White Paper

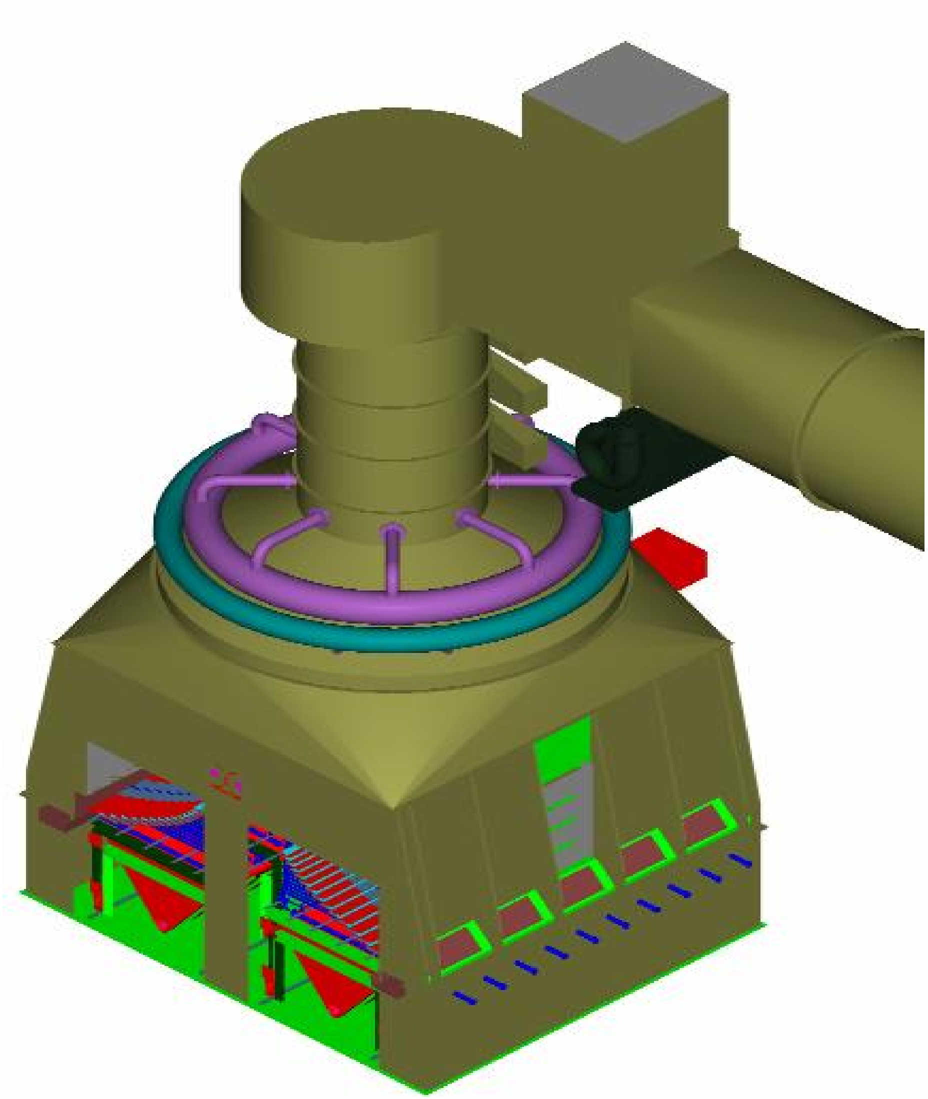
BIOSPHERE ENVIRONMENTAL ENERGY

Ecology Energy Wet Cell Gasification; The "EnvirOcycler"

GASIFICATION

OF MUNICIPAL SOLID WASTE

Municipal Solid Waste is Biomass.



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Municipal Solid Waste Composition

The composition of solid waste is very inconsistent when measured in small quantities. Any particular sample may vary widely when measured against a second sample from a particular waste stream. There are also seasonal and geographic variations in municipal solid waste streams. It is when measured in large aggregates that random samples begin to yield statistics which are meaningful. According to the US Environmental Protection Agency study completed for 2001 a standard waste sample on an American national basis would look as follows:

Figure ES-3: 2001 Total MSW Generation – 229 Million Tons (Before Recycling) [E.P.A., Municipal Solid Waste in The United States: 2001 Facts and Figures]

Paper 35.7%
Glass 5.5%
Metals 7.9%
Plastics 11.1%
Rubber, leather & textiles 7.1%
Wood 5.7%
Yard trimmings 12.2%
Food scraps 11.4%
Other 3.4%

Paper, packaging from cardboard, leather and textiles, wood, yard trimmings, food waste and scraps and a good portion of "other" would fall into the pure "biomass" description. On a national basis the percentage of biomass therefore would be classified as approximately 71% of unsorted single stream Municipal Solid Waste.

