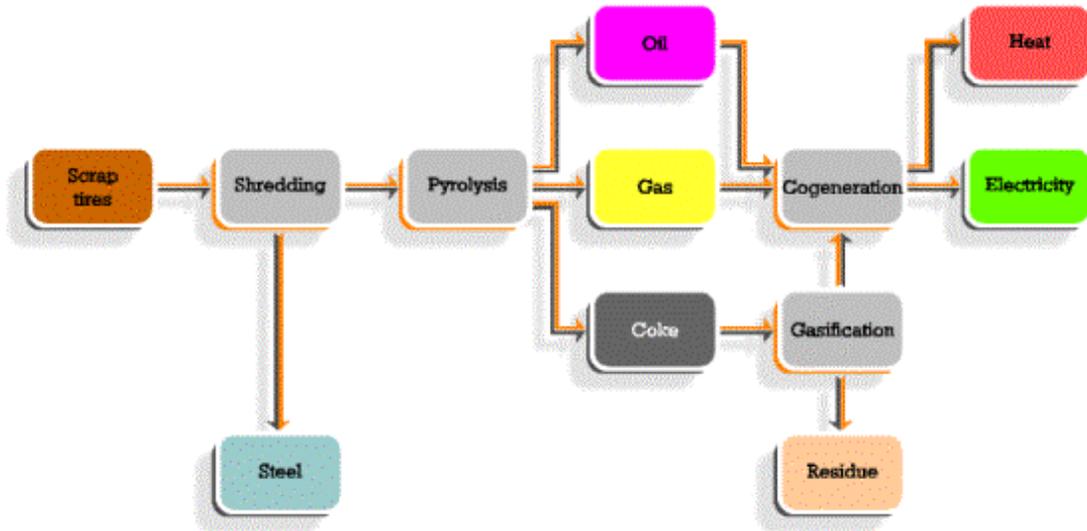


Fresh slurry is digested through an anaerobic digestion. Biogas is used for the generation of electricity and heat needed by the process.

Digested slurry is centrifuged. The solid phase is dried and granulated. The final product is a high quality dry, granulated natural fertilizer.

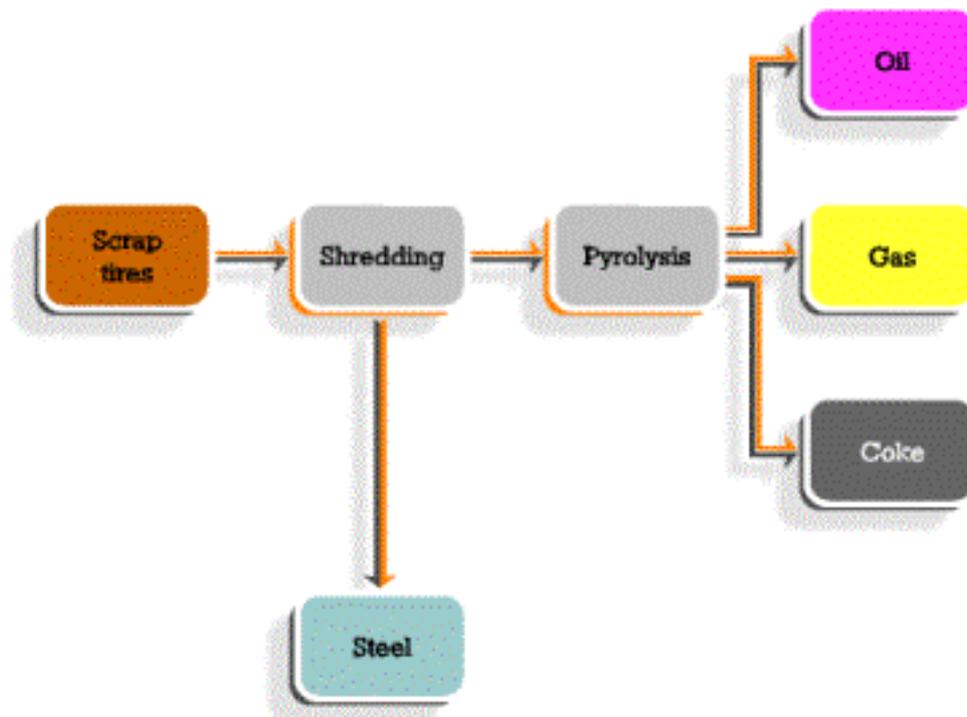
The liquid phase and the condensed vapors are distilled. The distillate can be released directly into a water course.

TiRec® COGEN



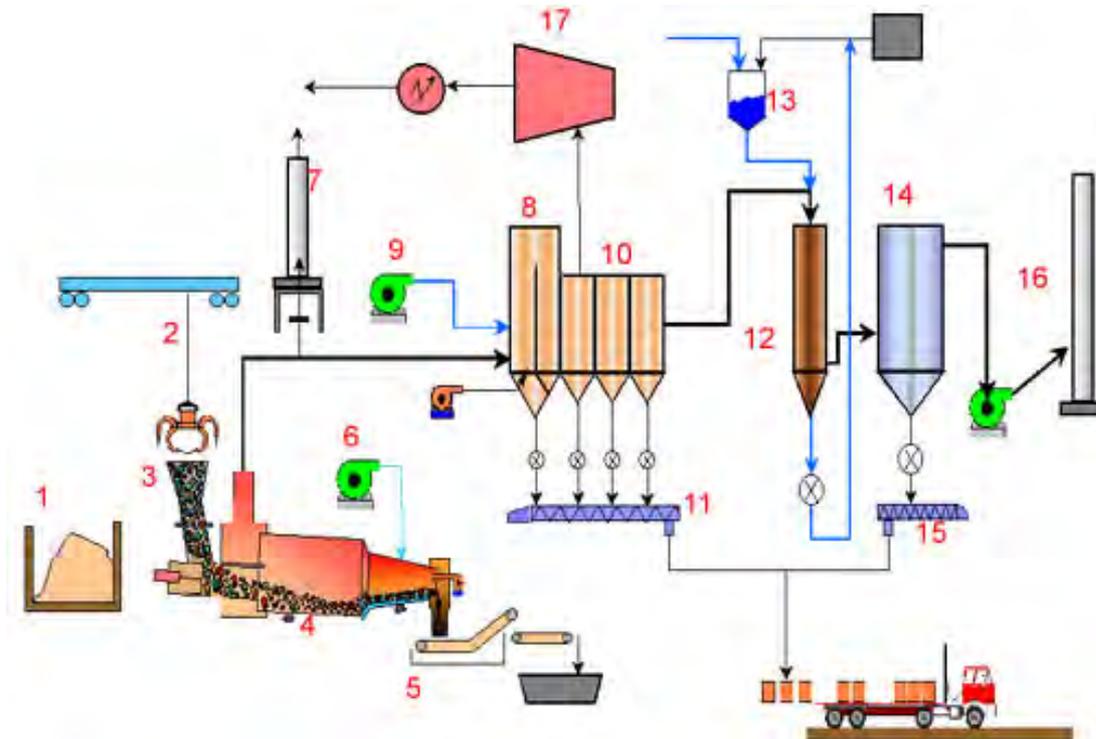
Whole tyres are shredded down to 2"x 2" crumbs, which are pyrolyzed under vacuum. The reaction produces combustible gas, oil and a coke residue containing zinc oxide, steel threads and silicates. The steel threads are removed by a magnetic separator. The coke residue is gasified.

In the TiRec® COGEN process, the oil and gas are used as fuel for the generation of energy (electricity and steam). The TiRec® FUEL process is a simplified version of the TiRec® COGEN process. In this case, oil, gas and coke are available as fuel



BS Engineering S.A.

The P.I.T. Pyroflam process, developed originally by Serpac Environnement, a French industrial company, is a gasification process aimed at the valorisation and conversion to energy of various solid wastes, including municipal solid wastes, industrial wastes, sludges, animal and meat wastes. BS Engineering S.A. acquired the patent, user's licence and trademark of the P.I.T. Pyroflam Process and Serpac Environnement's trademark in July 1999.



1= bunker; 2= crane with grab; 3= feeding hopper; 4= pyrolysis; 5= extractor of recyclable solid residues; 6= process air fan; 7= emergency stack ; 8= post combustion chamber; 9= combustion air fan; 10 = recovery boiler; 11 = fly ash collection; 12 = flue gas cleaning reactor; 13 = neutralizing reagents preparation; 14 = bag filter; 15 = collection of flue gas cleaning residues; 16 = stack; 17 = turbo-alternator.

The P.I.T. Pyroflam total pyrolysis process is based on heating a hydrocarbonated load without oxygen input at a fairly low temperature (between 450i and 750i C). This heating operation breaks down the organic materials, producing a thermolysis gas and a highly carbonated solid residue which is transformed into burnable gas by gasification.

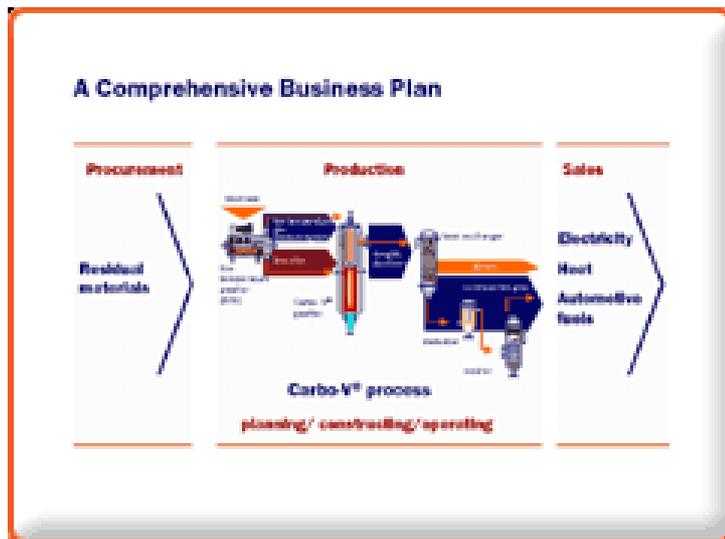
A highly efficient thermal conversion process:

- Simple
- Not limited by the calorific value of the waste
- Producing less flue gases
- Less heavy metals, fly ash, dioxins and furans
- Maximum valorisation of the energy contained in waste materials
- Without environmental nuisance
- Low running costs

Choren Industries

CHOREN provides gasification technology for solid biomass (organic waste) and waste materials containing carbon. The leading technology of the company group is the globally patented Carbo-V Process. For the first time this enables these materials to be converted into a combustion or synthesis gas, which is absolutely tar-free. This means the long-awaited breakthrough for biomass to become an energy carrier for either the chemical industry or energy sectors has been achieved.

CHOREN provides considerable additional services and attractive alternatives as a company, whose profile can be described a “user of biomass.” The company is exploiting biomass and its potential in existing material flows, it is linking sectors with each other in a new way and is cooperating with traditional companies at new stages in the defined chain of wealth creation.

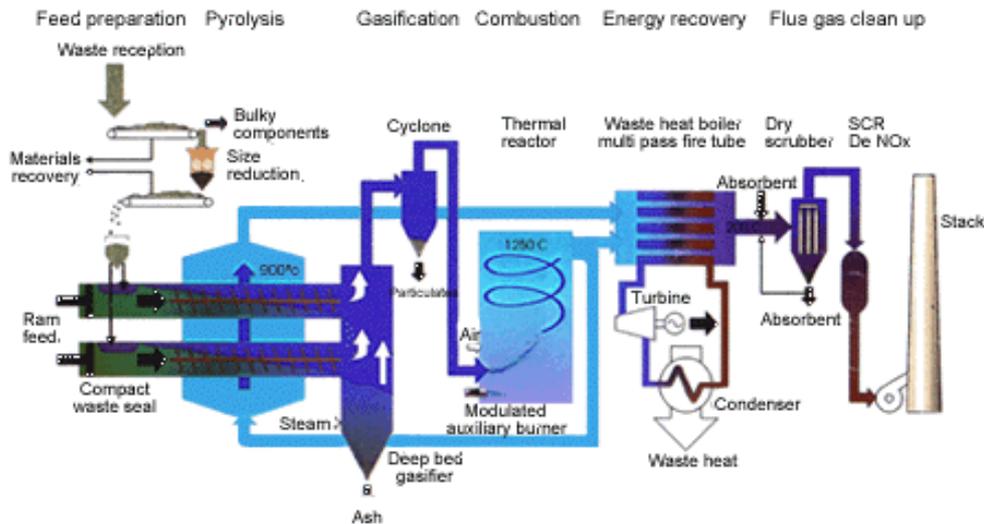


CARBO-V®

The Carbo-V Process, forms the core of the CHOREN Group’s technology, a universal gasification process, which can just as easily convert coal, biomass (organic waste) or pretreated domestic waste into a raw gas, which is absolutely tar-free.

This raw gas serves as a combustion gas in decentralized engine and turbine plant for generating heat or electricity required in the vicinity as a synthesis gas for further processing to make liquid fuels.

Compact Power



The Compact Power technology uses pyrolysis, gasification and high temperature oxidation to convert a wide range of wastes to fuel gas and other usable products (e.g. carbon of various grades and types). Facilities are designed to process multiple waste streams meeting highest international environmental standards and optimising energy and materials recovery.

A Compact Power facility is made up of multiples of a standard plant module (MT2) based on the following components:

- *Hopper and feed system.*
- *Pyrolysis chamber* with two pyrolysis tubes with each tube designed to process up to 500kg of waste per hour. Materials are taken through the tube and heated to c.800°C in the absence of oxygen. Hydrocarbons are converted to simple gases leaving residues of carbon char, inert grits and heavy metals
- *Gasifier* where residues are reacted within a superheated steam box in the classic “water gas” reaction to produce hydrogen and carbon monoxide.
- *Thermal reactor* where gases from pyrolysis and gasification are reacted with air at high temperature (more than 1250°C for more than two seconds) to ensure destruction of pollutant gases and any particulate carry over.
- *Steam boiler* where the exhaust gases are passed through a steam boiler.
- *Power generation* by steam turbine or steam reciprocating engine.

Cresttec AS

Cresttec was founded on the business idea to technically and commercially develop microwave technology. One of the main focus areas is to use microwaves to pyrolyse organic materials. Cresttec's patented processes are cost-effective and environmentally friendly ways to recover materials and energy from organic waste materials. At the same time challenging waste management problems are solved without polluting the environment.

Among the Group's clients are leading Norwegian and international oil companies, such as Statoil, Hydro, Shell, Exxon, Mobil, BP, Elf, Conoco, Petrobras, Petronas, and Phillips. We also serve the most important players within the building and service sectors, such as Aker, Kvaerner, Dresser, Heerema, Maersk and Brown & Root. The most important Norwegian shipping and process industry companies are also among the Group's clients.

1. Proven technology based on direct microwave energy:

- Destroys all types of biomedical waste
- Generates a sterilized carbon residue suitable for municipal landfill disposal eliminating the risk of infection of health care workers
- Eliminates special handling of waste
- Test results confirm greater than 6-log₁₀ reduction in viable spores

2. Low vessel temperature process

- Nitrogen environment inhibits the formation of hazardous toxic by-products such as dioxins
- Meets MOE and US EPA standards with low cost commercial air emission control system

3. Stainless steel construction

- Heavy-duty construction will extend the life expectancy of your capital investment
- Easy to clean

4. Heavy duty grinder located at back of process grinds only sterilized product

- No concern of infectious waste in grinder during maintenance
- Handles sharps, glass and metals
- No separation of waste types needed

5. Nitrogen gas supply with surge tank

- No bottled nitrogen required
- Backup supply of nitrogen ensures safe and orderly shutdown

6. Controlled by solid state PLC and components

- Low maintenance and easily accessible spare parts
- Increased operation time and reliability

7. State-of-the-art computer control system

- Monitors entire process simultaneously
- Minimizes operator intervention
- Controlled shutdown procedure ensures safe operation without operator monitoring

8. User friendly interface

- Ease of operation and interpretation of operating parameters will overcome any language barrier
- Minimizes operator training requirements

9. Remote monitoring

- EWI technicians can trouble shoot remote systems and optimize parameters on line to provide immediate service

10. Simplified loading

- Reduces handling time
- Increases safety
- Eliminates the need for refrigerated storage

11. Measuring chamber

- Each load is weighted by the control system to determine cycle time
- Minimizes human error

12. Air conveying system

- Carries sterilized carbon residue to remote disposal location
- Minimize handling
- Allows you the flexibility to locate the unit close to the collection point
- Can be directly discharged into hoppers

13. Low energy costs

- Reduces environmental services budget

14. Short cycle time

- Eliminates the need for long-term refrigerated storage of hazardous waste

15. Large capacity per year

- Significant throughput

16. Final mass and volume reduced by 80%

- Disposal issues are addressed efficiently
- Significantly reduces landfill disposal costs for treated residue

17. Emissions

- Water Scrubber discharge to sanitary sewer

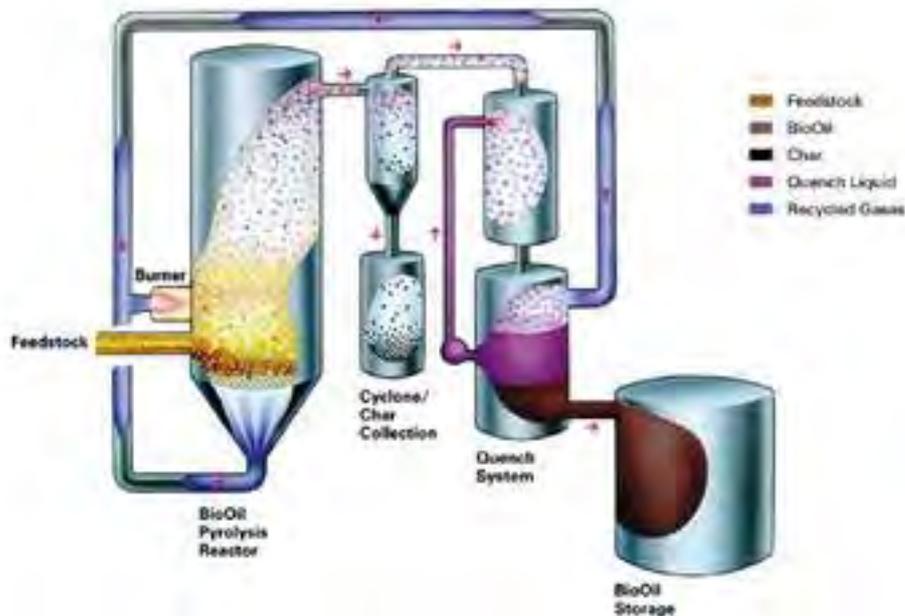
Air fed to microturbine or low volume thermal oxidizer (120 cfm peak)

DynaMotive

DynaMotive Energy Systems is commercialising a proprietary “fast pyrolysis” process that converts forest and agricultural residue (including bark) into liquid BioOil and char. BioOil is a clean burning, greenhouse gas neutral fuel that will initially be used to replace fossil fuels to generate power and heat in stationary gas turbines, diesel engines and boilers and to replace natural gas in the forest industry and to replace another product in the coal industry. The char is a high BTU (heating value) solid fuel that can be used in kilns, boilers and the briquette industry.

