January 10, 2007

To: Members of the Facility and Plan Review Subcommittee
Los Angeles County Solid Waste Management Committee/
Integrated Waste Management Task Force

From: Chuk Agu CA
Staff

POTENTIAL REVISIONS TO CHAPTER 5 OF THE LOS ANGELES COUNTY COUNTYWIDE SITING ELEMENT

Attached is a preliminary draft of Chapter 5 (Alternative Technologies) of the Countywide Siting Element for your review and discussion at the January 18, 2007, Subcommittee meeting.

Due to the complexity, sensitivity and uncertainty of issues, this draft is provided for discussion purposes and to seek the Subcommittee's guidance. Also, due to the extent of the proposed revisions to this Chapter, a redline (Attachment I) and clean (Attachment II) versions of the draft revisions are provided.

Based on Subcommittee's guidance, staff will fine-tune Chapter 5 revisions and resubmit to the Subcommittee for a detailed review and discussion.

If you have any questions, please contact me at (626) 458-3556, Monday through Thursday, 7 a.m. to 5:30 p.m.

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Attach.

ATTACHMENT I

Chapter 5 – Preliminary Draft (Redline Version)

CHAPTER 5 – ALTERNATIVE ~~DISPOSAL~~ TECHNOLOGIES

CHAPTER 5
ALTERNATIVE ~~DISPOSAL~~ TECHNOLOGIES

5.1 PURPOSE

The purpose of this chapter is to describe technologies which provide an alternative to existing solid waste disposal technologies and to provide a brief assessment on their current state of development. This chapter also describes a number of benefits, advantages, and environmental and constraints, regarding the identified alternative technologies.

This chapter will explore various alternative technologies which divert waste from landfills and be used to generate energy, produce "green" fuels and other products. Alternatives, such as conversion technologies, are beginning to be considered viable alternatives for solid waste management in the United States. Due to current concern regarding the permitting, siting, and environmental development of conversion technologies, the County of Los Angeles has studied challenges and benefits to these technologies. These challenges and benefits are also considered within the chapter text and in the technology summary Table 5-1.

5.2 DEFINITION OF TERMS

Due to increased interest in development of alternative technologies in the United States and the evolution of thermal technologies, there has been some confusion among widely used and overlapping terms. Section 5.2 defines a variety of terms and their application to alternative technologies. For clarity, select terms will be used throughout the Chapter.

Currently, California law does not properly define these alternative technologies. One term (transformation) is used to include both incineration (mass-burn) and some conversion (non-burn) technologies, while other technologies are not defined at all. Gasification is singled out, however the definition currently incorporated into State statute for gasification is technically and scientifically inaccurate.

The Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force (Task Force) has been lobbying the State Legislature to revise California law so that it accurately reflects the scientific distinctions among these technologies, and regulates them rationally based on their relative environmental benefits and impacts compared with other solid waste management options. To date, the Legislature has been reluctant to address this issue in any way; therefore the following definitions are offered to provide a clearer distinction between the various terminologies currently in use.

5.2.1 Combustion

Combustion refers to an oxidation process - a reaction between a fuel and an oxidant, typically ambient air or oxygen - producing an exothermic reaction in the form of heat. Full combustion includes complete reactions in the form of heat and a full flame.

5.2.2 Conversion Technologies

Conversion technologies refer to a wide array of state of the art technologies capable of converting post-recycled or residual solid waste into useful products, green fuels, and renewable energy through non-combustion thermal, chemical, or biological processes. Conversion technologies do not include mechanical processes. This definition is based on the Conversion Technology Evaluation Report adopted by the Task Force.

5.2.3 Incineration

Incineration refers to an oxidation reaction including heat and flame, that reduces the fuel to the state of ash. This definition is from the American Heritage Dictionary.

5.2.4 Transformation

Transformation refers to a process whose principal function is to process solid waste by incineration. Transformation does not include a composting, gasification, conversion, or biomass processing. Transformation is a term defined in California stature (PRC 40201) to currently include "incineration, pyrolysis, distillation, or biological conversion other than composting." Because the term as defined in statute does not make a distinction between incineration and conversion technologies, this Chapter will not reference this term.