It would be expected that Canadian Cities would follow this aggregate summary fairly closely. Herewith detailed Data from Vancouver's G.V.R.D. 2004 Waste Composition Study:

Table 3-7 Projection of study data to the entire GVRD waste stream

Primary Category Secondary Category	Residential Study results 3-site composition	Residential Projected GVRD mass generated (tonnes)	Total Residential, RDO and ICI Composition	Total Residential, RDO and ICI (kg/pers/yr)	Total Residential, RDO and ICI (tonnes/yr)
1 Paper and Paperboard					
Total Category	22.35%	53,305.59	18.65%	93.00	197,784.71
2 Plastics					
Total Category	11.29%	26,929.06	9.28%	46.27	98,399.93
3 Organic Waste					
Total Category	47.85%	114,120.82	45.37%	226.32	481,311.38
4 Metals					
Total Category	2.67%	6,372.21	4.19%	20.91	44,459.39
5 Glass					
Total Category	1.69%	4,041.08	1.34%	6.70	14,246.58
6 Inorganic					
Total Category	0.82%	1,967.22	2.55%	12.71	27,038.17
7 Smaller Appliances					
Total Category	2.26%	5,386.14	4.79%	23.89	50,797.42
8 Hazardous Wastes					
Total Category	0.72%	1,718.18	1.79%	8.95	19,026.06
9 Household Hygiene					
Total Category	6.92%	16,499.71	2.70%	13.47	28,650.44
10 Bulky Objects					
Total Category	1.79%	4,263.14	5.92%	29.55	62,848.20
11 Fines					
Total Category	0.79%	1,888.18	1.54%	7.70	16,384.84
Column Totals			98.13%	489.46	1,040,947.12
Total Received by the GVRD* (tonnes)		**238,518.01**			**1,060,748.29**

As can be seen from the above tables there are variances between the Canadian detail sample and the USA national average. Please note that this table has been abstracted and summarized. There are also some very significant differences between the USA national average and some U.S.A. cities. All of this points to the continuing issue in sampling waste streams –they are highly variable day to day from the same area; they are highly variable by season and by different areas as well.

The solid conclusions from study of MSW composition are that with MSW any system has to be able to handle significant ongoing variance in moisture content, material size, material composition and average Btu value per unit load; secondly despite variances in local conditions and contents, MSW is clearly around seventy percent (or more) pure biomass in complexion. We regard paperboard, paper and organic waste all as generic biomass in handling and material characteristics.

The MSW biomass shares certain physical characteristics with natural biomass. It is typically high moisture content, normally ranging from 35% to 60% average moisture. It is subject to processes of decay and changes in consistency.

Unlike natural biomass MSW has normally been sized to facilitate easier processing and therefore it is relatively smaller in size. It contains primarily the same energy level found in any other "natural" biomass. For example, people are often surprised to find out that spent coffee or coffee grounds contain a colorific value of 25,363 (HHV) KJ/KG. An olive pit has a calorific value of 20,834 (HHV) KJ/KG. Drinking coffee has more waste value than drinking a Martini.

In many cases there has been significant political discourse to prevent biomass in waste streams from being treated as biomass or being treated as "green" for any reason. While public point of view does have input, all discourse should be put through a reality screen and clear economic cost/benefit analysis. Nothing in life is one dimensional. Having a "religious" experience wherein one is told that "recycling is "better at any cost" is unlikely to encourage long term efforts to improve the environment.

One very little appreciated fact is that in general terms waste-to-energy plants have some of the highest recycling rates of any waste treatment system worldwide. Further, the ability to both use single stream waste handling and achieve recycling goals and targets in a single combined effort at reduced cost (which is far less that multi-streaming waste) is one of the most supportive of public goals.

Gasification of Biomass

Coal Gasification type power boilers are well known and understood in North America and the European Union. Large scale gasification units used by the petrochemical and power industries have several hundred installations worldwide. The characteristic of these systems typically is very high temperatures (1,100 C and higher); short residence time and extremely rapid conversion of material in the gasification zone; very careful feedstock preparation by means of crushing and sieving the feed with a very carefully controlled moisture content {coal, for example is reduced to precisely 55 to 57 microns in some processes and less than 3% moisture content}.

When reviewing the above constraints in handling and reviewing the nature of Municipal Solid Waste it quickly becomes evident that the handling characteristics of MSW does not easily conform to that precision. Feedstock preparation to meet these limiting factors in that type of gasification quickly exceeds all economic parameters. Also, copying the practices and principles of coal gasification and applying them to biomass gasification has proven to be naïve. The very short residence time of coal gasification in particular, measured in seconds or a fraction of a second is not applicable to the gasification of biomass. Heat and mass transfer dynamics between coal and biomass are very different. A significant number of failed prototypes and pilot plants have amply demonstrated that fact.

With respect to contemporary, affordable small scale gasification development, the requisite high temperatures have been maintained in order to keep the residence time very short in order to reduce the size of the equipment. However, such efforts have only yielded results that have been less than satisfactory. While short residence times in a small scale pilot situation could provide impeccable results, it only leads to incomplete reaction in the real world situation where the feedstock is not able to be closely controllable. High temperatures are well known to create obnoxious NOx in the flue gas. This in turn leads to unacceptable quality of effluents being discharged in the form of polluted flue gas being vented and the quality of ash still containing partly burnt feedstock being disposed. Where environmental regulations have force and effect and the removal of tars, phenols & other complex chemicals from the flue gas stream the target, the track record has been very poor due to generally inadequate performance of the high temperature low residence time biomass gasification units..

When gasification systems are typically aimed at biomass, two key problems are moisture content and feedstock size. Many systems require moisture contents of well under 20%. These systems have required extensive feedstock preparation in terms of both drying and sizing. Recent studies have put such feedstock preparation alone at an economic cost of $40 to $50 per short ton. Given the capital cost of large scale systems, these costs are not viable in addition to the investment cost and operations costs for a North American market.