Fast pyrolysis refers to the rapid heating of biomass (including forest residue such as bark, sawdust and shavings; and agricultural waste such as wheat straw and bagasse) in the absence of oxygen.

DynaMotive’s patented process called BioTherm[®] uses a bubbling fluidised bed reactor, which is generally believed to be a simpler and more robust process than other pyrolysis technologies under development. DynaMotive acquired the exclusive worldwide patent rights for its technology from Resources Transforms International (RTI), the original developers of the technology. Figure 2 below illustrates the DynaMotive fast pyrolysis process. Prepared feedstock (<10% moisture and 1-2 mm particle size) is fed into the bubbling fluid-bed reactor, which is heated to 450–500 iC with no oxygen. The feedstock is vapourised into gases and char, which are spun through a cyclone where the char is removed. The gases are quenched into BioOil and the non-condensed gases are re-circulated to fuel approximately 75% of the energy needed by the pyrolysis process.



Three products are produced: BioOil (60-75% by weight), char (15-25% wt.) and non-condensable gases (10-20% wt.). Yields vary depending on the feedstock composition. BioOil and char are commercial products and non-condensable gases are recycled and supply a major part of the energy required by the process. No waste is produced.

Ebara

Various kinds of wastes surround us, and each type is now treated separately. Such treatment is not the best way to recover more energy from wastes and reduce land reclamation. EBARA has developed fluidized-bed gasification and combustion technology to make these wastes treatment more wholly and earth-friendly. The Zero Emission system applied to this technology produces no secondary pollution, and enhances the efficiency of material, thermal and chemical recycling. This new system can be used to produce electric power, chemical industry materials, metal, slag, etc. EBARA Twin-Interchanging Fluidized - Bed Incineration System (TIF & ICFB), applicable for any kinds of waste treatment, helps the positive energy collection and secures the energy efficient and clean incineration.

Stoker-type incinerator for Municipal Waste

EBARA stoker-type incinerator system features high pressure / high speed incineration, applicable even for stable incineration of high calorie waste, controlling dioxin generation.

Stoker-type incinerator facility equipped with plasma ash melting system

With ever-increasing volumes of waste being produced in urban areas, the treatment and disposal of incinerator ash has become a problem. By using a plasma-type melting furnace, this system reduces the volume and toxicity of incinerator ash, and allows ash to be reused as a construction material.

Refuse-Derived Fuel Production facility

Ebara's Refuse-Derived Fuel(RDF) production facility processes burnable waste that is difficult to recycle, such as garbage and plastics, turning such waste into RDF. The facility burns the RDF to produce energy, which in turn is used by the facility. RDF is widely used for electric power generation and as supplementary fuel for heat energy supply to various facilities.

Aerated filter process (Biopac)

Advanced sewage and other waste treatment methods are needed to combat the pollution of rivers and lakes. By using microorganisms attached to granular media, Biopac removes suspended solids and soluble organic substances.

UF-membrane separator

This device processes night soil using a UF membrane to completely separate solids from liquid. High-density organic waste is kept inside the tank, where it is treated to remove nitrogen compounds causing eutrophication. By eliminating nitrogen and phosphorous in an efficient manner, this device contributes greatly to the creation of ideal environmental systems.

Upflow anaerobic sludge blanket process (Methapellet)

Using an anaerobic treatment method, Methapellet removes organic pollutants from wastewater, thus purifying it. Furthermore, methane gas emanating from the process can be recycled into an energy source.

Aquarium equipment

Ebara added marine biology-related know-how to its wealth of experience and technological expertise in water treatment to design and develop various devices used in aquariums and marine product cultivation farms throughout the country. These devices are highly regarded for their cost- and energy-saving features and excellent performance.

Two-stage rotating smelting furnace (Meltox System)

This system fully utilizes the latent heat contained in sewage sludge and also enables waste to be transformed into an energy source. Dried sludge is burned and vitrified while being rotated to produce a

molten slag that can be recycled for use in building materials and other items.

Electron-beam flue-gas treatment system

By injecting ammonia into waste gas and then applying an electron-beam treatment, this innovative system effectively removes NO_x and SO_x—the causes of acid rain. Substances thus removed can be used as ammonium sulphate and ammonium nitrate fertilizers.

Ebara's chemical lineup

As manufacturing plants become increasingly advanced and sophisticated, they use more and more chemicals in their plant operations. As a specialist manufacturer of water treatment and environmental facilities, Ebara combines chemical-related know-how with the latest production technologies to create a diverse line of chemicals, which are applied to such operations as water supply, sewage and night-soil treatments, and chemicals for cooling water and boilers.

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Enerkem

ENERKEM believes there is an opportunity for flexible energy companies backed by solid science and strong business skills to emerge in the market place as independent producers of alternative energy.

ENERKEM TECHNOLOGIES INC. is an advanced technology and knowledge-based corporation in the alternative energy sector. ENERKEM 's positioning is to become an independent producer of alternative energy based on its own portfolio of technologies (Syngas-Power and Biofuels).

ENERKEM 's short-to-mid term strategy is to develop and invest through equity position in decentralized Syngas-fueled Power plants. A portfolio of projects totaling 150 MWe is being implemented. Such projects use our proprietary technologies.

A world-premiere plant that uses ENERKEM 's Syngas technology was erected in late 2001 through a partnership in Europe. Located in Spain, this plant generates 7 MW of electricity (80 MMBTU/h of Syngas) for the local grid using up to 25,000 tones of spent, non-recyclable plastics per year. The Syngas is conditioned for use in internal gas combustion engines supplied by Jenbacher AG. Emissions meet the most stringent European directives. This plant enjoys green electricity premiums over the market price given that it falls within the country's recent policy set to foster renewable energies.

Joint venture approach

ENERKEM is interested in partnering with local investment groups and/or energy companies to penetrate various markets. The preferred approach is to structure joint ventures with local partners. Such joint ventures are responsible for conducting investments in Syngas-fueled Power plants and for securing feedstock supply and power purchase agreements. This model is currently being followed in Spain. Other geographical joint ventures are in progress in North America and Europe. Access to markets enjoying green electricity premiums is of great interest but not necessarily a priority.

R&D initiative

From a long-term perspective, ENERKEM is pursuing the development of various technologies aiming at: (1) enhancing value from Syngas and thus maintaining the competitive edge; (2) fractionation of residual biomass and selective upgrading of specific fractions into oxygenated biofuels. More precisely, ENERKEM 's R&D focus is on reactors and catalysts for the conversion of Syngas to alcohol fuels (ethanol, methanol and higher alcohols) via one-pass catalytic conversion, on catalytic reforming of Syngas into hydrogen, and linking Syngas with fuel cells. The R&D efforts on fractionation are to scale-up at the pilot/demo level aqueous/steam biomass fractionation technologies for the production of ethanol and other oxygenated biofuels. The Canadian and Quebec Governments, through appropriate agencies, financially support the research efforts of ENERKEM

BIOSYN™ technology

Syngas is the result of the partial-oxidation of organic feedstocks; this process is commonly referred to as the process of "Gasification".

Gasification is a thermal upgrading process, in which the organic matter is converted into a gas ("Syngas") by partial oxidation of the carbon with air, pure oxygen, oxygen-enriched air and/or steam. Gasification is designed to maximize the conversion of organic feedstocks to CO and H₂ which are the basic molecules found in Syngas. The secondary reactions take place in a reducing environment that prevents the formation of oxidized species such as SO₂ and NO_x. Free chlorine is never formed. Advanced gas conditioning technology and catalysts enhance the suitability of Syngas for either direct electricity production through internal gas combustion engines or gas turbines, or for further conversion into hydrogen and/or alcohol fuels

Dioxins and furans are not present in Syngas since the lack of oxygen in the secondary reactions (they are carried out in a reducing environment) precludes their de-novo formation.

The BIOSYN™ partial-oxidation process and advanced gas conditioning technology

The BIOSYN™ process, developed by ENERKEM TECHNOLOGIES INC. , is the result of efforts started in the early 80's that led to the development of a core technology which couples fluid bed reactors with advanced gas conditioning strategies to provide a clean Syngas.

The technology can be applied to readily available organic residues from diversified sources, such as sorted municipal solid waste (RDF), urban wood, agricultural residues, forest thinnings, sludges, as well as wastes from various industries, such as sawdust and pulp mill residues, spent oils, plastic-rich residues and rubber-containing wastes.

How it works

The waste material has to be pretreated in order to obtain a process feedstock as homogeneous as possible with a particle size having around 5 cm as typical dimension. The process feedstock may need to be dried since its humidity at the reactor entrance should not exceed 20 wt%. The bulk density of the process feedstock needs to be typically higher than 0.2 kg/l for uniform feeding to the reactor.

The feedstock prepared as described above is directed towards the gasification reactor via an appropriately designed feeding system. A water-cooled transfer screw injects the material into the fluid bed section where silica or alumina act as fluidizing media. Injection of the needed amounts of air or O₂-enriched air through a distributor grid located at the bottom of the fluid bed induces the fluidization patterns which result in high mixing and heat transfer rates responsible for the reactions taking place during gasification. The quantity of air or O₂-enriched air required depends on the organic composition of the residues; it is usually around 30% of the stoichiometric amount required for combustion of the organics. The temperature in the reactor can be varied between 700i and 900iC depending upon the physico-chemical characteristics of the feedstock and the desired Syngas composition. At these reactor-temperatures, gasification takes place in a few seconds.

The composition of the Syngas obtained varies according to the gasification agent (air or O₂-enriched air). The Syngas is composed of nitrogen (55% when air is the fluidizing agent; around 30% with O₂-enriched air having 40% O₂), carbon dioxide (from 16% to 30% by volume), carbon monoxide (from 12% to 30% by volume) and hydrogen (from 2% to 10% by volume). It also contains smaller percentages of light hydrocarbons, solid particulates and condensable vapors known as tar. After separation of the solid particulates, the tar and the light hydrocarbons in the gas can be converted into simple organic molecules (H₂ and CO).

Performances

The energy efficiency (HHV of the Syngas relative to the heating value of the feedstock) of the gasification process using wet scrubbing is typically 70 - 72%. The variables determining the energy performance of the BIOSYN™ process are the composition of the feedstock, its humidity and its inorganic matter content. Hot gas conditioning will increase the efficiency by approximately 5%. When using the Syngas for the generation of electricity, the efficiency of the energy conversion device has to be taken into consideration. Here is when gasification is superior to combustion. The latter requires to use steam turbines which have lower efficiencies than gas turbines, internal combustion engines or fuel cells, the three energy conversion devices that can accept Syngas as fuel. Hence via gasification, wet scrubbing and internal combustion engines we can reach 30% electrical efficiency from a variety of feedstocks whereas combustion coupled with steam turbine reaches about 20%.

When using air as the fluidizing agent the process generates around 2 Nm³ of Syngas per kg of biomass in the feedstock (dry basis) and as high as 4 Nm³ per kg of plastics (i.e. polyethylene). The upper mean calorific value of the gas (HHV) is of the order of 6 MJ/Nm³ (160 BTU/SCF). However, when using O₂-enriched air (40% O₂) a calorific value of 12 MJ/Nm³ (320 BTU/SCF) can be obtained, with a 50% reduction in the volume of gas produced (1 Nm³ per kg of biomass in the feedstock and up to 2 Nm³ per kg of plastics).

A cyclone(s) system removes 85-95% of solid particulates from the Syngas. After the cyclone(s) the Syngas is still hot (>600 iC) and the BIOSYN™ process offers two options for subsequent conditioning:

- A three-stage scrubbing system leads to a “clean cold Syngas”;
- A proprietary hot filtration/catalytic conversion system provides a “clean hot Syngas” compatible with gas turbines applications.

Both gas-conditioning strategies ensure that the Syngas is clean and can be combusted meeting the highest environmental standards.

The Syngas produced via the BIOSYN™ process plus the related gas-conditioning technology is a clean gas. Emissions from combusting the Syngas are limited to CO₂, H₂O, as well as levels of NO_x and particulates never superior to those from natural gas combustion. CO emissions are function of the combustion chamber used. They can be maintained to below regulatory levels by proper design of the chamber and burners. No dioxins, furans, sulfur-or chlorine-containing compounds are generated.

The solid residues from the BIOSYN™ process, i.e. the cyclone-collected small particulates and any solids withdrawn from the reactor, are accompanied by small amounts of carbonaceous deposits (known as char). The latter, i.e. the char, does not exceed 2 wt% of the initial dry feedstock for most practical applications. If wet scrubbing is used as the gas conditioning option, a sludge is also generated. It can be added to the other solid residues or it can be treated separately. Volume of the total solid residues depends on the amount of inorganic materials present in the initial feedstock. For feedstocks such as sorted municipal solid waste, biomass or plastic-rich streams that are composed of inorganic materials at levels usually less than 7% per weight, the volume of total solid residue from gasification is inferior to 8% of that present in the initial feedstock. If need be, the gasification solid residues can be stabilized in aggregates and thus inertized.

The only liquid effluent from the process is the purge water derived from the treatment of the scrubbing water, if wet scrubbing is used as the gas conditioning option. The purge water can meet the stringiest environmental standards since the BIOSYN™ process can incorporate (with the scrubbing option) proprietary wet oxidation and/or adsorption technologies. The latter can use the char-containing residue generated by the process.

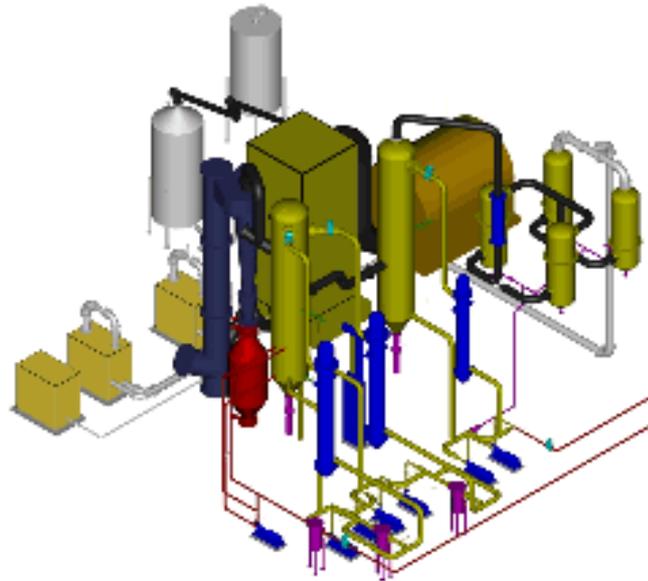
The tar, separated via decanting/skimming of the scrubbing water, is recycled back to the gasifier together with the organics adsorbed by the char-containing residue used in the wastewater adsorption treatment. The overall carbon conversion is thus enhanced and the energy efficiency can consistently reach values above 75%.

The BIOSYN™ process is fuel flexible and specifically designed for the conversion of wastes. The technology is modular and can be functional at low (1 tonne/h) or large (10 tonnes/h) capacities with high conversion efficiency. It incorporates an oxygen-enrichment unit, advanced gas conditioning technology and, if need be, a water treatment facility. ENERKEM is also backed by recent industrial scale-up experience in Europe (7 MWe), by the Biosyn experience (10 tonnes/h biomass gasification plant in the 1980s) as well as extensive piloting and R&D. ENERKEM provides performance guarantees: a minimum energy efficiency of 70% as well as the gas composition of its Syngas for each specific feedstock. 5 patents protect the BIOSYN™ technology and associated gas conditioning processes.

Investment costs for the BIOSYN™ partial-oxidation process with proprietary gas conditioning technology and power island vary between \$US 1,500/KWe and \$US 2,000/KWe depending on the type of feedstock and the size of a plant. Operating costs are between \$US 0.02/KWh and \$US 0.045/KWh and are also a function of the type of feedstock and the size of a plant.

Ensyn

Ensyn's patented core technology, Rapid Thermal Processing or RTP^a, is an extremely fast thermal conversion process characterized by moderate temperatures and atmospheric pressure. In the RTP^a system, carbon-based materials, including either wood (biomass) or petroleum hydrocarbons, are quickly transformed to more valuable chemical and fuel products by the rapid addition of heat. The process is simple, achieves high capacities utilizing a compact design and has a relatively low capital cost.



Renewable Energy from Biomass

When biomass and petroleum are processed using a combination of rapid heat addition and very short processing times (typically less than a few seconds), high yields of value-added products are obtained. In commercial RTP^a operations, processing times are usually less than one second and product yields are significantly higher than with any other available industrial technology.

Ensyn believes that RTP^a is the only bio-oil technology in the world that is operating commercially, and that RTP^a is the only technology capable of producing large quantities of bio-fuel from industrial operations.

In support of the core RTP^a process, Ensyn owns a significant array of additional intellectual property (I.P.). Such I.P. covers unique RTP^a products, as well as the extraction, recovery and use of certain chemicals and upgraded RTP^a products.

The 70 ton per day RTP^a facility in Wisconsin is owned by Red Arrow Products Company, Inc. and operated by Ensyn. This facility produces a number of food, natural chemical, and liquid "bio-fuel" products and operates with an availability exceeding 95%.

Ensyn's current bio-oil production capacity is 5 million gallons annually. The bio-oil is further processed to produce final chemical, fuel and carbon products that consistently meet stringent customer specifications.



Entech

Engineers and manufacturers of Pyrolytic Gasification System's and Renewable Energy System's for solid, liquid, sludge and gaseous type biomass and waste destruction or conversion into energy using third generation combustion technology known as pyrolytic gasification. The process is environmentally superior and more efficient than many other forms of biomass and waste destruction or recycling.

Products

- Pyrolytic Gasification Systems (Biomass and waste gasification)
- Renewable Energy Systems (Biomass and waste gasification and conversion to energy)
- Product Application
- Solid, liquid, sludge and gaseous type biomass and waste, including:
 - By-products of agricultural crops
 - By-products of forestry
 - By-products of food processing
 - Organic component of municipal waste
 - Medical
 - Industrial
 - Quarantine
 - Hazardous

Capacities

Biomass / Waste Input: Individual-unit system capacities range from 0.25 to ~125 T/day, with multiple-unit system capacities up to ~500 T/day. Energy Output: Up to ~95MWth energy, or up to ~20.5MWe power output.

Pyrolytic Gasification System Process

ENTECH's unique and proven process is based upon third generation combustion technology known as pyrolytic gasification.

