

WASTE GASIFICATION

IMPACTS ON THE ENVIRONMENT AND PUBLIC HEALTH

A TECHNICAL REPORT PUBLISHED BY

The Blue Ridge Environmental Defense League

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Preface

WASTE GASIFICATION: Impacts on the Environment and Public Health was first published by the Blue Ridge Environmental Defense League in 2002. The purpose of this updated and expanded revision remains unchanged: to inform community leaders, government officials and public policy makers about the environmental and health impacts of the thermal destruction of waste products. The report is intended for both the technical reader and the layperson. The investigation and documentation presented utilize generally available sources and techniques. The data and analyses are current as of the cover date. We have added a new chapter on global warming-inducing greenhouse gases. Revisions will continue to be done as necessary. Readers who note inactive or changed websites are encouraged to contact us.

Mission Statement

The Blue Ridge Environmental Defense League is a regional, community-based non-profit environmental organization whose founding principles are earth stewardship, environmental democracy, social justice, and community empowerment. BREDL encourages government agencies and citizens to take responsibility for conserving and protecting our natural resources. BREDL advocates grassroots involvement to empower whole communities in environmental issues. BREDL also functions as a “watchdog” of the environment, monitoring issues and holding government officials accountable for their actions.

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Overview: Pyrolysis and Thermal Gasification of Municipal Solid Waste

Gasification and pyrolysis are similar processes; both decompose organic waste by exposing it to high temperatures. Both processes limit the amount of oxygen present during decomposition; gasification allows a small amount of oxygen, pyrolysis allows none. In other words, gasification and pyrolysis limit or prevent oxidation. In this report we use the term “gasification” to include both starved air gasification and pyrolysis. Plasma arc gasification uses electrically generated plasma torches to converting waste material into gas and a slag byproduct.

In the presence of air, heat causes organic materials to burn. Burning or oxidation is what typical incinerators do. The burning of waste in incinerators causes well-known negative environmental and public health effects. Incinerators emit nitrogen oxides, sulfur dioxide, particulate matter, carbon monoxide, carbon dioxide, acid gases, lead, cadmium and mercury, and organic compounds, such as dioxins and furans, into the atmosphere. In 1960 mass burn incinerators burned 30% of the municipal solid waste in the United States. By 1988 this total had dropped to 13% because of air pollution problems.¹

Gasification facilities produce gas—primarily carbon monoxide and hydrogen (85%)—plus hydrocarbon oils, char and ash. Gasification plants’ air emissions also include nitrogen oxides, sulfur dioxide, particulate matter, carbon monoxide, carbon dioxide, methane, hydrogen chloride, hydrogen fluoride, ammonia, heavy metals mercury and cadmium, dioxins and furans.

Gasification of municipal solid waste, household garbage and commercial waste products was used in the United States in the 1970s, but those plants were closed because of operating and financial problems. Today there are only a handful of pyrolysis units burning municipal solid waste, located in Japan, Taiwan, Great Britain and Canada.

Gasification facilities share the same environmental problems associated with mass burn incinerators including:

- Air pollution
- Water pollution
- Disposal of ash and other by-products
- Large amounts of water for cooling purposes
- Health, safety, and odor impacts
- Disincentives for waste reduction
- Diversion of waste from composting and recycling

The gas produced from municipal solid waste contains hazardous organic compounds but the technology to remove these toxins does not exist on a commercial scale. (See Appendix A)

The ash which remains after gasification, 8% to 15% of the original volume, is toxic and presents special problems because of the acidic, or low pH, conditions in landfills. Leaching of toxic metals cadmium, lead, and mercury occurs more rapidly at low pH, resulting in contaminated groundwater.

¹ G. Fred Lee, *Environmental Contamination Problems Cased by Sanitary Landfills*, G. Fred Lee & Associates, El Macero, CA 95618, 1993

The organic material in solid waste necessary for the gasification process is the part of the waste stream most valuable for composting. Sixty percent of solid waste is paper, cardboard, wood, yard waste, and food scraps.

The economics of gas transport require power generation units burning the gas to locate at or near gasification facilities; multiple smoke stacks in an area bring larger air pollution problems.

Gasification undermines waste composting and recycling programs. Technologies which utilize high temperatures to process solid waste incineration, waste-to-energy, gasification, and others have negative effects on low tech methods, a problem which is compounded when recyclable materials are not removed before processing. For example, paper is a valuable material which is lost when reduced to a gas. Aluminum, steel, and glass are easily recycled when separated from solid waste but unrecoverable from gasification process slag.

The principal benefit touted by promoters of high temperature technologies, energy recovery, is far outweighed by the energy loss tied to the destruction of energy-intensive solid waste materials. Gasification produces a low-Btu gas with 25% of the heat content of natural gas. But recycling glass, aluminum, and paper preserves the large amounts of energy needed to produce them from silica, bauxite, and trees; products made from recycled cullet, cans, and paper utilize a fraction of the energy needed to make them from raw materials.

The Gasification Process

Gasification is a process that chemically and physically changes biomass through the addition of heat in an oxygen-starved environment. The end products of gasification include solids, ash and slag, liquids and synthesis gas, or syngas. The gas has a calorific value, or potential heat content, equivalent to 25% that of natural gas if ambient air is used or 40% if oxygen-enriched air is used.² Figure 1 on the following page illustrates the process: combustion chambers, power boiler, pollution controls, and pollution by-products: bottom ash and slag, fly ash, and air emissions.