In general terms, the use of high temperature sophisticated gasification systems with a target of clean synthesis/producer gas for power production is simply a wishful goal. The products and outputs from synthesis gas should be high value chemicals and compounds.

Using high value synthesis gas to power internal combustion engines after handling all the synthesis gas through complex and control intensive gas cleaning and conditioning is a significant misdirection of resources. It makes little sense to allocate the high capital and costs to waste handling for a product with such a low opportunity or alternative cost basis. This is why sophisticated plasma gasification systems which work so well in pilot/semi-commercial situations still are not widely used anywhere including the EU. Why would you spend $200 processing a ton of waste to yield $0.08/Kilowatt hour power when that same one ton of MSW can be processed for $60 yielding $0.08/Kilowatt hour with the same carbon dioxide goals being met? An additional problem with the plasma systems is their desire to handle everything in a "mass burn" format without recycling activities. Severe capital cost demands that maximum throughput be maintained or excessive tipping fees be established. Reduce, Reuse and Recycle is a pattern to be encouraged as a general statement and is built into our systems.

These high temperature gasification systems also have another issue with reference to MSW. The gasification zone within these carefully fueled gasification process systems is very small. In terms of time it would be expressed as a fraction of a second. The fuel needs to be absolutely predictable in moisture content and consistent in Btu availability if it has to perform at peak efficiency in order to meet the effluent specifications, which as we know is a critical operations target in the real world.

A fuel derived "drop out" or "surge" can be equally damaging and either extinguish the gasification process within the system or create a pressure surge damaging the system. One of the absolute guarantees with Municipal Solid Waste ("MSW") or even Refuse Derived Fuel ("RDF") is that it will be inconsistent from instant to instant on moisture content and highly variable from instant to instant on Btu values.

Similarly, pyrolysis and fast pyrolysis technologies which produce corrosive bio oils with up to 25% moisture content and acidic content requiring stainless steel holding and transportation equipment will not solve as many problems as they can cause. Even the burners using this fuel require stainless steel tips. It is never of high value to produce a product that requires massive and expensive infrastructure changes as typically these never occur.

In the thermal degradation of biomass it can be concluded that the simpler, versatile and more robust system with a generous ability to encompass the MSW, the all better for all. The gasification system should avoid the highly sophisticated petrochemical type approach for a solid basic system which has demonstrated that it is robust and versatile.

Reduction in cleaning systems should be built into the process in such a fashion that the outputs remain clean and best in class without the capital costs. With a target of power production which is in this class of equipment a low target in terms of benefit value, the expensive back end gas cleaning and handling should be dramatically simplified or eliminated. Further the gasification system should be able to handle dramatic swings in both moisture content and Btu values from moment to moment without process difficulties.

Gasification versus Incineration

Gasification normally results in a carbon conversion ratio of over 99% compared to 70%-80% or so for many mass burn incineration plants which will also require almost continuous additional fuel support. A mass burn incinerator has the potential to emit unburned tar and volatile organic carbons into the air producing obnoxious odors and unacceptable smoky air quality. Further, gasification done using our Ecology Wet Cell EnvirOcycler is very tolerant to varying moisture contents ranging from 30% moisture to 65% in the feed stocks while maintaining positive energy output on a fully self sustaining basis. The fact the gasifier can operate in stable condition under varying moisture percentages and organic material fractions of Municipal Solid Waste and other waste streams is a distinct advantage over other systems. The carbon conversion to producer gas is done in an air starved environment at about 75% of stoichiometric requirement. The producer gas thus produced is then completely oxidized using excess air in a highly turbulent double vortex chamber. Incineration is a one step high temperature highly oxidizing environment with almost continuous expensive external fuel support. Gasification is a two step controlled oxidation environment without the need for any additional fuel following startup.

Due to well controlled air intake, the output flue gas from gasification is smaller by volume than an incineration system. The gasifier flue gas composition from an environmental perspective is also much simpler and far less complex than the polluting Tar/VOC laden output from a mass burn incinerator. Gasification is the environmentally preferable way to secure thermal conversion of Biomass and related organic feed stock to energy.

Additionally the gasification system can handle comfortably and safely many incidental waste products like plastics which are very unsuitable for composting. This would also include waste food and food containers which axiomatically attract pests, vermin and disease carrying rats, chemically treated wood waste, construction wood wastes with old paints and chemical finish, diseased plants, pernicious weeds, meat, bones and animal fats, human and animal wastes.

While it is desirable to have goals of waste diversion, much of our quality of living rests on the appropriate packaging of food and products which are manufactured and grown far from home and which are transshipped and transported long distances. Most citizens are highly intolerant of suggestions that they reduce their standard of living to meet someone else's narrow perception of best practices. Our goal has been to incorporate generally recognized best practices in our projects on a single stream basis. We do recommend and normally install a Material Resource Recovery Facility ("MRRF") system in front of our gasification systems. We choose to make the maximum effort to recycle ferrous and non ferrous metals, plastics such as PVC, HDPE etc. and the cleaner fraction of papers and cardboards.

Many cities are well aware of the serious shortcomings and dramatic costs of curbside waste separation programs and recycling programs that are expensive to begin with produce more cosmetic results than a sustainable municipal ecosystem. Gasification with a MRRF is a flexible solution that fits current, medium and future needs. The savings on several fronts from a central gasification plant located in proximity to urban centers far exceed the tipping fees of landfills and avoidable environmentally damaging spills or exposure when transportation, source separation costs (such as multiple box programs) and all of the related costs and charges are considered.