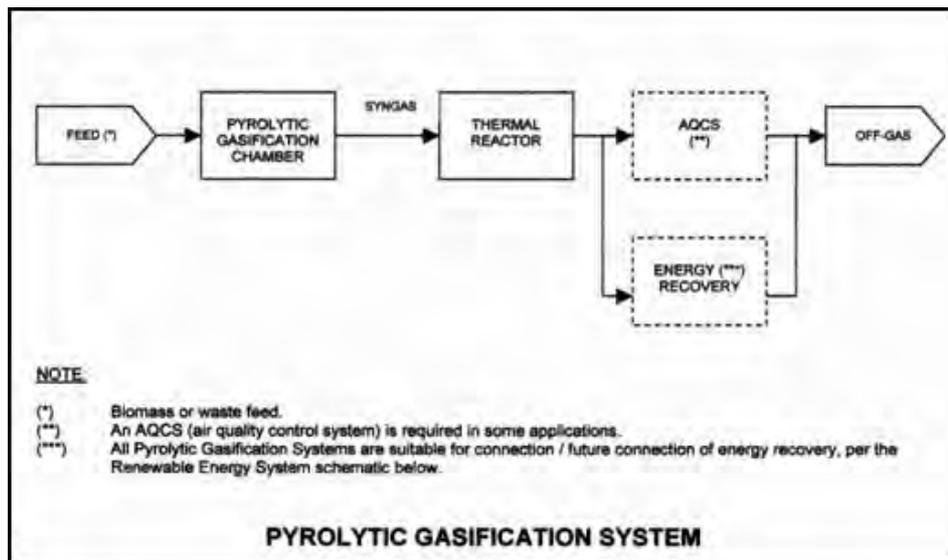
A Pyrolytic Gasification Chamber is used to heat and convert biomass or waste into a combustible gas mixture referred to as Syngas, which primarily consists of hydrogen, carbon monoxide, carbon dioxide and hydrocarbons. Non-combustibles remaining after gasification (e.g. silica, calcium and metals) are extracted from the Pyrolytic Gasification Chamber and can be saleable as fertilizer or disposed of at landfill.

The Syngas resulting from pyrolytic gasification has similar properties to methane gas, including the ability to burn cleanly, thus can be fired like a conventional gas fuel. In most applications the syngas is fired in ENTECH's unique Thermal Reactor that provides for thermal oxidization at high temperature, which maximizes combustion efficiency and recoverable energy.

The combustion of Syngas results in a clean and high temperature gas that is very low in NO_x, CO, particulates and volatile organic compounds (VOC's) and is therefore environmentally superior to firing of many conventional fuels such as coal and fuel oil. The absence of smoke, odour and undesirable gases demonstrates that emission control is an integral feature of the Gasification-Syngas combustion process. System emissions are comparable to firing of natural gas and emissions comply with stringent legislation.

The ENTECH Pyrolytic gasification System is the most advanced, commercially proven gasification system currently available for conversion of biomass and waste to a clean gas. The operating processes ensure emission control occurs within the process rather than an additional cost after combustion. The ENTECH

Pyrolytic Gasification System is environmentally superior and more efficient than forms of combustion.

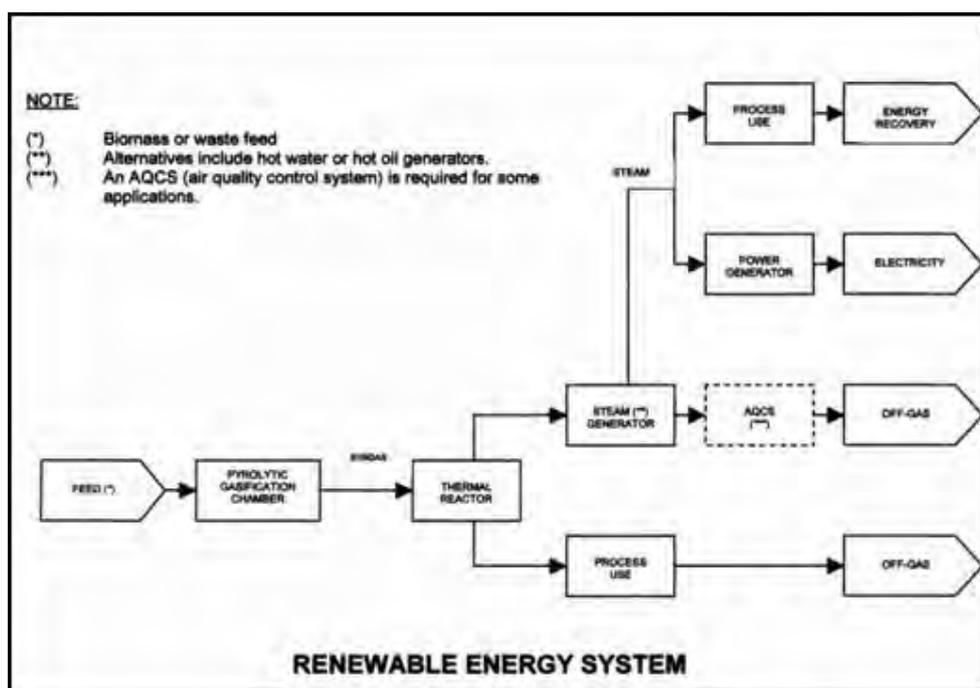


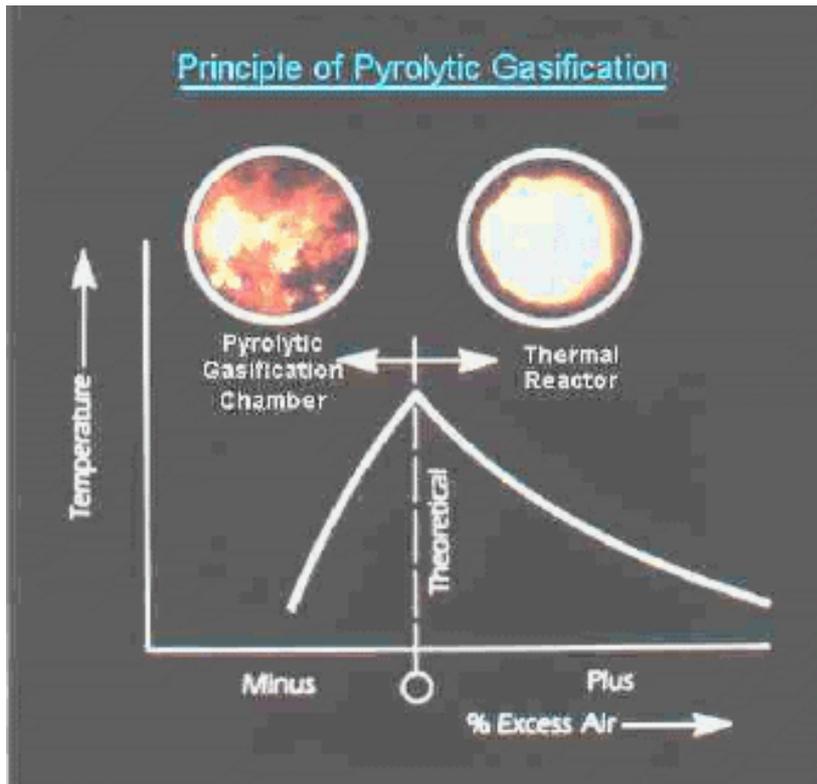
Renewable Energy System Process

ENTECH’s unique and proven process is based upon third generation combustion technology know as pyrolytic gasification.

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ENTECH Renewable Energy System's downstream process alternatives include:

- Energy utilization by a steam (or hot water) generator for production of steam for process use or cogeneration of electricity.
- Energy utilization by direct or indirect heating for process use.

The ENTECH Renewable Energy System is the most advanced, commercially proven gasification system currently available for conversion of biomass and waste to clean energy. The operating processes ensure emission control occurs within the process rather than an additional cost after combustion. The ENTECH Renewable System is environmentally superior and more efficient than many other forms of recycling.

Process Benefits

Both ENTECH systems described above simultaneously address three key environmental concerns facing mankind, namely biomass or waste disposal, atmospheric emissions and disease control. The ENTECH Renewable Energy System also addresses the key environmental concern of fossil fuel consumption.

Avoids dependence upon landfill and the subsequent environmental damage from landfill methane gas, plus landfill leachate. Landfill methane gas has been identified as a greenhouse gas and has an effect on the atmosphere 24 times greater than CO₂ from combustion.

Renewable Energy Systems

Same benefits as the Pyrolytic Gasification System.

Avoids dependence upon fossil fuels. Each 1 tonne of dry biomass of waste converted into renewable

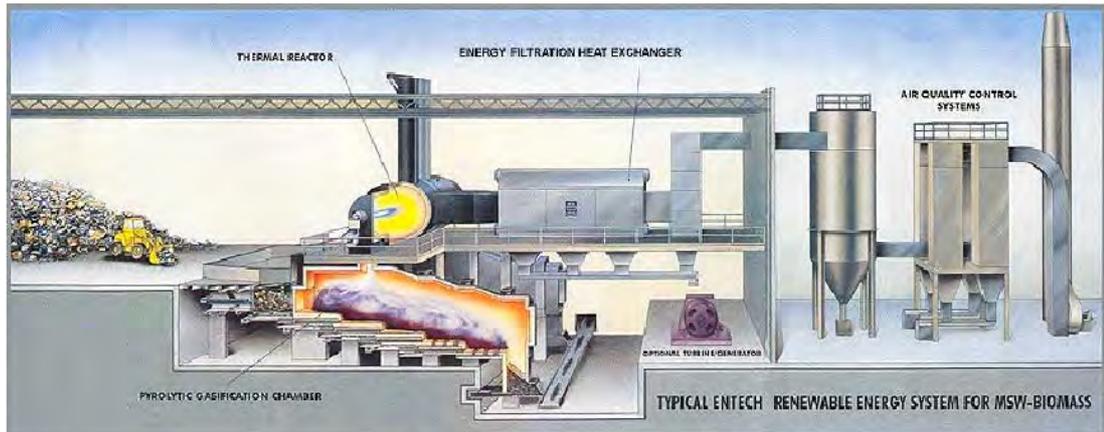
energy results in reduction of the use of between 200kg to 400kg of virgin fossil fuel.

Avoids the release of over 6.4 tonnes of CO₂ equivalent greenhouse gas for every tonne of dry biomass or waste processed rather than landfilled.

Off-gas is significantly cleaner than combustion of some other convention fuels such as coal and fuel oil.

Significant economical benefit from eliminating or reducing fossil fuel consumption.

Added economical benefit is available from carbon credits.

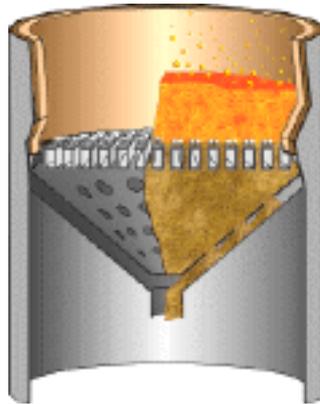


EPI

EPI is a world leader in the development and implementation of proprietary and patented technologies used to convert biomass and other waste fuels into usable forms of energy. Since 1973, EPI has pioneered and perfected fluidized bed and related technologies for utility, industrial and commercial uses. Although our primary focus remains our world renowned fluidized bed technologies, our vast experience has led to a stable of superior auxiliary and related proprietary technologies.

EPI's equipment and systems provide superior on-stream availability, lower operating/maintenance costs and more value for our customers. Our advanced research and development programs insure EPI remains a leader in an array of related technologies. With a world recognized fluidized bed combustion and gasification pilot plant, EPI has performed testing on over 200 varieties of biomass fuels and waste products.

EPI's state-of-the-art technologies include: fluidized bed combustion systems, fluidized bed gasification systems, fluidized bed boilers, fluidized bed retrofits of existing coal and oil fired facilities, heat transfer equipment, thermal fluid heating and distribution systems, gas clean-up systems, selective non-catalytic reduction (SNCR) systems for NO_x reduction, SO_x reduction systems, fuel storage and handling systems, fuel metering and conveyance systems, preinsulated flue gas ducting, gas turbine systems (for landfill, petroleum waste gases, natural gas, etc), and many more.



Fluidised bed combustion systems use a heated bed of sand-like material suspended (fluidised) within a rising column of air to burn many types and classes of fuel. This technique results in a vast improvement in combustion efficiency of high moisture content fuels, and is adaptable to a variety of “waste type” fuels. The scrubbing action of the bed material on the fuel particle enhances the combustion process by stripping away the carbon dioxide and char layers that normally form around the fuel particle. This allows oxygen to reach the combustible material much more readily and increases the rate and efficiency of the combustion process.

Foster Wheeler

Co-firing Biomass in Coal-Fired Boilers

Co-firing biomass in coal fired boilers has progressed from engineering concepts and parametric testing to demonstrations and commercialization. The most promising near term method of increasing the use of biofuels in electricity generation, biomass co-firing is inherently a low capital-cost application that permits the introduction of such fuels as wood waste, switchgrass, and other forestry and agricultural residues into high efficiency boilers.

Co-firing (the simultaneous combustion of a supplementary fuel with a base fuel) has been a traditional method for introducing new or different fossil fuels and opportunity fuels, such as petroleum coke added to a coal base fuel in a boiler.

“Co-firing biomass (i.e. wood waste) with coal is proving to be the lowest cost method for generating ‘green power’ in utility plant demonstrations,” said David Tillman, who manages the FWDC-EPRI contract and has authored several papers on the subject for the Global New Products Group of Foster Wheeler Development Corporation. “It also reduces the emissions of fossil-based CO₂. From a community service point-of-view, co-firing can provide an end use for low value or negative value products. These might include sawdust or other fine wood wastes produced by furniture mills, sawmills, and related industries in a generating plant’s locale.”

Non-woody biofuels, such as agribusiness wastes, also can be co-fired given the proper fuel preparation and feed systems. Although there are several ways to engineer the co-firing of biomass, and the best approach is usually very site specific. For three TVA plants, Allen, Kingston and Colbert Fossil Plants-and for the Seward (see Figure 1) and Shawville Generating Stations of GPU Genco plus the Michigan City and Bailly Generating Stations of NIPSCO-the following methods were evaluated:

Mixing the biomass with coal in the fuel yard, and transporting the blend to the boiler through the normal coal system (crushers and bunkers, and pulverizers if PC boilers were used)

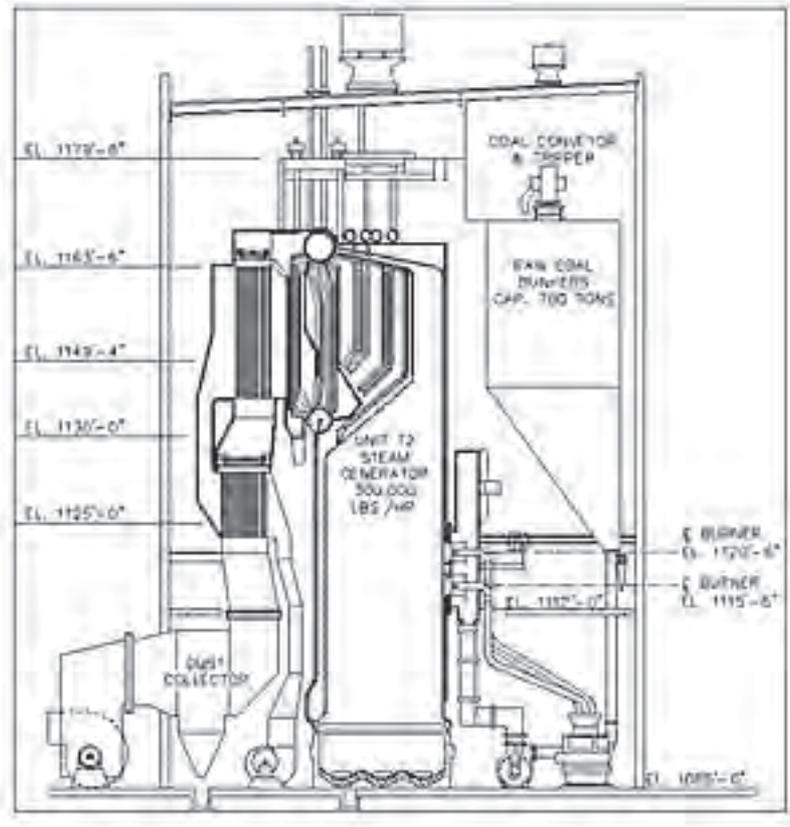
Preparing the biofuel separately from coal, and pneumatically injecting it into the boiler without impacting the fossil fuel delivery system

Gasifying the biofuel and firing the gas either in a coal fired boiler as supplementary fuel or in a combined cycle power plant, introducing the biomass gas through a duct burner downstream of the combustion turbine and upstream of the heat recovery steam generator

The Allen plant consists of three cyclone boilers; Kingston has nine tangentially fired boilers; and Colbert has five wall fired boilers. Extensive parametric testing was conducted at each location. The Allen facility co-fired up to 20 percent wood waste, whereas the Kingston and Colbert plants co-fired only up to 5 percent wood waste. Co-firing was subsequently commercialized at Colbert.

In all cases, the wood waste was sized to < 1 / 4 “ and blended with coal for transport to the fuel bunkers and the conventional coal delivery systems. GPU Genco also tested this concept of blending wood waste and coal for transport to the fuel bunkers, pulverisers, and coal burners. Blending biomass with coal in the fuel yard is the least expensive approach to co-firing. At the same time, however, there is an upper limit to the quantities or concentrations of bio-mass employed. Generally (5 percent biomass on a weight basis 2 percent biomass, heat content) can be injected without impacting the sieve analysis of the pulveriser product. Further, if the boiler is pulveriser limited, co-firing using this technique can cause de-rating of the unit as a consequence of lower bulk density (lb/ft³), lower calorific content (Btu/lb), and increased moisture.

The Greenidge Station of New York State Electric and Gas (NYSEG) implemented a program to prepare wood waste separately from coal, and to blow it into a tangentially fired boiler. A similar program is being



implemented at the Seward Generating Station of GPU Genco.

“Green Power”

“Separately preparing and firing the biomass with coal, without impacting the delivery of fossil fuel to the boiler, has several advantages,” explains Tillman. “For example, the demonstration at Seward Generating has shown lowered NOx emissions.” Among the study results are:

- Reducing NOx emissions by up to 15 percent
- Increasing boiler capacity when the unit is firing coal, and is consequently de-rated

Reducing fossil CO₂ emissions

GPU Genco has now completed two parametric tests of biofuel cofiring at the Seward Generating Station, and will demonstrate the process over the next two years. (Figure 1 on page 21 depicts Boiler #12, one of Seward’s three boilers.) Based on the success to date of both the parametric test program and the construction of the biomass handling facility, GPU Genco is expanding its efforts to include cofiring in a second boiler. This program is being funded by the Electric Power Research Institute, the U.S. Department of Energy at the Office of Energy Efficiency and Renewable Energy (EERE) and Federal Energy Technology Center (FETC).