A waste industry trade association monograph describes the starved air combustion process as follows:³

This type of incineration consists of two chambers: the primary is operated at below the stoichiometric air requirement and the second operated under excess air conditions. The waste is fed into the primary chamber and semi-pyrolysed, releasing moisture and volatile components. The heat is provided by the controlled combustion of fixed carbon within the waste. The syngas that is driven off contains a high calorific value and can act as a feedstock for the secondary chamber. Importantly, combustion air is then added to the syngas making it highly combustible and prone to self-ignition. The secondary chamber is equipped with a conventional burner to maintain operating temperature at all times. The combined gases are combusted in the

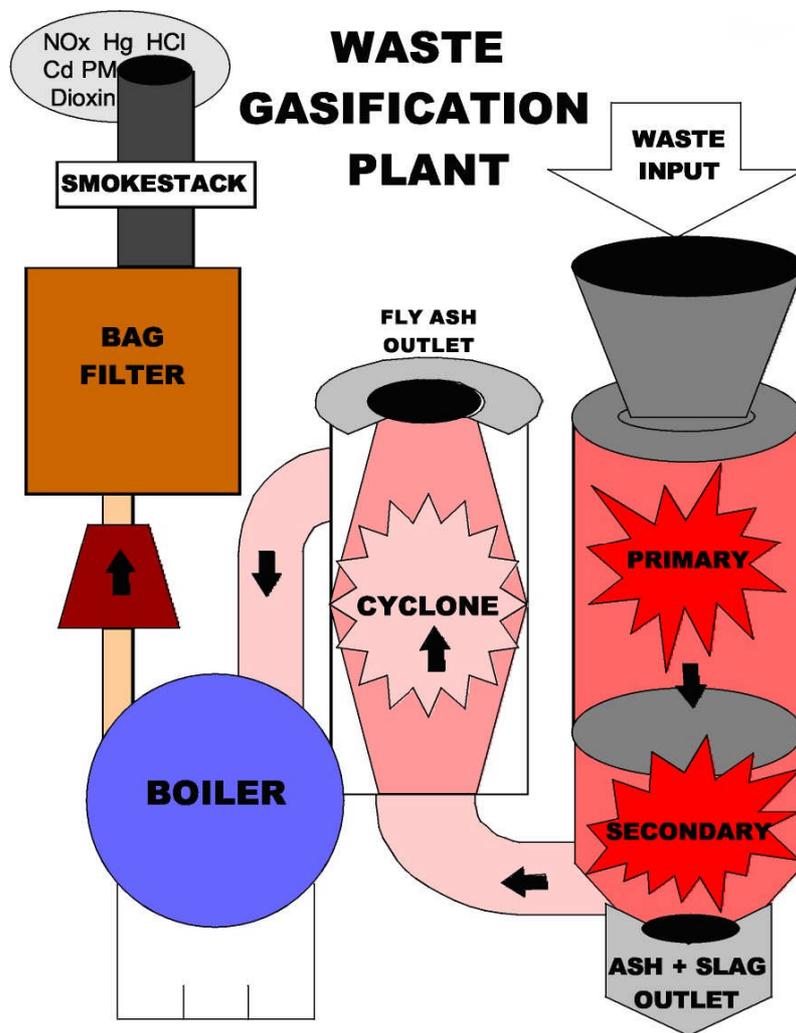
² "Update on Pyrolysis," monograph, Health Care Without Harm, March 19, 2002, downloaded February 3, 2009 from <http://www.noharm.org/details.cfm?type=document&id=623>

³ "Methods of waste treatment," monograph, Sanitary Medical Disposal Services Association, downloaded February 3, 2009 from <http://www.smdsa.com>

secondary chamber.

The industry monograph describes pyrolysis as a similar process but with no oxygen present in the first combustion chamber: “Materials are heated in the absence of Oxygen to about 800°C. Hydrocarbons are converted to simple gases leaving a residue of carbon char, inert materials and heavy metals.” Plasma arc furnaces replace the fossil-fuel heat source with an electric arc.

Figure 1: Diagram of the Waste Gasification Process



BLUE RIDGE ENVIRONMENTAL DEFENSE LEAGUE

Although some gasification facilities have been designed and constructed in the past two decades, most have been demonstration and laboratory-scale systems. A few large scale demonstration plants in the US experienced technological problems and are no longer operating. In 2006 the US Environmental Protection Agency Office Air and Radiation selected a solid

waste gasification project for research and development, but the project has not moved forward.⁴ There are currently no commercial-scale solid waste gasification systems operating in the United States. (See Appendix B)

Emission of Air Pollutants

Incineration of solid waste is a technology which is being phased out across the United States. According to Dr. Paul Connett, “Since 1985 over 280 incinerator proposals have either been defeated outright or put on hold.”⁵ Unreliability, economics, environmental concerns, and citizen opposition have forced municipal officials to find new methods of managing solid waste.

Gasification shares many characteristics with incineration. At high temperatures used in incineration and gasification, toxic metals including cadmium and mercury, acid gases including hydrochloric acid, and ozone-forming nitrogen oxides are released. Also, dioxins and furans are created in the cooling process following the burning of ordinary paper and plastic. These poisons are dangerous at extremely low levels and modern pollution control devices do a poor job of reducing these emissions into the atmosphere. Some including mercury and dioxin are persistent and bioaccumulative; they resist breakdown in the environment and are concentrated in the food chain.