5.2.5 Waste-to-Energy

Waste-to-Energy is a generic term for a process that uses solid waste to produce energy, however this term has become synonymous with incineration that generates electricity from the waste heat. The California Integrated Waste Management Board characterizes waste-to-energy in such terms as well.

For the sake of clarity, we will use the terms "combustion" and "conversion technologies" throughout this chapter.

5.3~~1~~ INTRODUCTION ~~AND PURPOSE~~

~~5.31.1 Introduction~~

As discussed in Chapter 1 (Subsection 1.4.2.4) and consistent with the goals established in Chapter 2, the primary goal of the Los Angeles County CSE is to address the solid waste disposal needs of the 88 cities in Los Angeles County and the County unincorporated communities for a 15-year planning period.

Adequate disposal capacity has been identified, discussed, and ~~discussed in Chapters 4 and 7 to address these~~ addressed in Chapters 4 and 7. ~~-~~Those needs are met through utilization of existing in-County solid waste disposal facilities, expansion of existing facilities, and development of new facilities~~ under various scenarios~~. Chapter 7 confirms that no new landfills can be developed in Los Angeles County and expanding existing landfills is a long and challenging process. Currently, nearly all refuse in Los Angeles County is transported by truck to disposal sites within the metropolitan area, however that will be changing within the decade. The County of Los Angeles is in a period of transition, and by the end of this planning period will rely on facilities outside of its borders to manage most of its waste. With the closure of the Puente Hills Landfill in 2013, and other landfills closing soon after in Los Angeles County, it is estimated that as much as 12,000 tons of solid waste will be flowing out of the County by 2025, therefore it is critical to invest in alternative solid waste infrastructure that can address this need. ~~these needs, through utilization of existing in-County solid waste disposal facilities, expansion of existing facilities, and development of new facilities under various scenarios.~~

However, past and current experience in siting new landfills and expanding existing landfills underscores the difficulty of achieving this goal. In the last few years, proposed new landfills and expansions of existing landfills have encountered strong opposition to their development, particularly from residents living in the vicinity of those facilities and from environmental groups. This has resulted in an increasing interest in finding alternatives to landfill disposal that would have reduced negative impacts or have beneficial impacts on the environment. ~~However, when evaluating alternatives to landfill disposal one must consider the definition of disposal under current State law to properly differentiate between disposal alternatives and diversion alternatives. State law (Section 40120.1 of the Public Resources Code) defines disposal as “the management of solid waste through landfill disposal or transformation at a permitted solid waste facility.” Therefore, under current law, the disposal alternatives to landfills are transformation facilities.~~

~~State law (Section 40201 of the Public Resources Code) also defines transformation to mean “incineration, pyrolysis, distillation, gasification, or biological conversion other than composting. ‘Transformation’ does not include composting or biomass conversion.” Alternative disposal technologies, i.e., transformation facilities, can extend the life of landfills by reducing the amount of waste in need of land disposal. Additionally, the life of existing landfills may be~~

~~extended by the adoption of measures at the landfills which may further reduce the amount of solid waste disposed and/or optimize the utilization of permitted landfill airspace by reducing the volume of cover materials and increasing compaction levels.~~

Among the most promising alternatives to landfill disposal and waste exporting are conversion technologies. For nearly a decade, Los Angeles County has been a consistent supporter of conversion technologies because of their potential to manage post-recycled MSW in an environmentally preferable manner. On July 27, 1999, the Los Angeles County Board of Supervisors formally adopted a series of recommendations that included support for the development of alternatives to landfilling and combustion, such as conversion technologies.

Since then, the County has supported local research and development of conversion technologies including supporting legislation to advance conversion within the state and working with members of the California Integrated Waste Management Board (Waste Board) and other stakeholders on this matter. The County has sponsored and supported legislation that would correct erroneous definitions currently in State stature, and provide conversion technologies with "diversion credit" for the material diverted from landfill disposal. Diversion credit represents an important incentive for local jurisdictions, therefore diversion credit, could invigorate research and development of environmentally beneficial technologies that can create jobs while transforming a liability (residual solid waste) into a benefit (renewable energy, green fuels and useful products).