Northern Indiana Public Service Company (NIPSCO), working with the Electric Power Research Institute (EPRI) and the U.S. Department of Energy (EERE and FETC), initiated cofiring tests using urban wood waste and firing it with a blend of Western bituminous and Powder River Basin coals. This program was implemented at the Michigan City Generating Station, a 469 MW (net) supercritical cyclone boiler. This program was sufficiently successful that NIPSCO has implemented a longer demonstration of biomass cofiring at its Bailly Generating Station 7 Boiler. This 160 MW (net) unit will cofire blends of biomass and petroleum coke with Illinois basin coal and Shoshone coal. Bailly Generating Station is equipped with a scrubber. This program is demonstrating that careful selection and blending of opportunity fuels can help both the efficiency and environmental aspects of power generation.

Both TVA and NIPSCO are in the process of developing second generation cofiring projects based upon biomass gasification. TVA is developing a project to gasify a wide variety of biofuels, with the product gas being ducted hot and unconditioned to a boiler. NIPSCO is in the initial stages of developing a gasification project where the biomass gasifier supports a combined-cycle combustion turbine (CCCT) project. The producer gas from the biomass gasifier would be introduced downstream of the combustion turbine, and would be fired in a duct burner supporting additional heat recovery steam generator (HRSG) capacity.

EPRI and the associated utility jointly funded all of these programs. As of 1997, the United States Department of Energy (USDOE) Federal Energy Technology Center entered into a cooperative agreement with EPRI to supply additional funding. In 1998, the USDOE Energy Efficiency and Renewable Energy biomass program supported the program with an infusion of funds as well. These partners in cofiring development permitted the projects to move to the demonstration and commercialization phase from the study and parametric phase.

TECHNICAL RESULTS OF THE EPRI/USDOE PROGRAM

EPRI/USDOE program has shown the following overall results:

- Cofiring a blend of biofuel and coal through the traditional coal transport and delivery system can significantly impact cyclone feeder speeds, pulverizer mill amps, and pulverizer capacity depending upon the percentage of biomass fired and the condition of that biomass.
- Cofiring can increase boiler capacity if it is injected separately into the unit and if pulverizer capacity is the limiting factor in overall unit capacity. Gasification would have the same impact as separate injection cofiring. Alternatively, cofiring can have a negative impact on boiler capacity if the biofuel is introduced through the coal transport pathway of crushers and pulverizers.
- Cofiring biofuels with coal can impact boiler efficiency. The impacts measured to date have generally been negative, however, the NIPSCO program is demonstrating that combinations of opportunity fuels can improve boiler efficiency. There are many other factors of significance in determining boiler efficiency, and these factors may be more significant than the fuel blend.
- Cofiring biofuels with coal can be used to reduce NO_x emissions as shown in Fig. 2. The mechanism for NO_x reduction appears to be associated with fuel volatility, with fuel nitrogen content and temperature impacts being of secondary importance.
- Cofiring biofuels reduces emissions of fossil CO₂, considered a target greenhouse gas in the voluntary utility programs associated with the Global Climate Challenge program.

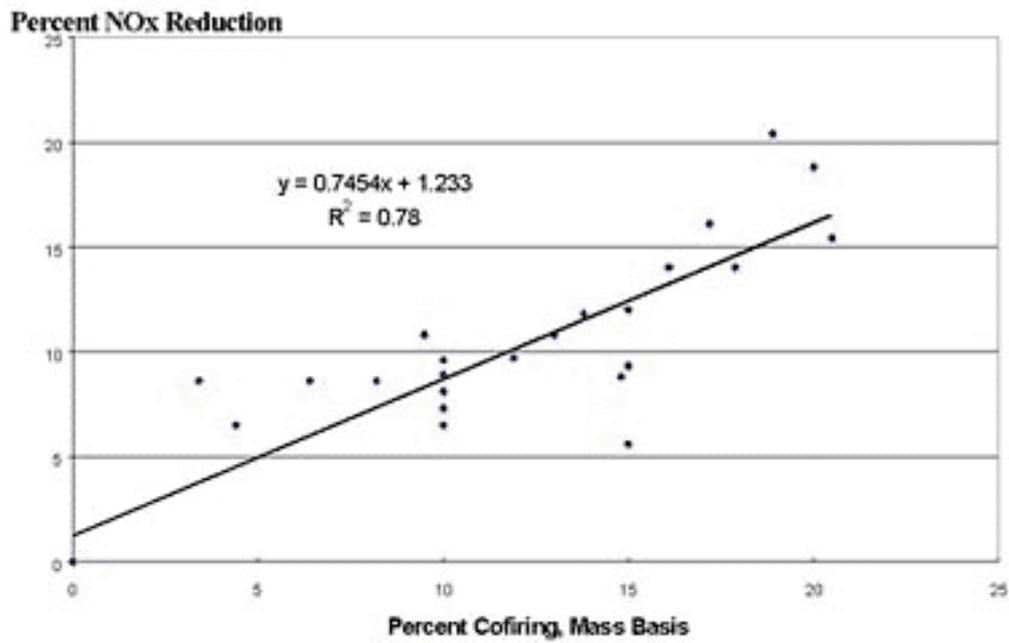
These technical results, along with site-specific findings, demonstrate that there are numerous benefits that can be achieved depending upon the type of boiler and the type of cofiring system.

NEXT STEPS

Cofiring has been developed from an engineering concept, with a few niche applications, to a technology in the early stages of commercialization. Commercialization will expand as the efficiency and cost-effectiveness of biomass cofiring are demonstrated by a growing number of generating plants. These demonstrations are progressing at several facilities, and more are planned—each addressing specific issues such as fuel selection, fuel procurement, fuel handling and processing, combustion or gasification, cash management, and institutional concerns. As these studies are completed, they will further define the overall technical, economic, and environmental benefits and costs associated with cofiring biofuels in coal-fired boilers which proliferate in the U.S. utility industry.

Cofiring must now move aggressively into the gasification arena (CCCT technology) if biomass is to be cofired with natural gas in such applications as combined-cycle combustion turbines and as an addition to certain boiler fuels. Such penetration into new markets, as well as cofiring in coal-fired boilers using direct combustion techniques, provides the most effective near-term approach for utilities to use biofuels in an era of deregulation.

**Fig. 2. Percent Reduction in NO_x by Cofiring in Five Tests:
'96 and '97, Allen '94 and '96, Michigan**



This article was based on a series of technical papers authored by David Tillman, Global New Products Group, Foster Wheeler Development Corporation.

Foster Wheeler Review

Spring 1999, Volume 1, No. 1

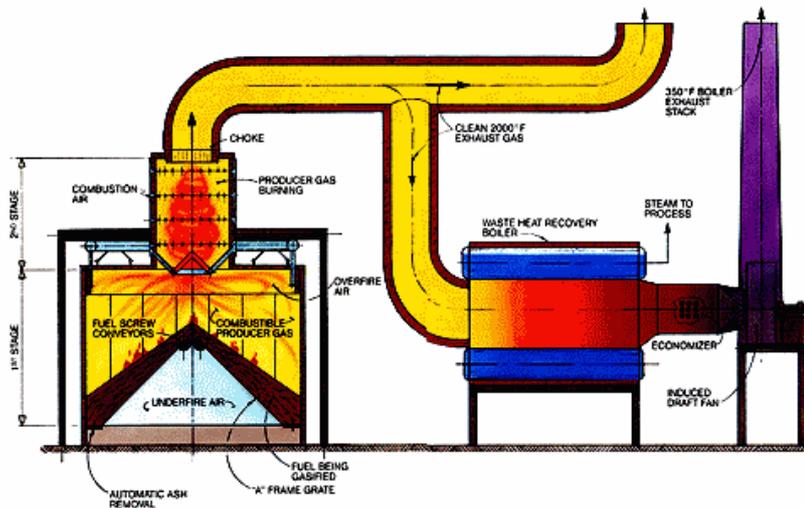
© 1999 by Foster Wheeler Corporation

Heuristic Engineering Inc.

Waste Disposal with Energy Recovery:

- Disposes of almost any biomass residue in an environmentally friendly manner.
- Meets the following limits on wood residue straight out of its 2,000iF (1100iC) stack: 0.05 gr/dscf (120 mg/Nm³) particulate, 1.5 ppm vCO, 15 ppm vNO x@ 12% CO₂ by vol.
- Recover energy from its clean exhaust to displace your power and/or process heat .
- Displace your fossil fuels and earn post Kyoto CO₂ "greenhouse gas" credits.
- Displace your electricity and market your surplus "green" power at a premium.

HEURISTIC ENVIROCYCLER WASTE DISPOSAL WITH ENERGY RECOVERY



OPERATING PRINCIPLE

- First stage: Gentle, updraft gasification generates combustible producer gas at controlled temperatures.
- Second stage: Vigorous, cyclonic combustion of first stage producer gas, with minimum excess air produces high temperature, clean products of combustion.

SPECIAL FEATURES

- Feed: Robust, dual screw conveyors or dual hydraulic rams.
- Grate: Large, stainless steel, low heat-release rate, A-frame grate.
- Ash Removal: Reciprocating, wedge-type unloaders on either side of grate bottom (easily removed for servicing).

Hitachi

Some 70-80% of dioxins—which have drawn attention recently in the context of environmental problems—are discharged from refuse incinerators. Hitachi has developed a “Kiln-type Gasification/Melting system—a next-generation refuse incinerating plant that dramatically reduces dioxin discharge—in efforts to resolve this problem in newly installed incinerators. In a further effort to improve even existing plants, it now offers the world’s first commercially available “Dioxin Precursor Monitor,” which provides, online and in real time, a new index aimed at reducing dioxins.

The Kiln-type Gasification / Melting System combines a gasification furnace, which is based on technologies developed by THIDE Environment Co. in France, and a rotary melting furnace based on Hitachi’s original coal gasification technologies. Refuse is steamed under oxygen-free, low temperature conditions in a gasification furnace and decomposed, so that metals and other valuable resources can be recovered in a form that allows reuse of these materials. Then, the remaining materials are subjected to high-temperature combustion (1,300–1,400iC) in a melting furnace, thus dramatically reducing dioxins. Ash containing dioxins are melted into slag, transformed into harmless waste, and recycled, for example, as materials for use in making roads. This system—which produces about 30% less exhaust gas than existing incinerators, and through exhaust gas processing reduces dioxin concentrations to within tenth parts of regulation levels—is extremely effective in cutting dioxins released into the atmosphere, and in modifying ash into a harmless, reusable form.

The gasification furnace and the melting furnace can be operated separately, making it possible to implement an independent carbonisation system centred on the gasification furnace segment. The carbon fuels that can be derived from this carbonisation system are easy to transport and can also be stored, so can be carried from individual municipalities to a shared melting furnace for wide-area processing. The pyrolytic gas derived from gasification of refuse is used as a heating source for gasification furnaces, enabling reduced running costs as well as reductions in the volume of CO₂ generated when using other outside energy sources. The gasification furnace also offers space-saving effects; for example, the dryer for removing moisture from waste materials has been separated from the rotary kiln, reducing the total length of the furnace by around 50% in comparison to traditional configurations.

In order to develop technologies to reduce the dioxins discharged from refuse incinerating plants, it is essential to measure the discharged dioxins quickly and continuously. Because the volumes of dioxins contained in exhaust gas, are extremely minute and difficult to measure, however, in the past it took several weeks before measurement results could be obtained. To resolve this problem, we now offer the “CP-2000” Dioxin Precursor Monitor, which focuses on chlorophenol— a dioxin precursor demonstrating a strong correlation with dioxin concentrations in exhaust gases—and because it executes continuous measurements it allows rapid measurement results within one minute of the actual condition being measured.

Hitachi Kiln-type Waste Thermolysis System

Hitachi, Ltd. and Babcock-Hitachi K.K. today announced the start of construction of a pilot plant for testing the Hitachi kiln-type waste thermolysis system. The pilot plant is being constructed at the Hitachinaka City Clean Center in Ibaraki Prefecture with the support of Hitachinaka City.

The thermolysis process is superior to conventional waste incineration methods in a number of ways, including its ability to reduce total CO₂ by efficient utilization of waste energy, to lower dioxin generation, and to melt and solidify the residual ash. Such capabilities enable the system to overcome many of drawbacks of conventional waste incineration methods and make it a primary candidate for use in next-generation waste processing.

Plans call for the pilot thermolysis plant to be completed in 1998 and tested in 1999. Orders will be actively sought following Ministry of Health and Welfare approval in 2000.

In response to the global need for stronger environmental protection, thirty companies of the Hitachi Group have moved to combine their technology resources under a wide-ranging environmental program called "Echo 2000." The thermolysis system, viewed as key element in this program, is being jointly developed by Hitachi and Babcock-Hitachi.

The development strategy is to combine Babcock-Hitachi's boiler and exhaust gas treatment technologies with Hitachi's coal gasification and slag melting technologies, while applying the know-how accrued by Babcock Hitachi over many years of business in the refuse incinerator business.

The kiln-type thermolyzer will use basic technology that was developed by THIDE ENVIRONNEMENT SA of France and has been tested for more than 4,000 hours at its pilot plant. Hitachi, Ltd. obtained rights to the technology under a licensing agreement concluded with THIDE and later granted a sublicense to Hitachi-Babcock.

In the Thide system, the gas generated by baking refuse in the thermolyzer is used as fuel for heating the thermolyzer and superheating steam for power generation.

The carbonaceous residue, called char, is processed for metal recovery and then fed to the melting furnace.

The Hitachi kiln-type thermolysis system is designed to:

- Reduce the thermolyzer to about one-half the conventional length and stabilize operation, by incorporating an independent drier.
- Enable the thermolyzer to generate combustible gas that contains almost no chlorine and is therefore noncorrosive, can be burned to heat the thermolyzer, and can be used to generate high-temperature, high-pressure (500 C degrees, 100 atmospheres) superheated steam for efficient power generation.
- Permit recovery and recycling of unoxidized metals from the thermolyzer.
- Utilize as a vertical cyclone melting furnace that achieves a high slagging rate of around 90%, minimizes carry-overs, reduces dioxin generation, and uses a low-temperature activated catalyst to hold the dioxin content of the exhaust gas to under 0.01ng-TEQ/Nm³.

THIDE ENVIRONNEMENT SA in Profile

Location: Near Paris

Established: 1994 (previously the environment division of SAGED SA)

CEO: Rene Willemin

Businesses: Construction of waste treatment plants using the kiln-type thermolysis system. Has completed testing at a pilot plant and is expanding its business mainly in the European market.

JND Energy

The JND Energy from Waste Plant (EfW) uses a process known as pyrolysis to produce a high CV combustible gas from which electric power can be generated.

Pyrolysis is the thermal decomposition of an organic material in the absence of oxygen, producing a range of combustible gases and an inert char. It is the most cost effective method of releasing and storing the energy contained in an organic material. More importantly, dioxin requires the presence of oxygen and so the EfW process prevents the formation of this pollutant.

General Description of plant

In the JND EfW process, raw material is converted to a combustible gas which is subsequently used to generate electricity using generator(s) powered by a series of spark ignition gas engines or gas turbines. The only residue remaining after the waste is pyrolysed is an inert char material representing typically between 10 and 15 percent by weight and only 2 to 5 percent by volume of the original waste. This material is readily disposed of by means of landfill.

The process is self sufficient in energy using its own gas to power the Pyrolysis Reactor and its own waste heat to operate the raw feed dryer.



Atmospheric emissions are no more than for any well designed gas fired combustion system or any spark ignition gas engine. Exhaust air from the dryer is subjected to rigorous scrubbing techniques to eliminate particles and also any offensive odours if present.

The EfW plant is fully automatic, designed to operate with the minimum of operator supervision and to shut down automatically and safely in the event of a breakdown or component failure. The plants operates continuously 24 hrs per day, 7 days per week with only a two week shut down annually for inspection and maintenance.

The major equipment items which comprise the EfW plant will all be skid mounted to readily allow transportation to an alternative site at some future date.

The EfW plant allows for a nominal 15 year design life assuming continuous operation 8,400 hrs per annum with an annual 2 weeks shutdown for maintenance and inspection. The plant is designed for indoor/undercover installation and for an ambient temperature range -5 deg C. to + 35 deg C.

Converts waste into energy and an inert char

- Volume of waste is reduced by 95% and over, dependent upon the material
- Self sufficient in energy consumption
- Emissions within currently prescribed levels
- All equipment skid mounted for ease of installation
- Fully automatic operation requiring the minimum of supervision
- Designed to operate with over 90% availability requiring only one annual shut-down for inspection and routine maintenance
- Safe operation. A full safety system ensures the plant operates safely at all times

Feed Materials

- M.S.W
- Poultry Litter
- Commercial Solid Waste
- Wood Waste
- Sewage Plant Screenings

Bagasse

No dust laden exhaust gas

No generation or dispersal of:

- Oxides of Nitrogen
- Dioxins
- Furans
- PCB's
- Sulphur Oxides
- No dispersal of Heavy Metals
- Heavy metals contained in the M.S.W feedstock are retained in the char.

Thrumpton Lane, Retford, Notts England DN22 7AN

Tel +44 (0) 1 777 706 777 Fax +44 (0) 1 777 710604 E-mail: info@jnd.co.uk

Kvaerner

Kvaerner, the Anglo-Norwegian engineering and construction Group, has been awarded a US\$50 million contract by United Waste Limited to develop a 60,000 tonnes per annum (tpa) integrated incineration (energy from waste) facility at Douglas, on the Isle of Man. Kvaerner is to provide a design and build capability for the facility to United Waste (part of Groupe Fabricom). United Waste is responsible to the Isle of Man for the design, building and operation of the plant.

The plant is designed to deal with the Island's non-recyclable waste and includes a capability to treat clinical waste and animal carcasses, as well as the municipal waste collected on the island.

With completion scheduled for November 2003, the plant replaces old and obsolete equipment as well as providing a means to avoid the landfill of untreated waste. The heat generated by the combustion process will generate 7 megawatts of electricity. This will be fed into the Manx Electricity network generating enough power to supply approximately 4,000 homes.

The plant incorporates technology from Noell-KRC Energie-und Umwelttechnik GmbH of Wurzburg, Germany, (part of Babcock Borsig Power) which will provide its high performance, water cooled, moving grate incineration technology – having a proven capability of ensuring high levels of plant availability and low maintenance costs. Kvaerner has a long-term collaboration agreement with Noell for the application of this technology in the UK market.