The Environmental Protection Agency database on industrial air pollution—Emission Factors AP-42—does not include a specific category for solid waste gasification. However, there is a category for “starved-air” combustion. When the oxygen level in a heating unit is reduced to a level below that needed for complete combustion, it is called a starved-air unit. EPA does list Emission Factors for Modular Starved-Air Combustors.⁶ The data table is reproduced in Appendix C of this report.

The regulatory requirements and permitting decisions for gasification units would likely be based on the facility which is most similar, a starved-air combustor. (see Appendix D) The AP-42 includes emission levels for 13 pollutants, with and without electrostatic precipitators: (beginning with the highest) carbon dioxide, particulates, sulfur dioxide, nitrogen oxides, hydrochloric acid, carbon monoxide, mercury, nickel, chromium, lead, cadmium, arsenic, and chlorinated dibenzo-furans and -dioxins. The AP-42 factors show that emissions of only five of the pollutants are reduced by ESPs, six are unchanged, and dioxins and furans are higher. The EPA AP-42 lists air emissions in pounds per ton and kilograms per metric tonne of waste input.

Using the AP-42, one can calculate the emissions from an air pollution source. For example, a 100 ton-per-day starved-air combustor could burn 36,500 tons of garbage per year. Based on these data, annual air emissions would be as shown in Table 1 (page 7).

⁴ Robert J. Wayland, U.S. EPA’s Clean Air Gasification Activities, U.S. EPA Office of Air and Radiation, Office of Air Quality Planning and Standards, Presentation at the Gasification Technologies Council, Tucson, Arizona, January 26, 2006

⁵ Paul H. Connett, WASTE NOT #315, A publication of Work On Waste USA, Inc., MARCH 1995, downloaded February 3, 2009 from <http://www.americanhealthstudies.org>

⁶ Emissions Factors & AP-42, Chapter 2 Solid Waste Disposal, Table 2.1-9, US Environmental Protection Agency Technology Transfer Network, downloaded February 3, 2009 from <http://www.epa.gov/ttn/chief/ap42>

TABLE 1. Air Pollutants from Starved-air Combustion/Gasification

Pollutant	Uncontrolled	Electrostatic precipitator
Particulate matter	125,195 pounds	12,702 pounds
Sulfur dioxide	117,895 pounds	*
Nitrogen oxides	115,340 pounds	*
Hydrochloric acid	78,475 pounds	*
Carbon monoxide	10,913 pounds	*
Mercury	204 pounds	*
Nickel	201 pounds	37 pounds
Chromium	121 pounds	22 pounds
Lead	103 pounds	-
Cadmium	88 pounds	17 pounds
Arsenic	24 pounds	4 pounds
Dioxins/furans	0.11 pound	0.14 pound

* same as uncontrolled

The EPA's AP-42 Emission Factors are the basis for air pollution regulations in all 50 states. There are no other regulatory emissions data or emissions factors for solid waste combustors. With no new federal studies to demonstrate otherwise, allowable hazardous air pollutant emissions from permitted gasification units will be identical to the limits for incinerators.

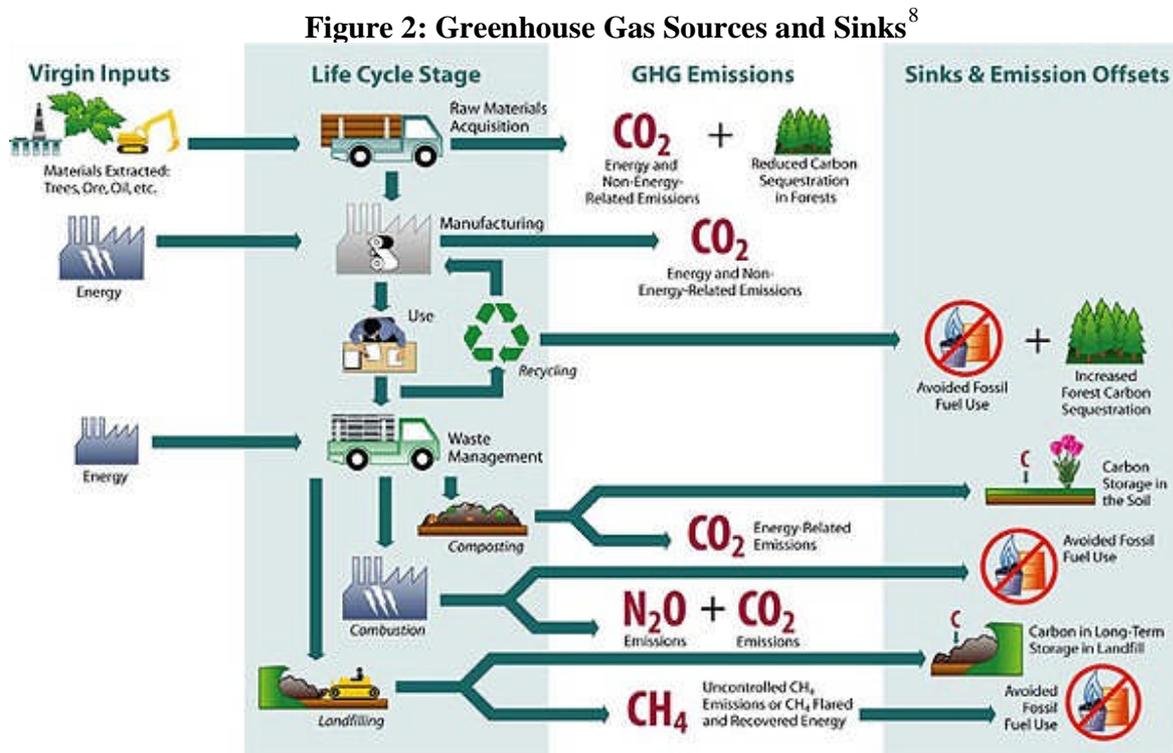
Waste Gasification Adds Greenhouse Gases