Gasification is a cleaner alternative which is much more palatable than incineration from general public perception.

The energy produced from our gasification systems is very attractive where electricity or heat is needed. Each of our standard energy trains which consists of two 100 MMBTU per hour gasification units will produce a net deliverable continuous output to the grid of approximately 12 megawatts in continuous flow from approximately 1000 wet tons of usable waste per day [using steam turbines driving a power generating alternator]. The potential by products of our process includes recovery of heat for heating, drying or energy co-production; feeding CO_2 outputs into greenhouses with some heat to boost horticultural production and using the dry solid ash as a co-product for construction and aggregate materials.

We have units running on our biomass process, on the original grates, which have been operational for 27 years of continuous work in the American mid west, under an ambient temperature range of -40 C to +40 C. Unlike some novel processes which would be deemed “prototypes” whose true field suitability and merits could be questioned by engineers and financial groups our systems are field proven.

For heat, power and environmental sensitivity our energy system can help projects and cities enjoy a controlled and clean energy output from almost any kind of waste products in an environmentally friendly and suitable manner. We can size our projects comfortably with modular prefabricated systems ranging from 500 tons per day to 5,000 tons per day of feedstock.

The Ecology Energy Wet Cell Gasifier "EnvirOcycler"

The EnvirOcycler is a Canadian developed (on the shores of the Fraser River in New Westminster, BC in 1976), 2-stage gasification unit that gasifies wet (typically) biomass (such as wood waste) in its large 1st stage of gentle, updraft gasification and immediately oxidizes the 1st stage "producer gas", so formed, in its 2nd stage of vigorous, cyclonic thermal oxidation. Units have been in continuous service in the US forest products industry for over 27 years. The EnvirOcycler is believed to be the cleanest wet biomass gasifier combustor in North America today.

Theory of Operation

The EnvirOcyclers 1st stage contains a large, A-frame grate with ash troughs located on either side at the bottom of the grate. Under fire air is admitted uniformly over the entire grate surface. Fuel (3" to 6" minus, depending upon the size of the EnvirOcycler) is supplied to the top of the grate. The fuel works its way, down both sides of the A-frame, to the ash troughs at the bottom of the grate.

As it does, its moisture is evaporated and its volatile matter goes through pyrolysis. The residual char is oxidized (converted to carbon dioxide) or gasified (converted to carbon monoxide), leaving ash in the ash troughs. The combustion of the char on the grate produces the heat that drives the pyrolysis and evaporation reactions. The ash is removed from the troughs by reciprocating unloaders, one unloader in each trough. Unloaders consist of a series of wedges welded to a stainless steel pipe.

1st stage gases – water vapor, pyrolized volatiles, carbon monoxide, carbon dioxide, nitrogen and some methane – rise up from the lower chamber towards the upper 2nd stage. Over fire air is admitted at the top of the 1st stage. The purpose of the over fire air is to burn some of the 1st stage gases so that the temperature of all the 1st stage gases is raised above the ignition temperature of that particular gas mixture.

Primary combustion air is admitted at the inlet to the 2nd stage combustion chamber through a "flame holder". The flame holder acts much like the wire gauze in the centre of a Bunsen burner, in reverse. Primary combustion air issues from the flame holder; the flame holder is surrounded by preheated, combustible, 1st stage producer gas rising upwards. Primary combustion air ignites the producer gas and combustion is initiated.

Secondary combustion air completes combustion. This air is admitted through a number of tangential openings called "tuyères" (from the French word for "nozzle") in the walls of the combustion chamber. Because the top of the combustion chamber is fitted with a "choke" – a restriction that reduces the diameter at the exit from the second stage – the injected secondary combustion air is forced to spiral down the walls towards the flame holder at the inlet to the 2nd stage.

Encountering the flame holder, and the rich mixture of burning 1st stage gases swirling around it, the secondary combustion air reverses axial direction, moves radially inwards and then spirals upwards. As it does, it mixes with – and completes – the combustion of 1st stage producer gas. The flaming gases burn in an intense, upward spiraling, inner vortex – surrounded by a sheath of downward spiraling secondary combustion air.

The flame holder also acts as a barrier to prevent the 2nd stage inner vortex from extending down into the 1st stage. Without the flame holder, a tornado-like funnel would reach down into the 1st stage and draw 1st stage particulate up into the 2nd stage.

The actual amount of 1st stage particulate carried up into the 2nd stage is minimized by the centrifugal action imparted to it by the tangentially injected, high velocity, over fire air. Any particulate, which does reach the 2nd stage, encounters the vigorously rotating inner and outer vortices of the "double vortex" combustion chamber. This particulate is then thrown outward against the combustion chamber wall. It then falls back, down into the 1st stage under the action of gravity. From there the ash is removed by the 1st stage's built-in ash removal system.

Unique features

Low Heat Release Rate Grate

One reason the EnvirOcycler stack is so clean is because of its very low grate heat release rate: a rate that is less than one-third that of a typical biomass combustor. Accordingly, the EnvirOcycler grate is at least three times as big as a typical boiler grate for a comparable Btu output. The large, (low temperature) grate and the high pressure drop across it (see below), minimize particulate lifted off the pile. This in layman terms means a much lower gasification temperature which not only reduces wear on the grate dramatically, it keeps potassium and sodium in agricultural waste from vaporizing and ultimately condensing on the boiler tubes to form "notorious" alkali deposits on the boiler tubing. Both factors reduce wear and tear and associated maintenance and extend equipment life.