With limited landfill sites on the Isle of Man and the existing facility nearing the end of its natural life, the Isle of Man Government has developed an 'all island' waste management plan for the next 25 years. This progressive plan aims to replace the Island's current landfill policy with one that focuses on recycling, the recovery of energy from waste and waste minimisation. As part of this policy, the Isle of Man Government has placed the contract to design and build an energy-from-waste facility, which will combust the non-recyclable waste arising on the Island.

The Isle of Man currently generates 110,000 tonnes of waste, of which 64,500 tonnes has no material value in recycling terms and can be incinerated. This waste falls into two categories: 60,000 tonnes of primary waste and 4,500 tonnes of secondary waste. The primary waste includes domestic municipal waste and civic community waste. The secondary waste includes animal waste, clinical waste (groups A-E) and sewage screenings, incinerated in a dedicated secondary incineration stream.

United Waste Isle of Man Ltd (UW[IOM]L), which will operate and maintain the facility, recently awarded

the £34.5 million design and build contract to Kvaerner's Energy and Environmental business based in Stockton, UK. To be located on the outskirts of Douglas, the facility will comprise two independently operated incineration streams – each operated under the European Waste Incineration Directive.

The facility will generate an average of 5.7 MWe of power providing the Isle of Man with power to supply approximately 4,000 homes (fed into the Manx Electricity Authority grid). The plant incorporates technology from Babcock Borsig Power, based in Gummersbach, Germany, which will provide its high performance, water-cooled, moving grate incineration technology. Kvaerner has a long-term collaboration agreement with Noell for the application of this technology in the UK market.

Water-cooling of the grate reduces the thermal wear and riddlings (waste passing through the grate); increases the lifetime of the equipment; improves the air distribution and reduces the overall operational costs. In harmony with the Island's policy of minimising waste, the aqueous process effluent will be recycled within the facility thus eliminating this as a discharge. Rainwater will also be recycled within the facility and will only be discharged to the river in exceptional storm conditions.

Solid discharges from the plant will comprise bottom ash from the two incinerators with a total organic carbon content of less than 2 per cent w/w and fly ash gas cleaning residue. The air pollution control residues, subject to Department of Environment approvals, will be disposed of in the UK at a licensed site and the bottom ash will be disposed of in landfill on the island. Work is currently being undertaken to find commercial outlets for both solid residues to maximise recycling. The flue gases from both streams enter the same gas cleaning process, using different sized equipment. Particulate is removed prior to the flue gases being discharged to atmosphere.

The plant will be continuously monitored for gaseous discharges of SO₂, O₂, CO and HCl. Particulate matter, H₂O, NO_x, and Volatile Organic Compounds and dioxins will be sampled continuously. The emission results, together with key process parameters, will be available for public scrutiny to ensure that the plant is operated within its agreed consents.

Lurgi Energie

Lurgi Energie und Entsorgung GmbH specialises in the sale, design, construction and commissioning of plants and sub-systems for energy generation, waste disposal and waste treatment. This includes mechanical, biological and thermal treatment of municipal and special wastes, sewage sludge and residual substances. Our product portfolio also encompasses processes for generating energy from fossil fuels and renewables by way of combustion in fluidised bed plants, combined-cycle and industrial power plants as well as cogeneration facilities.

Energy is fundamental to quality of life and technological advancement. A responsible use of our natural resources for energy generation requires sophisticated combustion processes offering maximum overall efficiencies. This is where innovative engineering services and novel technologies make the difference.

Energy from fossil fuels

The availability of our fossil fuels is limited. The point in time when the world's oil reserves will be depleted can already be predicted. It is therefore imperative that the most modern technologies be employed to make full use of the energy content of these fuels and other materials to conserve our natural resources. Lurgi specialises in power generation through combustion and gasification. Its tried and tested techniques and components are capable of using the energy trapped in the fuel with the highest possible efficiencies - tailor-made to the high standards of environmental protection.

Energy from waste

All of us generate large amounts of waste every year. In industrialised countries like Germany this can be as much as 300 kg per citizen. The thermal use of such high-calorific waste in modern Lurgi plants helps conserve resources by recovering part of the energy that went into producing the goods. The energy recovered from waste is used as electricity or for district heating purposes.

It was as early as the 1930s that Lurgi started developing its own processes for disposing of municipal waste through incineration. At its research centre in Frankfurt/Main (Germany), Lurgi Energie und Entsorgung GmbH is constantly seeking to improve their environmentally friendly technologies, so that wastes can be disposed of even more efficiently and effectively.

Production process wastes as a valuable resource - energy from biomass:

Production process wastes including special wastes, residual substances, biomass and (sewage) sludge are being produced in ever greater quantities. Unprofessionally treated wastes can do substantial harm to the environment in the long term. This is why these substances have to be disposed of in an environmentally compatible way, i.e. through residue-free combustion in line with local emission regulations and other requirements. This includes not discharging the generated heat to atmosphere but to use it in an appropriate manner.

Given the vast quantities of waste produced around the world, safe disposal, of course, cannot be the only option. Far more important is a comprehensive use of the resources which includes even processing the waste. The priorities should be: try to prevent waste, use waste in an environmentally acceptable manner and dispose of waste in an environmentally friendly way.

Where waste cannot be avoided, proper treatment and disposal are key elements of the circular flow. It is here that Lurgi Energie und Entsorgung GmbH - along with its sister company Lurgi Lentjes - can offer competent advice without losing sight of the economics.

Energy recovery conserves resources

Incineration and gasification of municipal waste helps to minimise dumping on landfill sites while allowing the energy content of the waste to be used. These are the only environmentally friendly ways of concentrating and removing pollutants from the circular flow.

Lurgi has decades of experience in designing, building and operating waste incineration plants of all sizes across the world and can draw on a range of technologies. Highly efficient incineration and energy recovery processes require tailor-made firing systems.

Rotary Kiln Incineration

Lurgi designs and builds turn-key rotary kiln plants for the incineration of the most diverse industrial and special wastes, with all necessary offsites and utilities.



Because of its composition (i.e. solid, liquid, pasty, mixed and its characteristics corrosive, caustic, reactive, not easily combustible) industrial and special wastes are often detrimental to health and cannot be burnt in normal incineration plants designed for municipal waste, such as grate or fluidised bed plants. The brick-lined rotary kiln therefore is the universal tool for heterogeneous requirements of this kind. In combination with a post-combustion chamber it ensures complete burnout of both the mineral and the gaseous combustion products.

The rotary kiln is used for the combustion of solid, liquid and pasty wastes as well as containerised wastes. Combustion usually takes place at temperatures above the ash melting point so that the ash can be removed as liquid slag. After cooling in the water-cooled de-slagger, it is collected as a glass-like, environmentally friendly granulate. The gas produced in the rotary kiln is burnt off in a circular post-combustion chamber at temperatures of as much as 1,200°C (and above). This process also involves the use of liquid wastes. The post-combustion chamber and the liquid waste burner are designed to ensure optimum mixing of the flue gases and a sufficient residence time, which are major prerequisites for full burnout, particularly of thermally stable components such as dioxins and furans.

The hot flue gases are piped to a waste heat boiler to be used for generating steam. The boiler is designed to allow for the special characteristics of the flue gases from industrial incineration plants, i.e. high levels of corrosive constituents and dust, as well as high temperatures. The flue gas cleaning plant is designed as necessary to meet the specific flue gas conditions and comply with local emission regulations.

The benefits of waste incineration in a Lurgi rotary kiln can be summarised as follows:

- wide range of commercial and industrial wastes including residues from chemical production processes
- feeding of containerised wastes
- high burnout temperatures
- excellent burnout of slag and flue gas

- immobilisation of the heavy metals in the glass-like slag
- high availability
- long service lives
- safe and reliable operation
- flexible adjustment of concepts to waste characteristics

Gasification principles

Gasification is the conversion of carbon-containing material into a combustible gas. The producer gas may be used for different purposes:

- as a fuel gas for generating heat and/or power
- as a synthesis gas for producing chemicals (methanol, H₂, F-T products, NH₃, SNG (synthetic natural gas) etc.

There are three different types of gasification:

- fixed bed gasification (co-current or counter-current)
- fluidised bed gasification (bubbling/circulating)
- entrained flow gasification

Apart from these three, there are various combinations. Depending on the utilisation of the producer gas and the type of solid fuel to be gasified the gasification process can be operated at atmospheric pressure or elevated pressures (32 bar e. g.) and may use either air or oxygen (plus steam) as gasification agent.

Gasification processes offered by Lurgi Energie und Entsorgung

- British Gas Lurgi (BGL) Gasification Process
- Fluidised Bed Gasification Process
- CFB (atmospheric pressure, Circulating Fluidised Bed gasifier)
- HTW (elevated pressure, High Temperature Winkler gasifier)
- For entrained flow and Lurgi rotary-grate gasifiers, please refer to Lurgi Oel Gas Chemie's website: www.lurgi-oel-gas-chemie.de .
- Circulating fluidised bed gasification
- Fixed bed gasification

Mitsui

Mitsui Recycling 21 is an advanced system for waste treatment (kiln type incinerator of pyrolysis gasification).

Firstly, shredded waste is heated without oxygen in pyrolysis drum and iron/aluminum are recovered. Secondly, pyrolysis products (gas and ash) are combusted at high temperature in furnace and the slug is recovered. High performance generation of electricity is also possible.

Main Features

- Very low environmental load
- Contribution to stop global warming
- Recovery of useful resources
- Adaptability to wide variety of waste
- Minimizing landfill
- Energy saving
- Reliable operation records

Plants in Operation

Yame Seibu (Fukuoka Pref.) , 220 tons/day, March 2000

Toyohashi (Aichi Pref.), 400 tons/day, March 2002

Ebetsu (Hokkaido), 140 tons/day, Nov. 2002

Koga and towns nearby (Fukuoka Pref.), 260 tons/day, March 2003

Nishi Iburi (Hokkaido), 210 tons/day, March 2003

Kyohohoku (Yamanashi Pref.), 160 tons/day, March 2003

MTCI-Thermochem Inc.

The Department of Energy (DOE) has generated, and continues to generate, large quantities of low-level mixed waste (LLMW) that require treatment prior to disposal. Existing treatment systems are expensive to operate and difficult to permit. Treatment systems are needed that reduce the volume of waste for final disposal, isolate the radionuclides in an acceptable final waste form, and destroy the hazardous component(s) in the LLMW.

Manufacturing and Technology Conversion International, Inc. (MTCI) has developed a patented, steam-reforming system which reacts the LLMW organics with superheated steam, generating a hydrogen-rich gas, and isolates the radioactive and nonradioactive inorganics in a form readily suitable for encapsulation and/or vitrification. Steam reforming takes place in an indirectly heated, fluidized bed reactor resulting in high throughput, high flexibility, complete organic destruction, and improved economics. ThermoChem is the exclusive licensee to MTCI's patented steam-reforming system. The heart of this steam-reforming system is an indirectly heated, fluidized bed reactor. Superheated steam fluidizes the bed and reacts with the organics in the waste feed material. The fluidized bed offers an ideal environment for effecting the endothermic steam-reforming reaction while retaining high processing throughput.

The steam-reforming reaction converts organics to a hydrogen-rich synthesis gas and converts chlorinated compounds to hydrochloric acid (HCl) which is subsequently removed. Dioxins and furans are not formed and, in fact, if dioxins are present in the feedstock, they will be destroyed in the reducing environment of the reactor. In the LLMW application the steam reformer is operated at temperatures that ensure retention of the lower-melting-point inorganics and radionuclides in the bed. The inorganic bed material is removed and processed for final disposal using a technique such as vitrification. The synthesis gas is catalytically oxidized and released as carbon dioxide and water vapour.

The ThermoChem steam-reforming system has been successfully tested on a wide spectrum of feedstocks such as biomass, industrial sludges, municipal solid waste, and sewage sludge. In 1995, a long duration demonstration test was successfully completed in a 5,000 pound-perhour system processing caustic spent liquor from a wood pulping mill. ThermoChem is currently marketing its PulseEnhanced™ steam-reforming system to pulp and paper manufacturers.

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Nuplex

The Nuplex Environmental Services division comprises of four Nuplex subsidiaries collectively known as Nuplex Environmental. The group companies and Nuplex's ownership are United Environmental Ltd (100%), Nuplex Medismart Ltd (100%), Medical Waste Wellington Ltd (50%) and Nuplex Special Waste Pty Ltd (100%).

United Environmental Ltd, trading as Nuplex Environmental, operates waste processing plants in Wellington and Auckland servicing the requirements of customers throughout the North Island of New Zealand. The wastes that are processed cover the entire range of industrial and municipal wastes that are commonly generated in New Zealand.

Nuplex Medismart with Medical Waste Wellington, supply services throughout New Zealand and operate disposal facilities in the four major cities. Medismart offers a fully integrated specialist collection and disposal service for clinical and quarantine wastes from waste assessments, to the supply of specialised containment, to the safe collection and disposal of hazardous wastes.

The Christchurch facility resource consent requires more stringent conditions beyond 2004. Incineration will not be able to meet these conditions so it is planned to change to steam sterilisation followed by sanitary landfill. Steam sterilisation is already taking place at the Auckland, Wellington and Dunedin sites.

Onyx

Veolia Environnement is major worldwide company of environmental services and provides tailored solutions to meet the needs of industrial and municipal customers in four complementary segments : water, waste management, energy and passenger transportation.

Through Onyx, its waste management division, Veolia Environnement has signed a contract with Shanghai Huancheng Waste-To-Energy Co., the Chinese company in charge of waste services for Shanghai. The 20-year contract covers the management of the Puxi Jiangqiao waste-to-energy plant, which is the largest plant of its kind in China. After eight months of tests and setting adjustments, the plant has a treatment capacity of 1,000 metric tons per day of household waste.

As concerns other waste management contracts, Onyx manages the Guangzhou Xingfeng landfill site, which is equipped to transform biogas into energy. The site is the first in China to be built to the latest international standards, and was designed by Onyx. Under a joint venture, Onyx also provides technical support for the Tianjin hazardous waste treatment centre, which is the first such plant in China. In Hong Kong, Onyx has a significant volume of business in household waste transfer and landfilling, with biogas-to-energy systems, as well as in hazardous waste treatment.

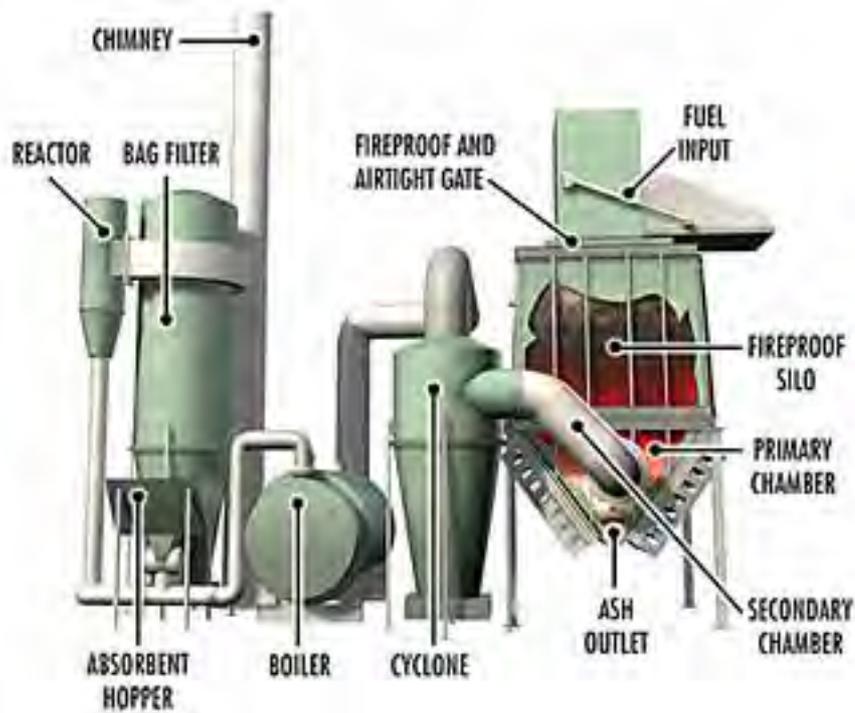
Energy recovery can make an important contribution towards sustainable development as a source of renewable energy, reducing the use of fossil fuels, cutting emissions of greenhouse gasses and reducing dependence on finite landfill capacity.

Energy from waste is used as part of an integrated strategy, recovering energy for the community from waste that cannot be recycled. Onyx currently operates three energy recovery plants in the UK, with three in planning and construction stages.

Site	Status	Capacity
SELCHP (South East London Heat and Power)	operational	420,000 tpa 30 MWe
Tyseley Waste Disposal (Birmingham)	operational	350,000 tpa 25 MWe
Chineham (Hampshire)	operational 2003	90,000 tpa 8MWe
Marchwood (Hampshire)	operational 2004	165,000 tpa 14MWe
Portsmouth (Hampshire)	operational 2005	165,000 tpa 14MWe
Sheffield Energy Recovery plant (old plant is currently operational)	planning	225,000 tpa 39MWh (district heating), 17MWe (National Grid) & 3MWe (site demand)

Organic Power Technology

Our technology is based on a three-step process: pyrolysis, gasification, and combustion of solid waste and biomass. The waste fuel is automatically batch-fed into the closed fuel silo (FIREPROOF SILO) through hydraulically- operated gates (FUEL INPUT), and gasification occurs at the bottom of the silo. By accurate and automatic control of the air supply to the primary chamber, the required gasification is achieved. Completely burned out ash and slag is pushed out through the bottom (ASH OUTLET). The low-calorie gas produced in the primary chamber flows into the secondary chamber (SECONDARY CHAMBER) where secondary air is added to support the complete combustion of the low-calorific flue gas. The temperature in the secondary chamber is set to 850-1100° C before the gas flows into the cyclone-shaped tertiary chamber (CYCLONE). Remaining unburned fractions are completely burned out, and any remaining heavy particles in the fly- ash are separated out. Leaving the tertiary chamber, the hot flue gas is cooled down in the flue gas-boiler where either hot water or steam is generated (BOILER). The thermal energy may be used directly for heating purposes or to generate electricity through steam turbines. Before the flue gas is discharged through the chimney (CHIMNEY), it passes through a filter system assuring low emission values (BAG FILTER, ABSORBENT HOPPER, REACTOR).



The Organic Power process is featured in the leading independent review of Waste Pyrolysis & Gasification. This review from industry specialist consultant Juniper concluded that: “Organic Power offers a very small scale system that should appeal to a particular segment of the market. It appears to be a flexible system, which can accept a wide variety of waste types with a relatively high moisture content and a range of CVs. It is well suited to the particular needs of the Norwegian market - but can also be of widespread interest in other markets across the world.”