In addition to the currently regulated air pollutants from municipal solid waste gasification, the process also adds greenhouse gases to the atmosphere. The biggest contributor to global warming, carbon dioxide, could soon be regulated as a pollutant by the US Environmental Protection Agency.

Using municipal solid waste for fuel releases into the atmosphere the carbon which is in the paper, cardboard, food wastes, yard wastes and other biological materials, plus the carbon in plastic products and containers made from petroleum. The gasification of petroleum-based plastics adds to greenhouse gases in the same way as burning fossil fuels such as coal, oil or natural gas.

It is the release of carbon, carbon that has been locked up in fossil deposits for millions of years, that is driving global warming. However, carbon released into the atmosphere from the burning or gasification of waste products made from trees and crops also adds to greenhouse gas levels in the atmosphere. Over time some of this carbon is taken up again by new growth in forests, but in the short-term the damage is done. The US EPA published an analysis of

greenhouse gas (GHG) impacts caused by various solid waste management options.⁷ As can be seen in the EPA illustration in Figure 2, solid waste disposal plays a role in global warming including the greenhouse gases from waste combustion.



The different sources of greenhouse gas (GHG) emissions from waste are shown above. The disposal of solid waste produces GHGs in a number of ways. First, the anaerobic decomposition of waste in landfills produces methane, a GHG 21 times more potent than carbon dioxide. Second, the incineration of waste produces carbon dioxide as a by-product. In addition, the transportation of waste to disposal sites produces GHGs from the combustion of the fuel used in the equipment. Finally, the disposal of materials indicate that new products are being produced as replacements; this production often requires the use of fossil fuels to obtain raw materials and manufacture the items.⁸

⁷ We note that the EPA assessment cited here concludes that there is a net greenhouse gas emission benefit from the combustion of municipal solid waste in waste-to-energy units. However, the EPA's methodology incorrectly assumes that electricity from waste combustion would offset only fossil-fueled power stations. The EPA study entitled *Solid Waste Management and Greenhouse Gases—A Life-Cycle Assessment of Emissions and Sinks* states: "Estimates of GHG emission reductions attributable to utility emissions avoided from waste management practices, however, are based solely on the reduction of fossil fuel use. We adopted this approach based on suggestions from several reviewers who argued that fossil fuels should be regarded as the marginal fuel displaced by waste-to-energy and landfill gas recovery systems." (Executive Summary, page E-7 and footnote 15) This is a fatal flaw.

⁸ *Solid Waste Management and Green House Gases: A Life-Cycle Assessment of Emissions and Sinks*, Second Edition, EPA530-R-02-006, May 2002, downloaded February 3, 2009 from [http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BUMHU/\\$File/greengas.pdf](http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/SHSU5BUMHU/$File/greengas.pdf)

Recycling and composting far exceed all other waste management options in reducing greenhouse gas emissions. A study by the Tellus Institute for the State of Massachusetts⁹ concluded that:

Our review of the LCA (life cycle analysis) literature and our modeling outputs confirm that, after source reduction, waste diversion through recycling and composting is the most advantageous management option from an environmental and energy perspective. Because it releases bound carbon in materials such as plastics, thermal conversion of certain materials to fuels or energy is problematic from a climate change perspective even at the potentially high energy recovery levels of advanced conversion technologies. Similar to the situation for WTE (waste to energy) incinerators, the capital requirements for building alternative technology facilities and their likely need for long-term contracts to ensure an adequate feedstock waste stream may limit the future flexibility of the state's overall materials management efforts.

Waste gasification adds both directly and indirectly to the build-up of greenhouse gases in the earth's atmosphere. It is not a solution to the global warming problem; it is instead part of the problem—a part that should be eliminated as a waste management option.

“By destroying resources rather than conserving them, all incinerators, including mass burn, pyrolysis, plasma and gasification, cause significant and unnecessary lifecycle GHG emissions.”¹⁰

Emission of Water Pollutants

Combustion and gasification may reduce solid waste volume by 85% to 92%,¹¹ but the remaining ash, 8-15% of the original waste, must be disposed of. Typically, it ends up in landfills and contains some of the same toxic compounds listed above, particularly heavy metals. Toxics in combustion ash ultimately find their way to groundwater and surface water, contaminating water supplies.

A national controversy about ash toxicity erupted in 1995 when then-EPA Administrator Carol Browner allowed incinerator operators to mix bottom ash and fly ash together prior to toxicity testing. Fly ash raises the pH of the ash, reducing the reliability of the tests. But citizens who gathered samples of ash from incinerators which had passed the EPA's tests found very high levels of toxic metals. The results of those tests are compiled in Table 2, below. Dr. Paul Connett described the methods used by landfill neighbors to get laboratory samples.