High Pressure Drop Grate

The high pressure drop across the EnvirOcyclers grate contributes to the stack cleanliness. The fuel pile's resistance to air flow is small compared to the grate's resistance to air flow. Therefore, the distribution of underfire air up through the grate is uniform, whether or not there is uniform fuel coverage of the grate. There is no bypassing or channeling of combustion air which ensures optimum contact of air and biomass. No "blow holes" develop: blow holes invariably lead to slag formation. In addition to eliminating slag formation the absence of "blow holes" translates into zero "fountains" of wood waste lifting off the fuel pile.

Tangentially Injected, High Velocity, Overfire and Secondary Air

A third reason for the EnvirOcyclers stack cleanliness is the high velocities with which the over fire air and the secondary combustion air are injected into the two chambers. The tangentially injected, high velocity jets centrifugally separate out particulate in the 1st and 2nd stages. Particulate hits the walls and falls back down onto the 1st stage grate. That stage's built-in, continuous ash discharge system removes this particulate matter from the burner.

Double Vortex Combustion Chamber

The fourth reason for the "clean" EnvirOcycler discharge is the double vortex flow established in its secondary combustion chamber. The choke (i.e., the constriction) at the top of the 2nd stage, and the tangential injection of the secondary combustion air, establishes a downward spiraling, outer vortex of secondary combustion air surrounding an upward spiraling, inner vortex of burning producer gas. This stage of combustion ensures almost complete oxidation of producer gas formed in the previous stage. This harnesses all of the energy from the exothermic reaction and helps ensure that the system meets the effluent gas discharge specification.

Particulate, carried up into the 2nd stage by the preheated producer gas, is centrifugally flung out to the walls where it is immediately captured by the downward spiraling outer vortex. Once the particulate reaches the bottom of the 2nd stage it is flung radially outward, hits the 1st stage wall, and falls down onto the fuel pile to be discharged, eventually, by that stage's built-in ash removal system. The "cyclonic" action here ensures very low solids carryover in the flue gas. This again greatly facilitates gas cleaning in order to meet our stringent flue venting targets.

Effect of Alkali in Biomass Ash

Because of the large size of the EnvirOcyclers grate, and because of its high resistance to under fire air flow, the temperature of the grate surface is only 1,250°F (650°C) when burning normal wood residue, relatively speaking really quite cool. In regular hog fuel boilers grate temperatures can exceed 2,000°F (1090°C)). This is significant when burning biomass rich in the alkalis of "potassium" – potash – (KOH) and "soda" (NaOH), such as agricultural waste.

In the early to mid -1990's the subject of alkali deposits in biomass fuelled boilers was quite topical. A DOE report entitled "Alkali Deposits Found in Biomass Boilers" was published in February 1996. The report, NREL/TP-433-8142/Sandia SAND96-8225, was prepared by Sandia, Thomas R. Miles Consulting Design Engineers, National Renewable Energy Laboratory, University of California at Davis, Foster Wheeler Development Corp and the U.S. Bureau of Mines. The report characterizes the different types of ash found in biomass. Based on an analysis of the various deposits found in a number of boilers, and on laboratory tests in a specially constructed apparatus at Sandia, the report concluded that potassium and sodium vapors were the main culprits.

Potassium vaporizes at 1,400°F (760°C); sodium vaporizes at 1,616°F (880°C). When typical biomass burning boilers burn fuels high in alkali content, the potassium and sodium vapors, released on the grate, form salts with chlorine and sulphur compounds in the cavernous furnace above the grate. When these salt molecules contact boiler tubes in the superheater, and elsewhere, they condense. The salts form sticky, flypaper-like, coatings on the boiler tubes. Particulate – lifted off the grate and carried up through the furnace by the rising products of intermediate and complete combustion – sticks to the coated boiler tubes. A progressive buildup of "alkali deposits" on the boiler tubes ensues – especially where a change in gas flow direction occurs.

Because the temperature of the EnvirOcyclers grate does not exceed 1,200^{o}F, the bulk of the potassium and sodium in high alkali wood ash does not vaporize. Rather, it stays in the fuel pile and is removed from the EnvirOcyclers 1st stage by its built-in ash removal system.

As a point of information, the ash removed from the two burners at Norbord Minnesota in Solway, MN is sold to local farmers as a liming agent. The ash was rigorously tested by the Minnesota Department of Agriculture before Norbord was allowed to sell it. In the 1980's Norbord charged the equivalent of $30/acre for the ash. The cost for commercial lime at that time was about $300/acre.

EnvirOcycler Emissions

Particulate, CO and NOx,

1999 tests on the Norbord units showed that, when disposing of typical sawmill residue, EnvirOcycler emissions do not exceed 1 ppmv of CO and 15 ppmv of NOx, all corrected to 8% O2 by volume, straight out of its 2,100^{o}F (1150^{o}C) stack. Translating these concentrations into the United States' Environmental Protection Agency's "source emission factors" format results in a result of: 0.001 lb/MM Btu for CO; and a further result of: 0.033 lb/MM Btu for NOx.