Benefits of Organic Power Small-Scale CHP Technology

- Air emissions below limits set by the EU 2000 directives on all parameters
- Accepts multi-fuel with medium to high moisture content, depending on caloric value
- Flexible energy output (20-100 %)
- Modular units fit the customer’s need
- Eliminates waste disposal problems; Reduces need for landfill space

- Decentralized solutions reduce need for fuel and energy transport
- Can serve as profitable and regularly maintained basic power supply system for public buildings, factories, hospitals, etc.
- Replaces expensive non-renewable energy sources (mitigate greenhouse effect: counts toward CO)

Gasifier	Max. effect kWth 1	Energy output per year 2		Waste process capacity 3	
		GWhth	GJth	max. Kg/h	ton/year
SK 1000	2,000	15	54,000	1,000	3,500-7,500

- 1 The heat output can be continuously regulated from 20 - 100% of max. effect
- 2 The energy output is based on 7,500 operating hours, or 86 % plant capacity utilization, per year.
- 3 The waste process capacity per year is based on waste derived fuel with energy content from 2,400 kWh/ton (8,600 MJ/ton) to 5,000 kWh/ton (18,000 MJ/ton).

The Organic Power gasifier is set for a certain energy output, not for a certain tonnage throughput. Thus, to maintain the same energy output, the lower the calorific content of the fuel the higher tonnage throughput, and vice versa.

Modules can be combined for greater effect. The modules are delivered complete with filter as:

- Complete Multiple Fuel plant for district heating and process steam delivery
- Multiple Fuel plant for combined electricity and heat.

PEAT, Inc.

PEAT, Inc., (PEAT) is a privately owned company, incorporated in the State of Alabama. Formally, Plasma Energy Applied Technology, Inc., established in 1991, as a wholly-owned subsidiary of a much larger private engineering/manufacturing company, the Mason & Hanger-Silas Mason Company, Inc. The company was formed to develop and commercialise a plasma heating system for the destruction of certain waste streams.

PEAT is an environmental technology company engaged in the commercialisation and marketing of its proprietary TDR system. As per a licensee agreement between PEAT and HI Disposal Systems, HI calls its system a “Plasma-Based Pyrolysis/Vitrification” System or “HI’s PBPV System”. PEAT’s TDR and HI’s PBPV System is a one-step process capable of sustaining extremely high temperatures (up to 3500 degrees Fahrenheit in the processing chamber) that utilizes a plasma arc torch to reduce a wide variety of hazardous and non-hazardous liquid and solid waste materials to their basic compounds or elements. The process reformulates these elements into one or more of three useful by-products: a synthetic gas (syngas) usable as a fuel or chemical feedstock, metals that can be reused, and a glass-like, vitrified solid that may be used as an aggregate, poured into moulds to make various re-saleable items or safely disposed of in a landfill. PEAT and HI-IN believes that TDR/PBPV System is an environmentally-sound waste treatment solution suited for medical and hazardous waste streams that pose significant treatment and disposal difficulties and therefore have higher associated processing costs.

PEAT’s process has been validated through extensive, certified tests and operation permitting. PEAT’s R&D facility in Huntsville has compiled a track record of performing hundreds of campaigns processing a wide range of waste streams including, waste solvents, PCBs, pesticides, military wastes, municipal solid waste, medical waste and electrical waste. Its database includes one of the largest independently validated gas composition and slag leachability tests - demonstrating the versatility and performance of the PTDR technology.

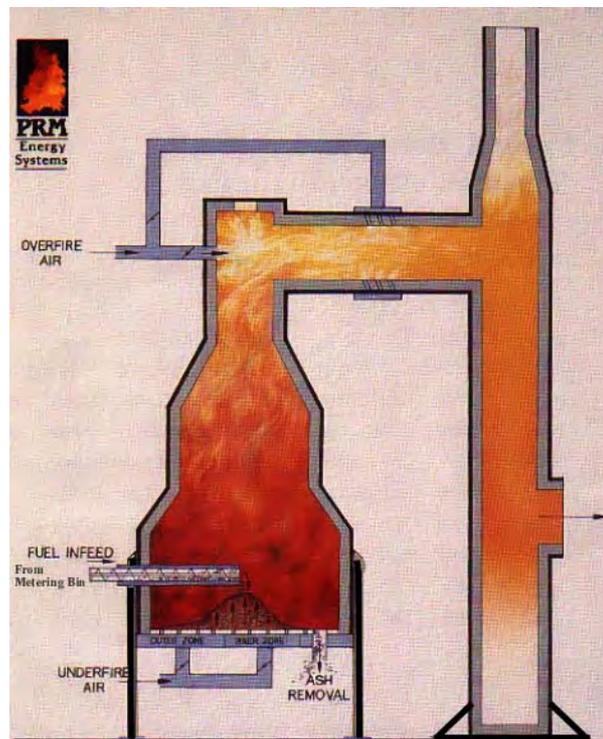
The PTDR technology has been tested and proven on many waste streams including:

- Municipal Solid Waste (MSW)
- Medical Waste
- Thermal Batteries
- Fly and Bottom Ash
- Military Waste, including weapon components
- PCB-contaminated materials
- Industrial and laboratory solvents
- Organic and inorganic chemicals
- Pesticides
- Organo-chlorides
- Refinery wastes

PRM Energy

A complete PRME biomass gasification system includes a fuel metering bin, the reactor/gasifier, the combustion tube and chamber, the gasifier cooling water system, water cooled ash discharge Conveyors, multi-zoned combustion air supply, rotary feeders and instrumentation required to provide automatic control over the process. The entire gasification/combustion process, from infeed to ash discharge, can be controlled manually or by computer.

As shown below, the PRME gasifier is basically a vertical cylindrical steel shell, reduced in diameter in the upper portion and lined with a refractory capable of withstanding temperatures as high as 1560 C in a reducing atmosphere. The cross sectional area of the upper portion of the gasifier is reduced to provide the turbulence required to insure proper mixing of the product gas and the combustion air introduced into the combustion tubes in this area of the gasifier. The lower portion of the gasifier contains an appropriately sized grate and develops a design heat rate of approximately 350,000 Btu/ft² of grate area.



Fuel is metered to the gasifier from the fuel metering bin. This bin is equipped with an infeed leveling conveyor and a variable speed outfeed conveyor that delivers fuel to the gasifier. The speed of the outfeed conveyor is automatically adjusted by the automatic control system to maintain a preset temperature in the first stage gasification zone. Discharge from the outfeed conveyor is directed through an impact weigh metering device that provides precise indication and control of the fuel feed rate. Fuel is introduced to the gasifier by a water-cooled screw conveyor that discharges into the drying and heating zone of the gasifier. The gasification process is controlled by the proportioned application of gasification and combustion air in a manner that supports efficient gasification. Residence time in the gasifier is varied by a residence control system that is adjusted to achieve a target carbon content of the ash residue. In the gasification zone of the gasifier, approximately 10 to 12% of the stoichiometric air requirement is admitted into the gasification air distribution area. The application of gasification air is multi-zoned and is controlled to maintain the proper temperature required to volatilize the biomass and allow partial combustion of the fixed carbon. Temperatures in this zone are controlled between 600 C and 1300 C, depending on the particular biomass fuel and the required ash quality. A low gasification air flow rate (0.1m/s) through the gasification zone, coupled with a low feed stock entry point and

continuous ash discharge minimizes the amount of particulate matter entrained in the gasifier exhaust.

Combustion of the gases starts in the combustion tube assembly where the temperature of the gases is increased to promote thermal cracking of tars and hydrocarbons that were liberated during gasification. Partial combustion of gases in the combustion tube assembly, the use of mechanical bed agitation and precise control of the zoning of gasification air produces a clean, low Btu content gas that can be burned in the combustion tube and chamber for drying applications or in the radiant section of the boiler. The gasification rate is controlled by demand from the dryer or boiler. The boiler exhaust is clean and may be used for direct drying applications, including food grains. Alternatively, when biomass destruction without energy recovery is desired, the clean gases may be diverted to the atmosphere via the combustion tube vent.

Technical Viability, Reliability and Manufacturability

The PRME technology has been successfully employed in “around the clock”, high demand, industrial applications since 1982, gasifying over 1,000,000 tons of rice hulls. Repairs on these gasifier systems have been negligible and the original refractory is still in place.

The design of the PRME gasification system enables complete fabrication and procurement of all components on a local basis. Seven complete turnkey PRME systems, including computerized control, are operating in remote areas of Malaysia - all fabricated and erected by local contractors.

Single gasifier input capacities range from 5 million to 110 million Btu/hr. The system is modular and several gasifiers can be coupled for large applications.

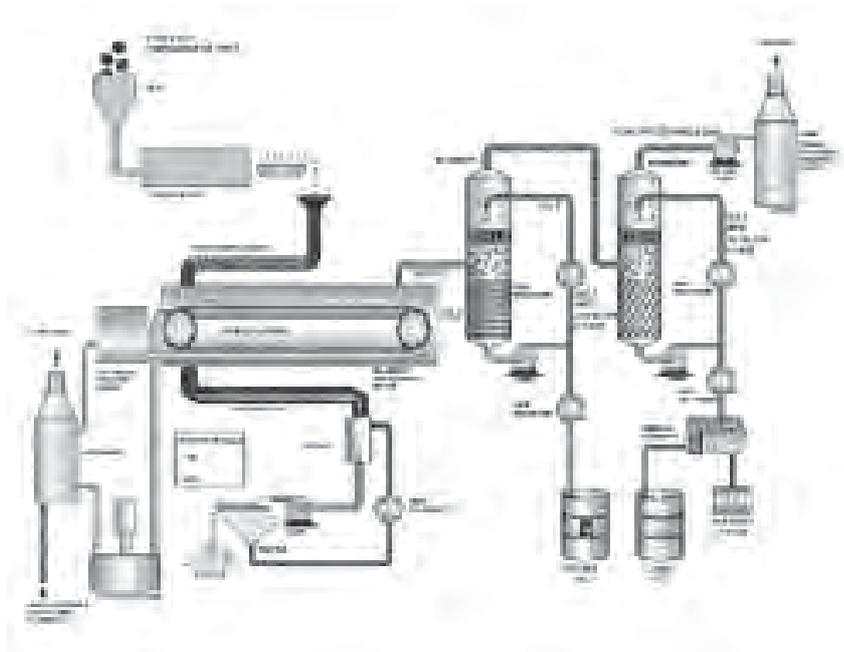
PYROVAC INTERNATIONAL INC.

Description of the technology

With the vacuum pyrolysis process known as Pyrocyling™ process, a wide variety of industrial and municipal wastes, such as biomass residues (bark, forestry and agricultural residues, bagasse etc.), sewage sludges, automobile shredder residues, biomedical wastes, used tyres and petroleum residues, can be reclaimed and recycled. This technology also enables soils to be remediated.

Pyrocyling™ process involves the thermal decomposition of matter under reduced pressure. The complex molecules which constitute the organic matter decompose into primary fragments when subjected to heat in the reactor. The macromolecules are quickly withdrawn from the reactor by a vacuum pump and are then recovered through condensation in the form of pyrolytic oils. This way, the secondary decomposition reactions are minimized. Thus the chemical structure of the pyrolysis products is parent with the structure of the complex molecules forming the original organic material.

Vacuum pyrolysis is generally conducted at a temperature of 450°C and a total pressure of 15 kPa. These operating conditions, not as extreme as those used with atmospheric pyrolysis and incineration, make it possible to obtain large quantities of pyrolytic oils as well as useful solids such as charcoal and carbon black.



Performance

Vacuum pyrolysis makes it possible to produce fuels (charcoal and pyrolytic oils) and also, under certain conditions, to obtain added-value products such as resins, solvents, pharmaceuticals, fragrances and flavouring compounds. The yield and quality of these by-products depend directly on the process operating conditions. One of the main factors affecting the proportions of the various products obtained, as well as their quality, is the degree of vacuum.

The main advantages of the technology are:

- no dust, toxic emission or secondary pollution ;
- wastes are transformed into oils and useful solid residues ;
- a small amount of clean gas is produced ;
- performance exceeds current Quebec environmental legislation;

- products and by-products can be sold;
- no need for an expensive gas scrubbing system.

Limitations

The Pyrocycling™ process is applicable to all types of wastes with an organic content (however small) as well as to contaminated soils.

The technology cannot be used to treat mine tailings or to dispose of PCBs, but in the case of PCB-contaminated soils, it can concentrate the PCBs in the pyrolytic oils.

Installation and Operation

The Pyrocycling™ unit, with a reactor as its central component, is of relatively modest size. For example, a reactor to treat 2 t/h of biomass residues will be 10 m long and 1.6 m in diameter. The plant as a whole will take up some 400 m², excluding the storage space. It is also possible to build mobile units to treat contaminated soils.

A Pyrocycling™ unit does not consume much energy since the thermal efficiency is approximately 88%. The energy requirement essentially stems from the initial moisture content of the waste. The unit is fully automated and can be operated by a team of three workers per shift with a supervisor.

Additional Information

The technology is an outgrowth of university-based research and is now in the hands of three private companies: Pyrovac Institute Inc. (R&D, testing, training, assistance), Pyrovac International Inc. (marketing) and Pyro Systems Inc. (engineering and project management). Groupe Pyrovac is pursuing R&D work in collaboration with Universit Laval in Qu bec. Pyrovac International already holds some thirty patents in the United States, Canada, Australia and Europe.

The development of the Pyrocycling™ process is based on an investment of more than \$10M over the past 15 years. Several Canadian and Quebec granting agencies (including NRC, NSERC, CANMET, FCAR [Fond pour la formation de chercheurs et l'aide ^ la recherche], MENV [Quebec Ministry of Environment], NRM (Natural Resource Ministry) and MIC [Quebec Ministry of Industry and Trade] have contributed to funding the research activities. A pilot unit with a capacity of 150 kg/h has been installed at the CRIQ [Centre de recherche industrielle du Qu bec] in Ste-Foy.

The Pyrovac technology is available under licensing agreement through Pyrovac International.

For further information on the Pyrocycling™ technology, please contact:

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RGR Ambiente

After having acquired the rights to the European Patent n. 0292987, in 1994 RGR began the planning and the realisation of a pilot gasification reactor of waste combustible part. This first prototype was dismantled in January 1998 after several trials. The trials were essential to learn how to structure an optimal pilot plant that was built with a number of changes and improvements on the original project in 1998, and patented in Italy in 1999.

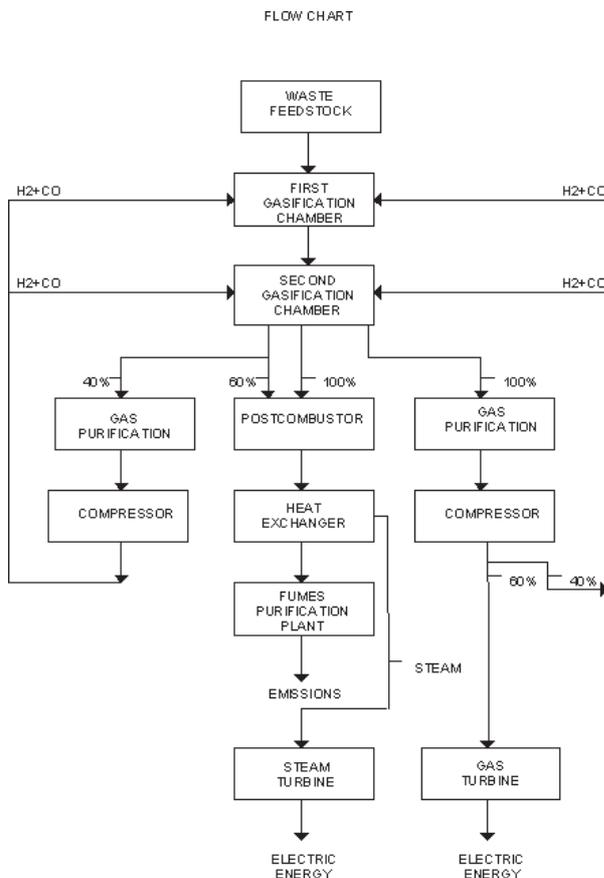
The operating temperature of the kiln ranges from 1.400 to 1.600°C, depending on the composition of the treated wastes.

The technical input capacity is scaled to 500 kg/h with an achievable productivity of 400 kg/h. The scale has been selected to test operating efficiency within a small, but significant, capacity context. A larger capacity will have a positive impact also on the per kg treatment costs.

Where waste feedstocks, rich in energy, Municipal Solid Waste and many other industrial wastes are processed, RGR system will be a net producer of energy. The energy surplus is recovered from the purified gas, with a net surplus ranging from 68% to 70% compared to every unit of energy used.

The energetic uses could be for instance:

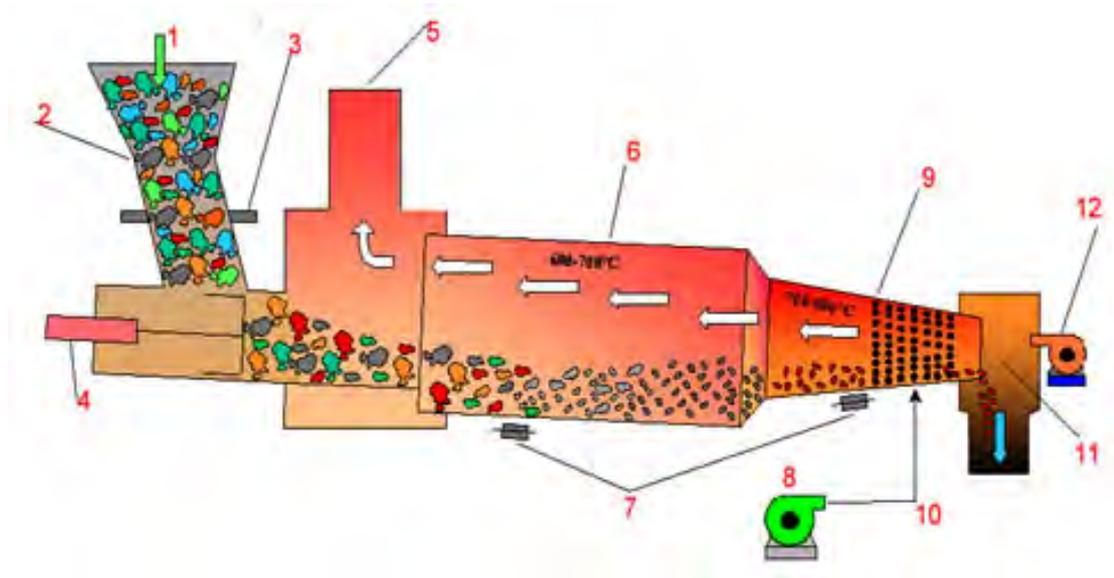
Steam production burning the pyrolytic gas in a post combustion chamber, recycling and then purify the final fumes; sending the dirty gas into a purification system and then in a gas engine generator and then steam cycle turbine-generator obtaining the optimal energetic efficiency; gas engine-generator after having taken off the CO₂ and purified the combustible gas; gas engine-generator and a 10 bar steam boiler; (flow chart)



E-mail: rgrambiente@easynet.it



Serpac-Pyroflam



1= input ; 2= hopper ; 3= baffle ; 4= pusher; 5= pyrolysis gas + char gasification products to post-combustion + energy recovery; 6= pyrolysis chamber; 7= rollers; 8= process air; 9= gasification chamber; 10 = inert solid residues; 11 = ash delivery; 12 = starting burner

The P.I.T. Pyroflam pyrolysis process is designed to operate continuously. Solid wastes can be fed into the pyrolysis reactor without any preliminary treatment. The reactor comprises two chambers which rotate around a common horizontal axis on a slight incline. The waste pyrolysis chamber is cylindrical and the char gasification reactor is in the form of a truncated cone. The pyrolysis reactor operates with an oxygen deficient atmosphere at a temperature between 600 and 700i C. The design of the complete reactor ensures that the solid waste spends sufficient time within the pyrolysis reaction zone to ensure that the organic constituents are converted into syngas and char.