The ash from Ogden Martin's 990 ton-per-day MSW incinerator in Syracuse, NY, which went on line in November 1994, was classified as non-hazardous after it passed the TCLP [toxicity characteristic leaching procedure] test. Citizens living close to the landfill, where the ash is used

⁹ *Assessment of Materials Management Options for the Massachusetts Solid Waste Master Plan Review*, Submitted by the Tellus Institute to the Massachusetts Department of Environmental Protection, Contract No. EQEH193, December 2008, downloaded February 2009 at <http://www.mass.gov/dep/recycle/priorities/tellusmmr.pdf>

¹⁰ Brenda Platt and Eric Lombardi, “Stop Trashing the Climate,” *BioCycle*, Vol. 49, No. 8, p. 24, August 2008

¹¹ Lowell Miller, Product Line Director, Fuel Systems Office of Fossil Energy, U.S. Department of Energy, Conversation with Louis Zeller on March 29, 2002

as a daily cover, surreptitiously retrieved some of this ash and asked N.Y. State Wildlife Pathologist, Ward Stone, to test the ash for heavy metals, because the landfill abuts the Montezuma Wildlife Refuge in Seneca County, NY. Stone analyzed the ash for total heavy metal content. The ash was found to contain hazardous levels of lead, cadmium and mercury.¹²

TABLE 2. Heavy Metals in Incinerator Ash Compared to Soil

Metal Tested Results in parts per Million (ppm)	Ogden Martin Syracuse, NY Incinerator	Foster Wheeler Hudson Falls, NY incinerator	Mean background levels in US soils
LEAD	1400 ppm	2650 ppm	35 ppm
CADMIUM	40.1 ppm	60.3 ppm	0.30 ppm
MERCURY	4.3 ppm	4.1 ppm	0.18 ppm

The TCLP test is still used to determine toxicity of solid waste ash; passing the test allows it to be disposed of in a solid waste landfill. However, passing the test does not mean that the waste ash is not hazardous. As the tests done by Ward Stone proved, the ash residue left after waste is burned may contain hundreds of times as much toxic metal as uncontaminated soil. Dr. Connett summarized the environmental and public health impacts:¹³

Carol Browner, the head of the US EPA, handed the incinerator industry a huge gift by allowing the incinerator operators to mix the fly ash with the bottom ash prior to testing. The bottom ash contains no lime. A TCLP test applied to this ash alone would probably yield a pH in the acid range and one would anticipate a failure rate of about 30 to 40 percent of the time, as in the case of the old EP Toxicity Tests. However, when the fly ash is mixed with the bottom ash, the lime protects the bottom ash as well. Again, the leaching medium will not reach pH 5, but stay in the range of lead's least solubility. As bottom ash represents 80 to 90 percent of the total ash, this protection represents a huge financial bonanza to the incineration industry. While the TCLP test serves the industry's interests, it presents a major threat to human health and the environment.

Gasification units produce both bottom ash and fly ash. (See Figure 1 on page 5.) The toxicity of gasification combustor ash would be no different than incinerator ash because the source, municipal solid waste, is the same.

Diversion of Wastes from Recycling and Composting

Zero Waste is a principle which maximizes recycling, minimizes waste, and reduces consumption. Zero waste ensures that products are made to be reused or recycled back into nature or the marketplace and tackles the fundamental issues of corporate irresponsibility environmental destruction. The Grassroots Recycling Network explains the concept:¹⁴

¹² Paul H. Connett, WASTE NOT #318, A publication of Work On Waste USA, Inc., MARCH 1995, downloaded February 3, 2009 from <http://www.americanhealthstudies.org>

¹³ Paul H. Connett, WASTE NOT #317, A publication of Work On Waste USA, Inc., MARCH 1995, downloaded February 3, 2009 from <http://www.americanhealthstudies.org>

¹⁴ Grassroots Recycling Network, "What is Zero Waste?" Downloaded February 3, 2009 from http://www.grrn.org/zerowaste/zerowaste_faq.html

Zero Waste:

1. redesigns the current, one-way industrial system into a circular system modeled on Nature's successful strategies;
2. challenges badly designed business systems that "use too many resources to make too few people more productive;"
3. addresses, through job creation and civic participation, increasing wastage of human resources and erosion of democracy;
4. helps communities achieve a local economy that operates efficiently, sustains good jobs, and provides a measure of self-sufficiency; and
5. aims to eliminate rather than manage waste.

Zero waste strategies rely on a comprehensive approach which takes into account waste reduction throughout the lifespan of a product, from raw material to assembly line to re-use. High quality recycled materials can be substituted for mined or harvested resources. Waste reduction at the production stage includes more efficient use of feedstocks and changes in design which promote recycling. At the end of the cycle materials must be sorted, cleaned, and stockpiled for use in the same or similar products. Closing the production-recycling loop saves both the resource and the energy used in its extraction from the earth. Air pollution reductions of 20% to 95% are achieved when recycled feedstocks are substituted for raw materials. And the recycling of steel, aluminum, paper, and glass reduces water pollution and water use from 35% to 97%. (See Table 3 on page 12.)