The low CO indicates very complete combustion; this is attributable to the EnvirOcyclers double vortex, combustion chamber. The low NOx – basically "fuel" NOx from nitrogen in the fuel (typically 0.1% in sawmill residue) – indicates the efficacy of the low temperature, "staged combustion" employed in the EnvirOcycler. The EnvirOcyclers discharge temperature is too low to generate much in the way of "thermal" NOx (as indicated in the following paragraph).

Much higher levels of NOx (50 to 150 ppmv) are common when burning fossil fuels. These higher NOx levels of "thermal" NOx are due to combustion temperatures typically in the 2,600^{o}F – 2,800^{o}F (1500^{o}C) range. At such temperatures the nitrogen in the combustion air (4 parts by weight of nitrogen are brought in with each part of oxygen) dissociates and readily combines with oxygen to form NOx. NOx leads to acid rain. It also reacts with VOC's (volatile organic compounds such as automobile exhaust), and forms ground level ozone.

In order to reduce this low NOx even further, additional steps are being taken, for which please review in the M.A.C.T. section of this paper.

Similarly, 1978 particulate tests on an earlier unit disposing of typical sawmill residue yielded 100 mg/Nm3, or 0.04 grains/dscf, of particulate straight out of the unit's stack. This translates into an EPA source emission factor of about 0.12 lb/MM Btu for particulate.

It needs to be pointed out that the EnvirOcyclers products of combustion are, typically, routed through waste-heat boilers or waste-heat heat exchangers. In so doing, the sensible heat extracted from the products of combustion lowers the waste-heat device's stack temperature down to, typically 350^{o}F (177^{o}C). A bag house can then be used to lower the amount of particulate released to atmosphere by a factor of 5, i.e. down to 0.01 grains/dscf, 20 mg/Nm3 or 0.02 lb/MM Btu.

Dioxins and Furans

The dioxin issue initially arose in the 1960's when chlorine, used by pulp mills to bleach Kraft (brown) pulp, was shown to create dioxins. Deformed fish in streams fed by pulp mill effluent were traced to dioxins and furans.

Dioxins, and their sister compounds, "furans", form when cellulose molecules (from wood and paper) react with chlorine molecules (from NaCl in bark from salt water borne logs, from bleach used in pulp mills and from PVC's – polyvinyl chlorides – in plastics). Physically what happens is that chlorine atoms exchange places with some of the hydrogen atoms along the cellulose molecule. The number and position of the chlorine atoms define the different dioxins and furans.

The dioxin issue was further fuelled in the 1970's when the 1973/1978 "oil shock" hit and US President Jimmy Carter declared "War on Energy". Around the same time cities began to run out of room in their landfills. The "in" thing to do was to burn garbage in municipal boilers, produce steam and generate electricity. However, once the plants were operational, emissions from some boilers were shown to contain dioxins and furans. The cause was traced to incomplete combustion of paper and plastic products in the boiler furnace.

The dioxins/furans formed because the paper and plastic wastes were typically burned in a shallow pile on a hot grate (temperatures above 2,200oF/1200oC) in a big, cavernous furnace. The furnace was lined with "black" water walls (boiler tubes filled with water). The adjective "black" is used in a radiation sense. A "black body" absorbs 100% of the radiation it receives.

Small and large chunks of cellulose based material in these furnaces were lifted off the grate – and flew around the furnace – due to the large volume of air injected up through the grate. Some of the burnable gases distilled off the fuel pile did not complete combustion. Their combustion reactions were chilled before completion by heat radiated away to the black water walls. These products of incomplete combustion left the furnace, traveled through the boiler's convective banks and were discharged up the stack to atmosphere.

The foregoing describes what took place and, more than likely, still takes place, in large, mass burning, municipal boilers in cities around the world. However, none of the above takes place in an EnvirOcycler.

The fuel in the EnvirOcycler forms a deep pile – particularly for wet fuels – on the EnvirOcyclers very large, low temperature grate. Under fire air (in quantities greatly reduced from those used in conventional furnaces) gently percolates up through the high pressure drop grate, gasifies the fuel in the pile above, and generates a low Btu, "producer" gas. As explained above the producer gas is preheated by over fire air, admitted above the pile, which ensures the ignition of the producer gas in the EnvirOcyclers yellow hot 2nd stage.

Any dioxins or furans that might have formed in the EnvirOcyclers 1st stage are completely consumed in the EnvirOcyclers second stage of vigorous, cyclonic combustion. No black water-walls are present to chill the reactions taking place in its inner vortex of flaming gases. The second stage is lined with hot, glowing refractory. No dioxins or furans survive the Time, Temperature and Turbulence in the EnvirOcyclers second stage inner vortex.

Material Resource Recovery Facilities and our Gasification Systems

The Ecology Wet Cell gasification systems is all about converting waste biomass of every description into clean renewable process heat and electricity. We are not about indiscriminate incineration of recyclable materials or hazardous materials. Our projects are based on a Material Resource Recovery Facility ("MRRF") between our waste reception and gasification areas. We use state of the art equipment to sort, size and remove ferrous and non ferrous metals, plastics, glass and clean papers for recycling whenever economically possible.

We will also receive other non-recyclable biomass from other MRRF's for beneficial conversion to energy. Our output is reduced by approximately 94% before inert content, and that output consists of dry, sterile fly ash. Our fly ash can be beneficially reused as aggregate additions, daily cover, mix in aggregate for concretes, and depending on waste composition an excellent liming agent for farmers.