The rotating motion of the pyrolysis reactor transports the char (pyrolysis coke) formed towards the gasification reactor. Substoichiometric amounts of air are injected into the char gasification reactor and the char is gasified in a partial oxidation zone at about 800i C. The temperature of the gases from the char gasification reactor are sufficient to maintain the pyrolysis reactor at the required temperature without the need for additional fuel. The solid inert residue leaves the char gasification zone and after an eventual recovery of metals, is disposed of.

The syngas produced from the char mixes with the syngas from the waste pyrolysis reactions as it flows counter-currently through the reactor. The combined syngas stream then passes to a heat recovery boiler where it is combusted at 1100 - 1200iC for a residence time of 2 seconds with 6% excess oxygen. Energy is extracted from the hot flue gases in a waste heat boiler and the produced steam is used as process steam or for district heating or to generate electricity via a steam turbine. The gases are then cleaned using a conventional dry scrubbing process with lime or sodium bicarbonate as sorbent and a bag filter prior to discharge to atmosphere. The process produces a stable solid residue, which can increase recycling, and no liquid effluents.

SFT-Nexus

The French SFT company is a subsidiary of the Nexus Technologies Group which is involved in the development of industrial and municipal waste reprocessing. It provides local communities and industries with global, flexible, innovative and effective solutions adapted to present and future environmental requirements. SFT specialises in the Softer process, a physico-chemical process which transforms organic wastes into fuel and energy.

Prior to the industrial stage, SFT tunes its process with a pilot unit the capacity of which is 5000 tons a year. The understanding of the thermolysis process according to the type of waste is crucial to derive the optimal operating parameters of an industrial unit with a capacity of 30 000 tons a year. As an alternative to the construction of an intermediary pilot, which would cost about 3 million Euro, one can consider numerical simulation.

The three French partners SFT, CCIMP, with the help of a research institute in thermal processes, IUSTI, and SIMULOG, a company specialised in scientific computing and in particular in high performance computing, have worked together on a simplified numerical model of the pilot oven and on the simulation of the physical phenomena that occur during the thermolysis process. First, a series of simulations compared to experimental results have confirmed the validity of the model. To fulfil the requirement of the validation of the approach a total of 324 simulations were needed. Without high performance computing, such a simulation was an unrealistic option because it would take about 9 months of CPU time. After parallelisation and optimisation of the software, the simulation time was then reduced to 1 month.

SFT has now in hand a powerful tool in the form of an abacus. This will allow them to offer their future clients a quick answer to their reprocessing waste problem, and to provide them with the best possible system. SFT expects from now on to sell 10 industrial units by 2003. The business benefit could be clearly very high.

Contact

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SIMULOG

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Solena

IPGCC is Solena's unique process that converts low value fuels such as biomass, wastes, petcoke, coal wastes/fines, as well as coal, into a fuel laden "synthesis gas" or "syngas". The heavy and/or dirty solid fuels are "cleansed" with the PGV ("flexible fuel gasification") process and converts them into a high value fuel (syngas) for use in turbines. Unlike any other thermal systems, such as incineration or gasification, the feedstock for the IPGCC can be very heterogeneous (MSW) or homogeneous (coal) or a combination allowing it the plant to continue operations even if the fuel feedstock are inconsistent or changed, thus mitigating risks for the plant owners.

The unique characteristic of the PGV process is that it can handle a wide variety of feedstock and thus is completely "fuel flexible". Unlike standard gasification technology, the PGV process utilizes a powerful and independent heat source (plasma torches) and can thus accommodate and adapt to the varying feedstock. Operating at atmospheric pressure the PGV system can achieve an 85% availability, allowing it to function on a "base-load" mode for electrical power production.

The PGV reactor operates at a temperature around 5,000 C and can effectively cause the complete disassociation of all hydrocarbon and organic materials into its elemental compounds, which in turn is converted via the patented PGV process into a valuable fuel gas comprising mostly of H₂ and CO, commonly referred to as "syngas". Inorganic components of the feedstock are melted and vitrified under plasma temperature into an inert non-leachable "plasma slag" for re-use as construction materials.

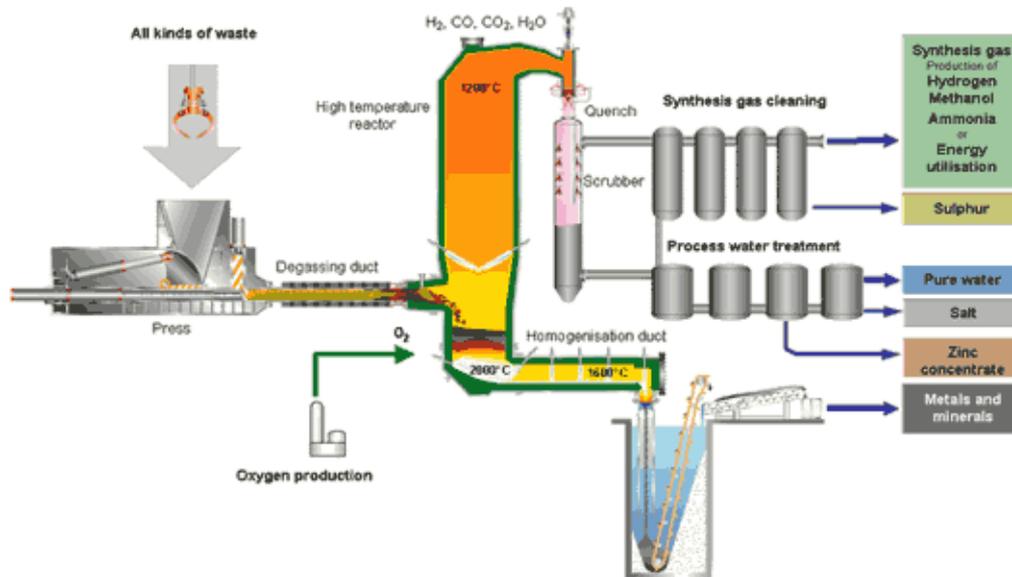
At high plasma temperature, the PGV reactor does not produce any air pollutants such as SVOCs (dioxins/furans) or NOX, tar, fly ash or flue gas as do incinerators or boilers. There is no ash production as all fixed carbon bonds are also depolymerized at plasma temperature. PGV reactors are therefore environmentally safe and meet the strictest emissions standards and can be sited in areas where incinerators and combustion technology are prohibited.

Power generation typically employs General Electric LCV turbines ranging from 10 MW to 90 MW in single cycle or 15MW to 130MW on combined cycle. These LCV turbines are proven products with a total of 34 GE LCV turbines operating on syngas from gasification processes with over 380,000 hours accumulated worldwide.

The core of a LCV gas turbine design is based on combustion system adaptation through laboratory testing. Combustors must be designed for a wide range of operating conditions with primary syngas, backup fuel, and possible co-firing of both fuels. The multiple can-annular LCV combustor design of GE gas turbines results in excellent flame stability and mixing properties that produce very low emissions. This design also makes it possible to burn multiple fuels, including distillate, naphtha, syngas, propane and methane.

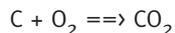
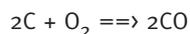
Thermoselect

The THERMOSELECT process recovers a synthesis gas, utilisable glass-like minerals, metals rich in iron and sulphur from municipal solid waste, commercial waste, industrial waste and hazardous waste in a continuous recycling process by means of high temperature gasification of the organic waste constituents and direct fusion of the inorganic components. Pure water, salt and zinc concentrate are produced as usable raw materials during the process water treatment. Unlike other thermal processes, there are no ashes, slag or filter dusts to be expensively landfilled or passed through secondary treatment.

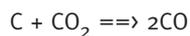


During the first process step the waste is delivered, without pre-treatment, to a press in which it is compacted, liquids are distributed and residual air is pressed out (removal of the nitrogen ballast). A high compressive force is applied to form gastight plugs from the waste and to press it into a degassing duct.

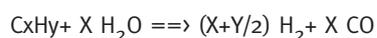
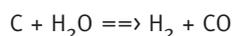
With increasing heat, the waste is dried, organic constituents are degassed and enter the high temperature reactor. The carbon and carbon compounds produced are gasified under controlled addition of oxygen at temperatures up to 2000°C in an environment rich in water vapour. The following exothermic reactions lead to the formation of carbon monoxide and carbon dioxide.



The endothermic Boudouard reaction takes place simultaneously

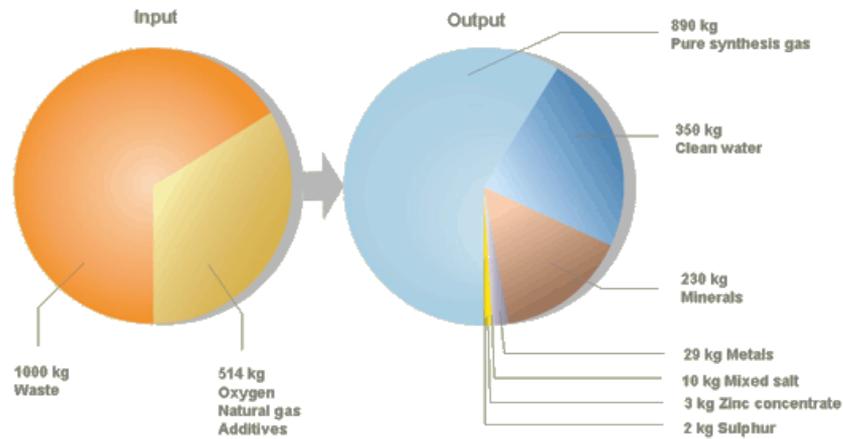


as well as endothermic hydrogen reactions, e.g.



During a residence time of at least 2 seconds and gas temperatures above 1200°C, chlorinated hydrocarbons, dioxins and furans as well as other organic compounds are reliably destroyed. The main components of the synthesis gas produced are the smallest possible molecules (H₂, CO, CO₂, H₂O). Subsequent shock cooling of the synthesis gas from 1200°C to below 90°C with water prevents

reformation of chlorinated hydrocarbons. The synthesis gas passes through multi-stage cleaning, in which the contaminants are absorbed or condensed. The clean synthesis gas is then available as an energy carrier or as a raw material – for example for the synthesis of primary chemical materials such as methanol.

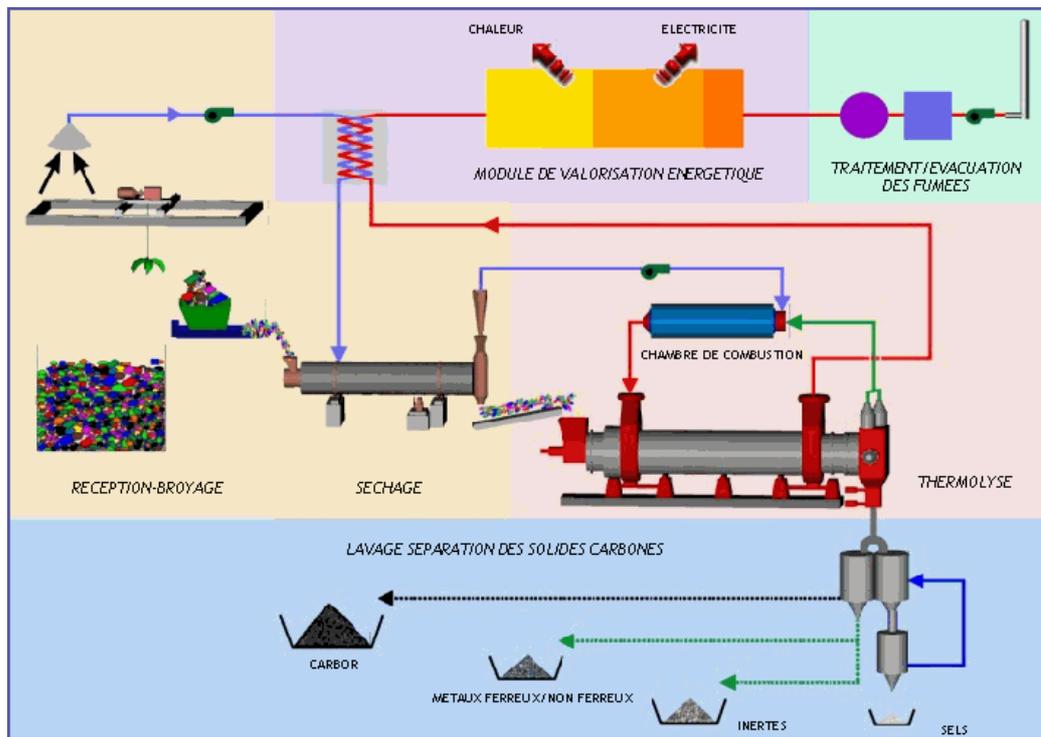


The inorganic metallic and mineral constituents are melted in the high temperature reactor at temperatures up to 2000°C. The molten material is homogenised in a duct connected to the high temperature reactor. Two stable high temperature phases (minerals, metal) are produced at approx. 1600°C. The homogenised molten mass is subsequently shock cooled with water, the metals and minerals separate and are extracted out of the gas sealing water basin as granulate. The separation of the mineral and the metallic granulate takes place outside the system by means of magnetic separation. The quality of the glass-like minerals is equivalent to that of natural products. The metals can be used in metallurgy.

Process water - originating from the waste moisture and the gasification reactions - is treated and then used in the plant as cooling water. Salt, zinc concentrate and sulphur can be reused by industry. All intermediate products produced during the cleaning phases are fed back into the thermal process.

THERMOSELECT S.A.
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e-mail: info@thermoselect.ch

Thide Environment SA



The preparation of waste, consisted of stages of crushing, drying and sifting, makes it possible to homogenize waste in order to facilitate the mechanics transfers and thermics; The phase of thermolysis intervenes in a rotary cylinder equipped with a double fixed heat-resisting steel envelope in which circulate of the hot fume.

The interior of the cylinder is thus brought up to a temperature close to 500°C. During their progression in this hot cylinder, waste undergoes a thermal degradation which leads to the formation of gas of Thermolysis and the carbonaceous solids. Constituted from not-condensable light gases, heavy vapor tar type and water vapor, the gas is extracted from the furnace uninterrupted, vacuum-cleaned then directed towards a combustion chamber in which it is burned and produces the hot fume (1100 °C) used for the heating of the furnace. Treatment of the carbonaceous solids: At exit of furnace, the carbonaceous solids are delivered in a mixing vat filled with water to be cooled there.

Complementary mechanical operations make it possible to separate from them the inert mineral fractions and metals directly which may undergo beneficiation. After this separation a complementary stage of rinsing allows D ' to eliminate the chlorine initially contained in waste and fixed on the solid fraction during the reaction of thermolysis. The d chlorur end product, called Carbor ", constitutes a source of energy (NCV: +de 4000 kcal/kg) or of Carbon usable by various industries. Energy valorization: According to the local outlets and composition of waste, various options of energy valorization are possible: direct use of gases (or purified gross), production of heat and/or electricity.

Toshiba PKA

Tokyo—Toshiba Corporation have a technology collaboration agreement with a leading German environmental technology company, PKA Umwelttechnik GmbH & Co. KG (PKA), which gives Toshiba exclusive rights to market waste processing plants in Japan based on PKA's technology. PKA is renowned for its advanced expertise in environmental protection technologies, particularly its proprietary waste-processing technology.

The PKA technology-based pyrolysis and gasification system can treat diverse household and industrial waste, including shredded cars, tyres, plastic waste, and contaminated soil. The waste is processed into useable products, among them clean combustible gases, such as hydrogen and carbon-monoxide, ferrous and non-ferrous metals, and carbon. Another advantage of the PKA system is that emissions of dioxins, NO_x and SO_x into the atmosphere are substantially lower than with conventional waste treatment systems. The overall system provides an environmentally-friendly and efficient solution for treating a wide range of waste, and recovering resources for reuse. The plant will provide a core product for Toshiba's new business activities in waste treatment and recycling systems, complementing Toshiba's systems currently in the market, such as the plastic waste petroliiser and sewage control systems. The company will start marketing the new system in 1998, with a target of orders for ten plants in Japan by the end of 2000.