Burning lowers the quality of recycled feedstocks and diverts them to lower uses, breaking the recycling loop and increases the need for replacement resources from raw materials. For example, using incinerator ash or slag in cinderblocks locks up the materials which could have been re-used; incineration and gasification methods which do not separate aluminum, steel, and glass before processing aggravate this problem. The Global Recycling Council states that mixed garbage/recycling collection systems and high-temperature processing methods such as pyrolysis are incompatible with zero waste systems. Gary Liss, Secretary of the Council, said, "Certain conversion technologies represent an 'end-of-pipe' approach that could serve as yet another obstacle to...waste reduction." Gasification plans fail to reduce garbage volumes, divert money from recycling programs, and exacerbate the problems of waste.

Composting of solid waste utilizes a natural process to break down the organic fraction of household garbage. This low-tech method is inexpensive and produces a useful soil conditioner or mulch which returns organic matter to the earth. As other methods of waste management such as incineration fall out of favor, composting of municipal waste continues to grow nationwide. The United Nations Environmental Programme gives the following assessment:¹⁵

Upwards of 5% of the MSW stream in North America is now managed through centralized composting programs, which were insignificant prior to the mid-1980s. The compostable portion of MSW can constitute 30-60% of a community's waste stream. Composting programs have been designed for a variety of organic waste streams, including yard wastes (grass trimmings, leaves, or tree prunings), food wastes, agricultural wastes, and wastewater treatment sludge. Another alternative, which has been used only on a limited basis in North America, is

¹⁵ United Nations Environment Programme, Regional Overviews and Information Sources, North America, 2.5 Topic c: Composting, Downloaded February 3, 2009 from http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/RO/North_A/Topic_c.asp

mixed waste composting. Mixed waste processing facilities accept unsorted MSW in the same form as it would be received at a landfill or a waste-to-energy facility, and separate recyclable materials. The relatively small community of Guelph, Ontario, [pop. 90,000] has been operating such a facility successfully since early 1996.

Today, there are many municipal composting programs in the United States. Some are smaller operations handling less than 50 tons of waste per day. In 1995, rural Madison County, NC (population 17,000) initiated a composting project to demonstrate its practicability. Food wastes from school cafeterias, grocery stores, and restaurants, and old newspapers were composted, helping to reduce volume, toxic leachate, methane generation, and odor caused by 48 tons of solid waste per day.

Composting is incompatible with gasification because both require the same organic materials to operate. The compounds of carbon and hydrogen which comprise compostable waste would go up the smokestack of a gasification unit.

Energy Balance of Electric Generation Versus Recycling

Energy is wasted by gasification. Energy recovery in gasification is limited to the burning of a low-Btu gas which has about 25% of the energy value of natural gas, meaning four times as much synthetic gas must be burned to equal the heat of natural gas. Efficiency losses inherent in combustion reduces the recovered energy by 60-70%.

Energy recovery from waste burners of all types pales in comparison to the energy needed to manufacture new products. Paper made from trees requires double the energy of recycled paper. Each ton of recycled paper saves about two dozen trees and 410 gallons of fuel needed to produce new paper. And beverage cans made from aluminum ore require 20 times as much energy to produce compared cans made of recycled aluminum. Table 3 lists the relative benefits of using recycled materials instead of virgin raw materials:

TABLE 3. Energy Savings and Environmental Benefits of Recycling¹⁶

Reduction of:	Aluminum	Steel	Paper	Glass
Energy Use	95%	60%	50%	20%
Air Pollution	95%	85%	74%	20%
Water Pollution	97%	76%	35%	-
Water Use	-	40%	58%	50%

According to the US Energy Information Administration,¹⁷ the aluminum industry's demand for electricity was 72,972 million kilowatt-hours (KWh) in 1998. A gasification cost analysis done by the Environmental Engineering Corporation states that a gasification unit using

¹⁶ Source: The Solid Waste Handbook: A Practical Guide, William D. Robinson, Editor, ISBN: 978-0-471-87711-0, March 1986

¹⁷ US Department of Energy, EIA, 1998 Manufacturing Energy Consumption Survey, downloaded February 3, 2009 from <http://www.eia.doe.gov/emeu/mecs/mecs98/datatables/contents.html>

72 tons of solid waste per day, or 23,652 tons per year, could produce excess power of 18,138 MWh per year, or 18.1 million KWh/year. (1 Megawatt-hour = 1000 Kilowatt-hours) The EEC's analysis for "energy recovery" from solid waste would be 0.02 % of annual electricity usage for the aluminum industry. In other words, it would take 5,000 such gasification units to provide the power needed by the aluminum industry. Or, as we see above, the aluminum industry could save 69,323 million KWh/year (95% of 72,972 million KWh), 3800 times as much electric power, if all the aluminum was recycled. Unlike 5,000 new gasification units, 100% aluminum recycling is economical, practical and environmentally sound. Also in 1998, steel mills used 52,591 million KWh, glass plants used 12,298 million KWh, paper mills used 50,241 million KWh, and newsprint mills used 18,469 million KWh. Similar analyses with similar results can be shown for these industries.