We support diversion goals of municipalities through our MRRF systems. We also understand and appreciate that smaller scale handling of waste streams in outlying areas cannot be based on the capital equipment intensive central projects. Logistics dictate and require that we adopt effective alternative strategies. These can include bio digestion (large and small) or fermentation to create usable bio gas, landfill gas systems on existing waste sites, compost systems to convert appropriate wastes to new soil amendments, changes to packaging and retail models as well as other innovative modalities.

Creosote and Tars

Creosote is created by the natural combustion of fresh and dried wood. It also is present as a wood preservative on numerous waste feed stocks which enter the waste stream such as old railway ties, discarded wooden telephone poles and similar.

Creosotes, tars, resins are complex mixtures of variable composition. They contain primarily condensed organic aromatic ring compounds or phenols. It is a mixture of compounds and so it is not possible to represent these materials with a single chemical formula and structure. Wood creosotes are derived from the trunk and stems of trees and the resin is from leaves of the trees. Wood creosote consists mainly of phenol, cresols, guaiacols, and xylenols. Depending on the type of wood, Creostote is a colorless or pale yellowish liquid to darker yellow fluid, and it has a characteristic smoky odor and burnt taste. Beechwood Creostote had therapeutic applications in the past as a disinfectant, laxative, and a stimulating expectorant, but it is not a major pharmaceutical ingredient today in the United States. The mixture can be characterized as mainly consisting of Phenol, *p*-cresol, and guaiacols. Creosote is given off by the wood when is subjected to heat. Initial flow is mainly the lighter fraction. The flow of Creosote is slow to start with and gradually increases as the temperature is increased. Creosote flows out vigorously from wood at about 200-220 ^{o}C.

During our process of gasification biomass drops from our auger feed onto the top of the walking grate forming an initial “pile”. The wood then migrates into the bulk of the pile and during the process slowly gains heat. As the piece of wood is heated the moisture starts to evaporate at a faster rate. Most of the moisture is lost as the wood reaches closer to 100^{o} C. As the wood moves further down the pile and attains higher temperature creosote starts to flow out and slowly vaporize. At about 200 ^{o} C creosote starts to emerge vigorously out of the wood and vaporize. However the creosote vapors have to percolate through the upper sections of the conical pile which is cooler and at a lower temperature. Hence the Creosote condenses on the wood in the cooler section of the bed and is again vaporized and released slowly as the bed moves lower into the pile as it gradually picks up heat. In this manner the Creosote vigorously coming off a smaller cross section of warmer bed below is absorbed by a much larger section of cooler bed above, which is then slowly vaporized to be carried away by the under-fire air.

Essentially the bed by itself functions as a self controlled “slow release” mechanism for releasing Creosote. Eventually Creosote vapors flow out, leave the pile and enters the flame holder section of where it undergoes decomposition and partial oxidation to yield Carbon Monoxide and Hydrogen. Since Creosote release is slow, well dispersed in air and is very well “self controlled” by the pile, the reaction above the pile in the flame holder section is essentially 100% complete.

The gases flowing into the flame holder section is at very low velocity and well under the turbulent region. It is not possible for the creosote in vapor state to short circuit or bypass the flame holder section in any manner whatsoever. Hence the destruction of Creosote is total as the gases leave the flame holder section in the 1st stage.

The 2nd stage of the gasifier is at a much higher temperature, richer in excess oxygen and highly turbulent in order to completely convert Carbon Monoxide to Carbon Dioxide and Hydrogen to Water. Creosote is highly reactive to oxygen at higher temperatures. Any minute trace of Creosote that may escape the flame holder section in the 1st stage is bound to decompose and burn up given the very aggressively hot conditions in the 2nd stage. Therefore it is impossible for the Creosote to escape the gasifier.

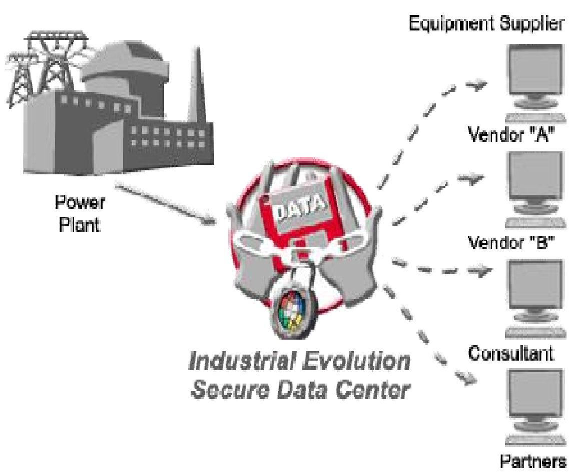
An excellent indicator of quality of gasification and efficiency of the gasifier is the Carbon Monoxide content in the flue gas finally being vented. Carbon Monoxide content in the flue of 10 ppm or less indicates excellent and efficient performance of the gasifier. This indicates conclusively that the oxidation of Carbon Monoxide is complete, hence the reaction of all other highly flammable substances like Creosote are also complete. If Creosote were to escape into the flue gas, which could only happen if there were inefficient reaction conditions in the gasifier, the Carbon Monoxide content in the flue will immediately shoot up beyond 100 ppm and well into 1000 ppm range. Hence one can conclusively say that there can be absolutely no Creosote in the flue gas if the Carbon Monoxide content in the flue gas is under 10 ppm. The test conditions on the running gasification units are well below the 10 parts per million level, so we have both efficient gasification and no Creosote.