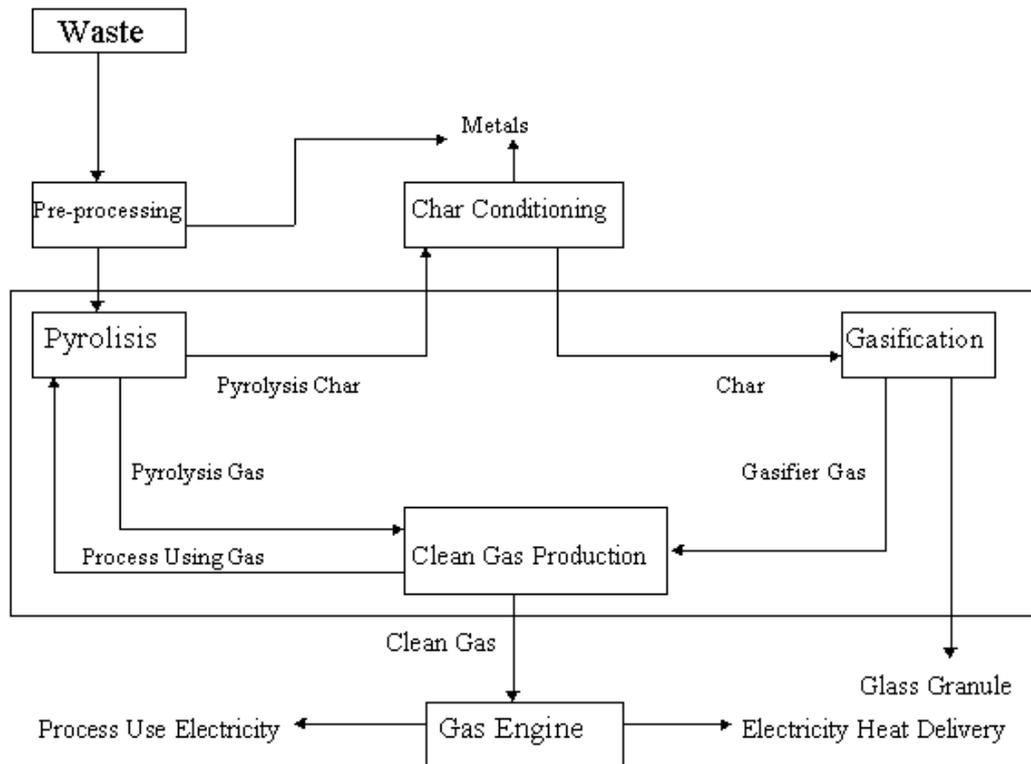
PKA's innovative pyrolysis and gasification technology minimizes generation of hazardous materials during processing. Verification testing in Germany has confirmed that the system offers an environmentally-friendly means to thermal decomposition of waste that minimizes the release of hazardous substances, including dioxins. PKA is now constructing commercial plants in Aalen and Freiberg, both in Germany, with more at the planning stage. The system offers design and operating advantages: (1) a modular unit structure enables flexible plant design and modification to deal with different kinds of waste, such as household waste and industrial waste; (2) the treatment process reduces discharged dioxins levels to less than 0.1ng/Nm³, a level below Japanese and German requirements; (3) the combustible clean gas produced can be used for the power and heat supply of the plant itself, and any excess can be made available for direct delivery to external users; (4) reusable metals and carbon are recovered from the process.

Following separation and preparation, waste is fed into a rotary kiln that is externally heated to 500–600 deg. The organic gas generated in the kiln is then lead to a cracker, a high temperature thermal decomposer, where dioxins are almost entirely destroyed and the organic gases are cracked into their light components. The gas is next transferred to a gas cleaning system, which removes chloride and sulphur, leaving a clean reusable gas. The metal residue from the kiln can be reused. The carbon residue can be used as a reduction material in furnaces, and also can be supplied to a gasification device to produce combustible gas, which is mixed with the pyrolysis clean gas.

Toshiba is committed to respecting the environment in all of its activities, and to the development of products and systems that contribute to environmental preservation and management. Towards this, the company set up an Environmental Management Business Group in April 1997, bringing together its diverse environment-related businesses. The new organization focuses on essentials - clean and safe water supply, improved air quality, reduced industrial waste and increased recycling. It markets recycling equipment and systems and offer comprehensive consulting services in these and other areas. The group also brings together the diverse capabilities of Toshiba's business groups in such areas as energy, biotechnology, information processing and sensors, to promote new systems and services.

Outline of PKA Umwelttechnik GmbH & Co. KG

Established:	1983
President:	Dipl.-Wirt.-Ing. Andreas Schieber
Address:	Aalen, Baden-Württemberg, Germany
Business:	Engineering company for the development and marketing of pyrolysis



Von Roll RCP

The new RCP (Recycled Clean Products) process is Von Roll's unique synthesis of tested and upgraded process modules. Pyrolysis and controlled high-temperature melting with oxygen injection yield an extraordinary result: an environmentally neutral, immediately usable raw material for the construction industry.

Slag is vitrified in the RCP process, with full extraction of heavy metals in the slag refinement step. The granular end product is environmentally safe and can be returned directly to the resource cycle, so that there is no cost for landfill disposal of slag.



Wellman Process Engineering

Wellman Process Engineering Limited has designed and built an Integrated Fast Pyrolysis Plant to produce 223 kg/hr of pyrolysis liquid.

Pyrolysis liquid is a stable single phase liquid mixture of water and organic components. These range from low molecular weight molecules such as formaldehyde and acetic acid to complex high molecular weight phenols and anhydrosugars. Pyrolysis liquid can be used as a fuel either within a combustion engine or by direct combustion. The liquid can also be used as a chemical feedstock.

Biomass subjected to heat in a non-oxidising atmosphere converts to a mixture of gases, vapours and char. On cooling, the vapours condense to form pyrolysis liquid. The liquid yield and composition is dependent on the biomass feedstock, rate of heating, temperature and residence time. Careful control of these variables optimises pyrolysis liquid production.



Appendix B: Compact Power - A Case History

The business of Compact Power was established in 1992 by Nic Cooper, the current chairman of the Company, and Professor Sharpe, an expert on thermal power plant. They believed that there was a niche in the market for a waste to energy plant which was economic at a small scale and could meet the highest environmental standards. By 1993 the team, which by then included directors John Acton and David Bulman, had produced a design for a prototype plant suitable for processing a variety of waste streams.

In 1994 a full-scale prototype plant based on a single pyrolysis tube was built at the Finham Sewage Treatment Works of Severn Trent Water, near Coventry, under the supervision of John Acton. Between 1995 and 1997 a series of trials were conducted on different types of waste in order to test the Compact Power technology and to obtain emissions and performance data.

In 1998 the Company began work on the preparations to build its first commercial plant at the site of a waste transfer station owned by Bristol City Council at Avonmouth in Bristol. Having obtained a lease from Bristol City Council, the necessary planning permission and local air pollution control authorisation, construction started in early 2000. The plant was completed in April 2001 following which a commissioning programme was undertaken which included the processing of MSW supplied by Bristol City Council.

In September 2001 the Environment Agency granted the Company an IPPC authorisation for the Avonmouth plant, which permitted the plant to process a wider range of wastes. At this stage the plant was handed over to the operational team and shortly thereafter the first revenues from the plant were granted.

The Company declared the Avonmouth plant commercially operational from 1 January 2002 with its cost being capitalised at £3.5 million. Since January, the Avonmouth plant has been processing clinical and other wastes. In addition, the plant has been used to demonstrate the performance of the technology to potential customers and strategic partners, and other interested parties.

In order to fund its development to date Compact Power has raised approximately £12 million. More than half of this finance has come from Cooper Holdings, with the balance coming from other investors, including employees. In January 2002 BHP Billiton, a global leader in the resources industry, invested £1 million in the Company through its venture capital arm, BBIG Venture Capital. In addition, it has agreed to invest a further £500,400 in the Placing, which will result in it holding 6.28 per cent. of the Company's issued share capital immediately following Admission.

Intellectual Property

The Company has sought to protect all the intellectual property rights to its technology. The Company's most significant patent, which has been registered in Europe and the U.S.A, is the "Pyrolysis Shelf", a wide-ranging patent to protect the combination of pyrolysis, gasification and oxidation used by the Company. In addition the Company has a further patent, the "Ablative Seal", which is a seal for the purpose of preventing the ingress of air into the pyrolysis tube when it is being charged with pre compacted waste.

The Company has made two further patent applications: the "Trombone" patent relates to an element of the gasification process; and the "Bag Splitter and Wet Separator" patent relates to a waste sorting facility which the Company is developing to refine its feedstock for the process. An International (PCT) Patent Application has been filed for both inventions.

In addition, the Company has accumulated a large body of proprietary know-how based on its development work.

Compact Power Holdings PLC

Highlights of 2002/03 Report to Shareholders

- Participation in three well advanced municipal projects; further proposals under review by the relevant authorities
- Market interest continues to grow for fully integrated waste management facilities which use advanced thermal conversion technologies
- Collaborations have been established with Ferrovial Group and EMTE in Spain, SNC Lavalin in Benelux and France, ITA in Greece and HLC Group to develop UK and international opportunities
- The Avonmouth plant continues to be the only commercial pyrolysis and gasification plant operating in the UK and the only one operating under the Integrated Pollution Prevention and Control (IPPC) regime
- The Avonmouth plant has achieved accreditation from Ofgem as a renewable energy generator eligible for Renewable Obligation Credits (ROCs)
- Admission to AIM April 2002
- Capital restructuring significantly improves strength of balance sheet
- Debt free and cash reserves at 31st March 2003 of £3.7m
- Increase in turnover to £411,000 (2002: £98,000)
- Net loss in the period of £3.7m in line with market expectations (2002: £3.8m), loss per share 13.3p (2002: 41.6p)

Chairman's Statement

Introduction

I am pleased to present the results for the year just ended and the first full set of results as a publicly listed company. In a market known for long development and contract cycles, Compact Power continues to make progress demonstrating and improving the technology for the benefit of future plants and developing relationships with industry players to create the platform to deliver future growth.

Operating review

We have now operated the Avonmouth plant in commercial conditions for over 18 months under the Integrated Pollution Prevention and Control regime. We remain the only pyrolysis and gasification technology operating under IPPC in the UK and we are recognised by the Environment Agency for our outstanding environmental performance. In addition, the Avonmouth plant has recently received accreditation from Ofgem as a renewable energy generator eligible for Renewable Obligation Credits (ROCs). This has given Compact Power a unique position among advanced thermal conversion technologies which are being promoted in the market.

Although the environmental performance has been excellent, technical and operating constraints have affected profitability, and in this sense we have failed to meet our own expectations. A principal factor has been the thermal limit of the original specification of the plant which was based on the lower calorific value waste which was typical of clinical waste when the plant was designed. However, our continuing presence as a commercial operator and the experience and technical data that we are gaining significantly increases our credibility as a technology provider and underlines the importance of this plant in the marketing of our technology nationally and internationally.

Lessons learned have of course contributed to design improvements for the next generation of plant and our commercial strategy for different applications of the technology has evolved with developments in the market and our experience of operating with our own technology. For the clinical waste sector this is demonstrated by the planned extension of the Avonmouth facility described below. We have conducted

trials with other waste feedstocks, principally refuse derived fuel from municipal waste, tyre shred and shredder waste from the automotive industry, dewatered sewage sludges, paper and paper pulp and rubber industry waste. The results give further data on our capacity to process mixed wastes and reinforce the credibility of our process.

We are planning to consolidate our investment in the Avonmouth plant by the addition of a steam sterilisation plant that will expand its capacity, improve the energy efficiency of the total facility and improve the financial return. This will involve further investment in the region of £1 million which will largely be provided by a lease purchase arrangement secured on the assets of the project. We expect the plant to make an increased contribution from the second half of this year. By offering this additional process, Compact Power can optimise the cost benefits for customers and provide a more comprehensive service which we believe will strengthen our market position.

There were several project situations that at the time of our listing we expected to come to fruition within the financial year. In the case of Dumfries, Scotland, we have already reported delays but we are still hoping to structure the project within the framework of our existing planning permission.

In relation to projects in the water sector, we have been affected by delays in the adoption of strategies based on advanced thermal conversion.

In connection with our relationship with CES and the Roche project, the decision by Cornwall County Council to procure new waste management capacity through the PFI mechanism has led to the withdrawal of the planning application and a requirement that the project be put out to competitive tender.

Despite the above delays we are pursuing at least three active prospects which we hope will enable us to make a positive announcement before the end of the year.

Technical

We are also happy to report that the ready to build design and procurement package commissioned from AMEC and reported at the interims has been successfully completed and we are now in a position to proceed in project situations to deliver our solutions.

Strategic review

Our strategy in the municipal market has been developed on the model of integrated facilities maximising recycling of materials and the diversion from landfill to meet the latest requirements under the Landfill Directive and avoid related financial penalties. We have now developed a portfolio of specific project opportunities based on this model and plan to build relationships with industrial and financial partners with the capacity to respond to market demand.

That said, we believe that municipal waste strategies, which are being developed at regional and local level to meet Government targets, are increasingly recognising the need for a thermal process to recover energy from residual waste following recycling and composting. Industry commentators support this view and see the place of thermal process and energy recovery as much more fundamental to achieving these targets.

We are also promoting the wider implications of our technology as a provider of heat and power to industrial developments which can also exploit the potential of our pyrolysis process to recover carbon and other materials for added value applications. This links in with regulatory initiatives, which are affecting certain sectors such as the automotive industry, and emphasises the potential role of our technology in more advanced recycling and materials recovery applications.

Internationally, the company has continued to form strategic relationships with key industry players which can create a platform for growth. We have specific project opportunities in Spain, Italy, Belgium and Australia which are being developed under the collaborations which we have already established. These will create the framework for a programme of projects around which we are already planning for the next

few years.

The increasing level of enquiries to which we are responding on a regular basis gives us confidence that the interest will continue to grow as we continue to demonstrate that we are one of the few technologies in the world that can deliver environmental performance that is well within all relevant standards.

On factors affecting our market and on our competitive position, we have the following general observations:

- The last 12 months have seen our position as a leading advanced thermal conversion technology reinforced by the further period of operation in commercial conditions and the fact that since September 2001 we have been the only pyrolysis process operating under the new IPPC regime.
- There are few available alternatives to our technology. Several of the other advanced thermal conversion technologies that have been actively promoted in the sector are not generally regarded as sufficiently developed. These factors have undoubtedly increased our competitive advantage.
- In reality, our main competitor in the UK municipal waste market remains landfill, which still presents operators with a practical and economic disposal option for wastes other than those which are now prohibited. The government has so far failed to impose sufficient increases in the landfill levy to redress the balance and to make a compelling economic case for waste management companies to change their current practice.
- Our focus is, therefore, on those specific situations where there is already recognition of the need for a new thermal process and Compact Power's technology can be seen as the best environmental option based on our achievements to date.

Our business model continues to be based on a mix of profit from plant sales, participation in build own operate projects and fees from ongoing technology support. This approach continues to be justified as we negotiate the detailed arrangements for projects in development.

In planning for the next phase of the company's development the board has paid particular attention to the funding requirement and the adequacy of existing cash resources. We have taken particular care to prioritise those projects which we believe will be brought to financial close within the reasonably short term and to use our existing resources to meet those objectives.

Contacts

Nic Cooper – Chairman +44 117980 2909

John Acton - Chief Executive +44 117980 2909

Management

Nic Cooper (Executive Chairman) was a founder member of Compact Power and has focused over the last eight years on developing the business and on the promotion of two other start-up companies which have successfully developed technologies with major potential markets. Before that for over 20 years he practised as a solicitor in London specialising in commercial and company work in the UK and internationally including projects in the emerging renewable energy and waste to energy sectors.

John Acton (Chief Executive) has led the development of the Company's technology and the subsequent design, construction and operation of the Company's first commercial plant at Avonmouth, Bristol. He joined Compact Power in 1993, prior to which he was business development director of South West Water, responsible for property development, new business start-ups and non-core business development. During that period he was also managing director of the South West Water/Weir Westgarth joint venture company developing new technologies for the waste water industry. He has also held senior executive and consulting appointments in the paper, the port and harbour, the aluminium smelting and the chemical industries. During his career he has gained extensive experience in the UK and internationally in projects involving the generation and distribution of power and related services.

David Bulman (Development Director) has been commercial director since 1994. He is a solicitor with a background in local authority and environmental law and has specialised in the development of energy projects. He has particular experience of the commercial, industrial and regulatory environment in which Compact Power is intending to promote its project opportunities. Previously, through the development of the privatised UK electricity industry, he has worked on over 30 projects, including the first combined cycle gas turbine, wind, and energy from waste deals. In addition, he has written various reports on renewable energy financing for the Government.

Gonzalo Trujillo (Finance Director) is a Chartered Accountant. Having graduated from Brunel University in 1994 with a degree in engineering, he joined the business advisory division of Coopers & Lybrand where he gained experience working with growing businesses and fast expanding public companies. In 1997, he joined Xerox Corporation as part of the worldwide operational review function leading a number of international finance assignments. He was subsequently appointed as European finance manager for the European professional services division. He joined Compact Power in November 2000 to head the finance function and become finance director in February 2002 having held the position of group financial controller since his appointment.

Max Pearce (Non-Executive Director) has experience in a variety of industries. He is currently Group Chief Executive and Group Deputy Chairman of Haynes Publishing Group plc and a non-executive director of Pennant International Group plc.

Tim Ross (Non-Executive Director), was previously a main board director of George Wimpey plc and responsible for the group's Minerals Division. This division included substantial operations in the collection of commercial, industrial and special wastes, environmental consultancy and the ownership and management of major landfill sites. He is currently a director of Ennstone plc, Connaught plc and other public and private companies, including Churngold Holdings Limited, a venture-capital backed waste collection and recycling business.

Martin Davies Jones (Company Secretary) is a solicitor with over 30 years' experience in commercial and commercial property work. Having graduated in law from Cambridge University, he worked first at Herbert Smith in London before becoming a partner and ultimately managing partner of the Bristol based firm of Osborne Clarke. In 1988 he set up his own firm Crawford Owen specialising in commercial property work before joining Beachcroft Wansbroughs as a partner in 2000.

Senior Management

Benoit Allehaut (European Business Development Manager) joined Compact Power in September 2001. He is responsible for developing alliances with key European market participants. Previously, he worked for SIF, a French investment group, on independent power projects in Eastern Europe and for Enron Europe on government and regulatory affairs, supporting gas and electricity trading initiatives in Romania. He has a degree in international business from the ESCE in Paris and an MBA from Cambridge University.

John Clist (Plant Manager Avonmouth) has over 15 years' experience in the management and operation of waste to energy plant in the hazardous waste sector. Prior to joining Compact Power in December 2000 he was Plant Manager of a clinical waste plant.

Scott Edmondson (Senior Control and Instrumentation Manager) joined Compact Power in January 2000 as senior control and instrumentation manager responsible for the electrical and control systems design, installation and commissioning of the Avonmouth plant. Prior to joining Compact Power he has worked on a variety of projects in the waste water and oil industries as a systems integration project manager.

Richard Hogg (Business Development Manager) joined Compact Power in 1998. Prior to joining Compact Power he was responsible for the national sales and marketing for UK's second largest small and medium business pressure group, The Forum of Private Business.

Iain Johnston (Project Manager) is a chemical engineer and joined Compact Power in May 2001. He has

responsibility for evaluating opportunities and coordinating the development of adopted projects. He has 15 years' experience in the power industry with the Central Electricity Generating Board and National Power Plc the latter for whom he was head of international project development and established a project management framework.

Chris Peggs (Senior Mechanical Engineer) is a chartered engineer and joined Compact Power in September 2000. He is responsible for waste preparation and mechanical handling systems. Prior to joining Compact Power he was a senior engineer for a Japanese company, where he was responsible for the design of integrated waste management systems capable of processing 100,000 to 600,000 tonnes of MSW per annum.

David Sweeting (Engineering Manager) has a degree in engineering science from Cambridge University and started working with Compact Power in 1994. He assisted in the design, construction and operation of the Company's Finham prototype plant and was responsible for the construction and commissioning of the Avonmouth plant. He is now the Company's senior project manager and is responsible for the Company's engineering department.