Trends in Recycling: The Goal of Zero Waste

About 20-25% of solid waste in North America is currently recycled, including about 5% that is composted. In 1975 the recycling rate was below 10% and there was no centralized composting. Today, more than 8,000 recycling programs are operating in communities in the US. This has come about through a combination of citizen action and legislative activity at local, state and federal levels. The amounts and types of materials recovered per capita differ by region, depending on whether the area is urban, suburban, or rural. The level of convenience coupled with economic incentives motivates a the change in the way people respond to recycling programs. The trend is towards higher recycling rates. The United Nations Environmental Programme found:¹⁸

The number of curbside programs in the US grew from just over 1,000 in 1988 to over 7,000 at present; over 100 million people receive curbside pickup of recyclables. In the province of Ontario, the first curbside recycling program was introduced in 1983. By 1987, programs were operating in 41 communities, and between 1988 and 1990, the number of household units being serviced increased dramatically from 34% to 60%. Legislation has since been passed requiring any municipality with a population greater than 5,000 to provide curbside recycling, and currently, 90% of households in Ontario receive this service. Most North American curbside programs collect recyclables from single family-homes.

Household hazardous waste contains some of the same chemicals as hazardous waste generated by industry. But because of the small quantities generated they are generally exempt from regulation. Household hazardous waste collection programs have the potential to reduce the toxicity of the municipal waste stream. But more must be done to reduce the volume and toxicity of solid waste.

Some of the most commonly collected materials are oil-based paints, paint thinners, used motor oil, pesticides, household cleaners, wood preservatives, antifreeze, and batteries. Paints, lead-

¹⁸ United Nations Environment Programme, Regional Overviews and Information Sources, North America, 2.5 Topic a: Waste Reduction, Downloaded February 3, 2009 from http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/RO/north_a/topic_a.asp

acid batteries, and used oil are typically recycled; the other products are sent to licensed hazardous waste disposal facilities. While household hazardous waste programs can raise community awareness, they do not, in and of themselves, encourage citizens to reduce the amount of hazardous waste they generate.¹⁹

Zero Waste programs would be seriously undermined if gasification units replace mass-burn incinerators. Capital investment in new combustors would drain financial resources from curbside pick-up, household hazardous waste collection, and other services which promote recycling. The toxicity of the household and commercial waste streams are ominous signs for gasification units, warnings of ash landfills, water pollution, and toxic air emissions.

Conclusion

The false promise offered by gasification is that one single solution can solve all waste disposal problems. But municipal solid waste, household hazardous waste, commercial and industrial wastes, and so-called special wastes cannot be dumped in a hopper and gassed out of existence. Programs based on zero waste are the best means to ensure that the environment and public health are protected.

¹⁹ United Nations Environment Programme, Regional Overviews and Information Sources, North America, 2.5 Topic f: Special wastes, Downloaded February 3, 2009 from http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/RO/North_A/Topic_f.asp

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Grassroots Recycling Network

website http://www.grn.org/zerowaste/zerowaste_faq.html

HCWH Health Care Without Harm

Update On Pyrolysis A Non-traditional Thermal Treatment Technology, <http://www.noharm.org/>

National Renewable Energy Laboratory

http://rredc.nrel.gov/biomass/doe/nrel/waste_data/msw/msw_data_sum/options.html

United Nations Environment Programme

Division of Technology, Industry, and Economics Newsletter and Technical Publications:
Municipal Solid Waste Management, Regional Overviews and Information Sources, North America.
http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/RO/contents_North_A.asp

United States Department of Energy

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Telephone conversation of March 29, 2002 with Louis Zeller

United States Environmental Protection Agency

General Information on the Link Between Solid Waste and Climate Change
<http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteBasicInfoGeneral.html>

WASTE NOT

A publication of Work on Waste USA

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<http://www.americanhealthstudies.org/wastenot/>

Appendix A

California Energy Commission

Pyrolysis/Thermal Gasification

Pyrolysis and thermal gasification are related technologies. Pyrolysis is the thermal decomposition of organic material at elevated temperatures in the absence of gases such as air or oxygen. The process, which requires heat, produces a mixture of combustible gases (primarily methane, complex hydrocarbons, hydrogen and carbon monoxide), liquids and solid residues.

Thermal gasification of MSW is different from pyrolysis in that the thermal decomposition takes place in the presence of a limited amount of oxygen or air. The producer gas which is generated can then be used in either boilers or cleaned up and used in combustion turbine/generators. The primary area of research for this technology is the scrubbing of the producer gas of tars and particulates at high temperatures in order to protect combustion equipment downstream of the gasifier and still maintain high thermal efficiency.

Both of these technologies are in the development stage with a limited number of units in operation. The Hyperion Energy Recovery System operated by the City of Los Angeles had a system designed to fire dried sewage sludge in a staged fluidized bed combustor. The resulting gas was then combusted in stages, and the heat was used to turn water into steam, driving a 10 MW steam turbine-generator.

Permitting Issues for Pyrolysis/Thermal Gasification Facilities

Most of the permitting issues discussed above for mass burn facilities also apply to pyrolysis and thermal gasification facilities. It is not economical to transport the gas produced by such facilities over long distances, so the power generation equipment must be sited with the gasification facilities. As with most refuse-to-energy facilities, it is typically only economical to site gasification facilities near urban centers.

Air emissions may be easier to control than with mass burn technology because the gas produced by the pyrolysis or thermal gasification facility can be scrubbed to remove contaminants prior to combustion. However, scrubbing the producer gas at high temperature is currently under research and the technology has yet to be demonstrated on a large scale. In addition, the pyrolysis and gasifier streams may contain organic compounds of concern that are difficult to remove.