M.A.C.T. and the EnvirOcycler

The environmental control of any thermal process is of the highest concern to regulators. It is also of primary concern to a "green" group who seek to establish waste to energy as an environmentally positive project changing a perception paradigm while meeting the highest possible standards. In order to accomplish this, we have started with a proven gasification unit which has very high conformance to existing standards. As with any technology it will also be equipped with maximum available control technology to provide state of the art conformance to operate continuously within permitting conditions.

The untreated outputs of CO at less than 10 ppm and NOx at 15 ppm or better are a good start on full conformance to tough permitting conditions. The new generation of our EnvirOcycler will have enhanced performance parameters which come from several areas.

Firstly, the sensor suite which is being installed on the equipment will have well over 100 discrete data points throughout the entire process giving us very detailed and highly accurate measurements of system performance. This should allow us to very effectively tune system performance. These measurements are fully captured electronically and are available not only in real time, but in historical data sets as well on a web basis.



Our model on data sets gives us remote access on the internet; it also stores the data offsite in a data vault. The data sets are available in a minute to minute history, and as well the data parameters are preprogrammed to send alarms to multiple parties if any set conditions are beyond normal operating parameters.

This allows the plant operations staff, the engineering support center and the key system vendors to respond without delay to any exception conditions, often before those exception conditions have an opportunity to get to outside of boundary events. It also ensures that conditions throughout the pollution control section of the plant are subject to very tight ongoing control.

Secondly, we have been very careful to select vendors and proven leading edge treatment systems that do the job, reliably and well under tough plant conditions. For example, our bag house is set to trap all particulate at 2.5 parts per million. Further, our bags contain a catalytic material that will chemically decompose dioxins and furans and is proven in hazardous waste incineration facilities that do produce large amounts of dioxins and furans, which our equipment does not.

Thirdly, we achieve some significant reduction in undesirable waste streams in our front end MRRF. We target to keep out of the thermal reduction things such as plastics, mercury light bulbs, ferrous and non ferrous metals, tires, aluminum cans, batteries, chemicals and the like. We do not want hazardous waste in our systems and we work to make it so. We want to see plastics recycled and we work within a concept of reduce, reuse and recycle. If undesirables go not go into the systems, then undesirables do not have any chance to come out of the systems.

Fourthly, where waste composition studies prior to project commencement show that there will be some undesirables that cannot be fully captured or prevented from entering the waste stream at the front end of our project, we plan accordingly. We will install a very advanced Wet Electrostatic Precipitator ("WESP") downstream of our catalytic bag house. WESP's perform the dual function of a scrubber and an ESP (dry) in order to maximize capture efficiency. This will effectively reduce our very low particulate count even further while catching a very high percentage of vaporized metals in the waste gases. Typically we can achieve a five nines [99.999%] reduction in many potential outputs, and we have documented case studies where this has been achieved. Due to "cooler" grate temperatures of our technology compared to many other gasification technologies the amount of metals vaporized into the flue gas will be significantly lower; the less vaporized metal going in, axiomatically, the less vaporized metal coming out.

In addition to the standard M.A.C.T. work being applied to our technology, we are developing some new equipment which should help reduce emissions even further. In concert with the Department of Energy's Idaho National Laboratory we will shortly be commissioning design work on a new third stage re-burn unit for our products of combustion. Department of Energy field testing and work has indicated a 60% reduction of existing NOx should be possible using a specifically designed unit. This has the potential of dropping our existing 15 ppm output to 6 ppm. Once we achieve this limit it is our intention to marry urea injection with this which may yield up to another 1.2 ppm to 2 ppm reduction so that our systems would have reduced NOx to a very impressive 4.0 to 4.4 ppm limit. While we are not there yet we expect that this will become commercial on our equipment within thirty six months.

Summary of Key Features, Ecology Energy Wet Cell Gasification

To summarize here are some of the key features in of our two-stage gasifier/thermal oxidizer which are critical for the clean disposal of Municipal Solid Waste and Biomass of every description:

- ✓ Up to 1 hour and longer (depending on moisture content) biomass residence time in the gasifier bed for slow and complete updraft gasification.
- ✓ Biomass moisture variation acceptable from 30%to 65%
- ✓ Biomass size up to 6 inch minus is acceptable.
- ✓ Large grate area, more than three times the regular size for low temperature and low velocity air flow.
- ✓ Large biomass inventory in the gasifier to even out feedstock moisture and Btu variations for steady operation
- ✓ Very low air velocity up through the biomass bed for very low solids elutriation (lifting off the pile).
- ✓ Low grate temperature for very low NOx production.
- ✓ Low grate temperature for zero vaporization of alkali metals.
- ✓ Low grate temperature for very low dioxin and furan production.
- ✓ Highly turbulent second stage for complete combustion of Creosote, Tars and CO, less than 10 ppm CO in flue gas.
- ✓ Highly turbulent second stage for total destruction of dioxins and furans.
- ✓ Catalytic bag filter for capturing and decomposing dioxins and furans in flue gas.
- ✓ Wet ESP to capture 99.99% of heavy metals such as Mercury, Arsenic, Chromium and Copper in flue gas.
- ✓ Wet ESP to capture traces of NOx, SOx and Cl_2 before venting.
- ✓ Two stages of cleaning virtually capture all solid particulate.