Formerly available at:

<http://www.energy.ca.gov/development/biomass/msw.html>

Appendix B

National Renewable Energy Laboratory

Gasification/Pyrolysis

Gasification/pyrolysis can be used to produce a fuel gas or synthesis gas consisting principally of carbon monoxide and hydrogen (once called "town gas") from MSW. The fuel is compatible with existing boilers or furnaces. The process operates at a high temperature and in the absence of air. Under special conditions, a liquid fuel or chemical feedstock could also be formed. The process has been used commercially with coal and wood chips. It was used with MSW in the United States in the 1970s, but all those plants have been shut down because of operating and financial problems. Some gasification/pyrolysis plants were built and operated in Europe in the early 1980s.

Formerly available at:

http://rredc.nrel.gov/biomass/doe/nrel/waste_data/msw/msw_data_sum/options.html

Appendix C

US Environmental Protection Agency
 Technology Transfer Network
 Emissions Factors & AP-42
 Chapter 2 Solid Waste Disposal
 Table 2.1-9, Page 2.1-28, 10/96
<http://www.epa.gov/ttn/chief/ap42>

Table 2.1-9 (Metric And English Units). EMISSION FACTORS FOR MODULAR STARVED-AIR COMBUSTORS^{a,b}

Pollutant	Uncontrolled			ESP ^c		
	kg/Mg	lb/ton	EMISSION FACTOR RATING	kg/Mg	lb/ton	EMISSION FACTOR RATING
PM ^d	1.72 E+00	3.43 E+00	B	1.74 E-01	3.48 E-01	B
As ^e	3.34 E-04	6.69 E-04	C	5.25 E-05	1.05 E-04	D
Cd ^e	1.20 E-03	2.41 E-03	D	2.30 E-04	4.59 E-04	D
Cr ^e	1.65 E-03	3.31 E-03	C	3.08 E-04	6.16 E-04	D
Hg ^{e,f}	2.8 E-03	5.6 E-03	A	2.8 E-03	5.6 E-03	A
Ni ^e	2.76 E-03	5.52 E-03	D	5.04 E-04	1.01 E-03	E
Pb ^e	ND	ND	NA	1.41 E-03	2.82 E-03	C
SO ₂	1.61 E+00	3.23 E+00	E	*	*	
HCl ^g	1.08 E+00	2.15 E+00	D	*	*	
NO _x ^g	1.58 E+00	3.16 E+00	B	*	*	
CO ^g	1.50 E-01	2.99 E-01	B	*	*	
CO ₂ ^h	9.85 E+02	1.97 E+03	D	*	*	
CDD/CDF ⁱ	1.47 E-06	2.94 E-06	D	1.88 E-06	3.76 E-06	C

^a Emission factors were calculated from concentrations using an F-factor of 0.26 dscm/J (9,570 dscf/MBtu) and a heating value of 10,466 J/g (4,500 Btu/lb). Other heating values can be substituted by multiplying the emission factor by the new heating value and dividing by 10,466 J/g (4,500 Btu/lb). Source Classification Codes 5-01-001-01, 5-03-001-14. ND = no data. NA = not applicable. * = Same as "uncontrolled" for these pollutants.

^b Emission factors should be used for estimating long-term, not short-term, emission levels. This particularly applies to pollutants measured with a continuous emission monitoring system (e.g., CO, NO_x).

^c ESP = Electrostatic Precipitator

^d PM = total particulate matter, as measured with EPA Reference Method 5.

^e Hazardous air pollutants listed in the *Clean Air Act*.

^f Mercury levels based on emission levels measured at mass burn, MOD/EA, and MOD/SA combustors.

^g Control of NO_x and CO is not tied to traditional acid gas/PM control devices.

^h Calculated assuming a dry carbon content of 26.8% for feed refuse.^{26,135} CO₂ emitted from this source may not increase total atmospheric CO₂ because emissions may be offset by the uptake of CO₂ by regrowing biomass.

ⁱ CDD/CDF = total tetra- through octa- chlorinated dibenzo-p-dioxin/chlorinated dibenzofurans, 2,3,7,8-tetrachlorodibenzo-p-dioxin, and dibenzofurans are hazardous air pollutants listed in the *Clean Air Act*.

Appendix D

California Integrated Waste Management Board
<http://www.ciwmb.ca.gov/Organics/Conversion/Gasification/>
Last updated: October 21, 2008

Gasification

Gasification is a process that uses heat, pressure, and steam to convert materials directly into a gas composed primarily of carbon monoxide and hydrogen. Gasification technologies differ in many aspects but rely on four key engineering factors:

1. Gasification reactor atmosphere (level of oxygen or air content).
2. Reactor design.
3. Internal and external heating.
4. Operating temperature.

Typical raw materials used in gasification are coal, petroleum-based materials, and organic materials. The feedstock is prepared and fed, in either dry or slurried form, into a sealed reactor chamber called a gasifier. The feedstock is subjected to high heat, pressure, and either an oxygen-rich or oxygen-starved environment within the gasifier. Most commercial gasification technologies do not use oxygen. All require an energy source to generate heat and begin processing.

There are three primary products from gasification:

- Hydrocarbon gases (also called syngas).
- Hydrocarbon liquids (oils).
- Char (carbon black and ash).

Syngas is primarily carbon monoxide and hydrogen (more than 85 percent by volume) and smaller quantities of carbon dioxide and methane. Syngas can be used as a fuel to generate electricity or steam, or as a basic chemical building block for a multitude of uses. When mixed with air, syngas can be used in gasoline or diesel engines with few modifications to the engine.