In 2004, the Los Angeles County Integrated Waste Management Task Force (Task Force) established the Alternative Technology Advisory Subcommittee as an outgrowth of its commitment to conversion technologies, supported by a condition in the CUP of the Puente Hills landfill adopted in 2003. The Subcommittee is comprised of a diverse group of professionals including representatives from local government, the Waste Board, consultants, all experts in the field of conversion technologies who are responsible for evaluating and promoting the development of conversion technologies. The ultimate goal of the Subcommittee is to facilitate the development of a demonstration conversion technology facility in Southern California, which would showcase the benefits of conversion technologies as technically, economically, and environmentally viable alternative method of managing solid waste within the County.

On August 18, 2005, the Task Force officially adopted the "Conversion Technology Evaluation Report". Research for this report was conducted which assessed the viability of various conversion technologies, with the goal of vetting technologies for a potential demonstration facility. This demonstration facility is proposed to be partnered with a Material Recovery Facility/Transfer Station, the benefits of such a pairing are significant and include readily available feedstock otherwise destined for landfill disposal, appropriate siting, preprocessing capacity, transportation (cost and pollution) avoidance, and a host of symbiotic benefits.

Los Angeles County, like many other municipalities, is proposing to exclusively site conversion technology facilities at Material Recovery Facilities or Transfer Stations. This proposed siting requirement would further ensure that the waste stream processed by conversion technology facilities are strictly residual solid waste remaining after all feasibly recoverable recyclables have been removed.

The development and viability of the various proposed alternative ~~disposal~~ technologies, and the methods to enhance existing landfill capacity, depend on technical and economic factors, air quality standards, and public acceptance. Further studies and testing of many of these technologies may be needed to determine if they are viable~~economically feasible~~. Data contained within the Conversion Technology Evaluation Report provides clearly defined information regarding all of the above mentioned areas of concern. There have been significant developments regarding the use of MSW as feedstock for alternative technologies, including conversion technologies.

~~5.1.2 Purpose~~

~~The purpose of this chapter is to describe existing and potential alternative solid waste disposal technologies and to provide a brief assessment on their current state of development. This chapter also describes a number of potential landfill capacity saving measures and the potential savings that may be realized by their adoption, together with their limitations and/or current state of development.~~

5.4~~2~~ ~~SOLID WASTE DISPOSAL FACILITIES~~ COMBUSTION SYSTEMS

~~A solid waste disposal facility is defined as a facility at which solid waste is managed through land disposal and/or transformation processes. Solid waste disposal facilities include only solid waste landfills and transformation facilities.~~ Combustion facilities that utilize municipal solid waste as a feedstock are currently used within the County of Los Angeles. End products for combustion facilities are typically ash, inert material, and energy generation. Energy produced from the combustion facilities is sold to power utilities, in addition to being used on-site.

Combustion systems are used to reduce the volume of solid waste, destroy pathogens, break down chemical compound structures, and produce energy. Combustion occurs at high temperatures to produce gas, ash, and inert residual material. Heat from the controlled burning process is used to produce steam, which is then used to generate power. Pollution control for gas produced is typically in the form of scrubbers and filters. The scrubbers neutralize the acid gases within the resulting gas. Filters remove minute ash particles from any gas produced due to current air quality standards. Typically the ash and minimal inert material produced from combustion is stored and used as road base material.

~~5.2.1 Landfill Facilities~~

~~A solid waste landfill facility is a disposal site which employs an engineered method of disposing of solid waste on land in a manner that minimizes environmental hazards as mandated by Federal, State, and local laws and regulations. Solid waste landfill facilities include only Class III landfills and unclassified landfills. Chapter 3, Section 3.3.1 discusses the two classes of landfills.~~

5.4.1 ~~Incineration~~ Combustion

~~5.2.2 Transformation Facilities~~

~~Incineration is a term commonly used in referring to transformation process where refuse is incinerated, in compliance with strict air quality regulations and standards, with or without preprocessing to shred the incoming solid waste.~~ Combustion, as defined in section 5.2.3 of this chapter, is used to manage solid waste in compliance with state and regional environmental regulations. Units without preprocessing are referred to as mass-fired or mass burn combustion facilities. Waste processed prior to burning is referred to as refuse-derived-fuel (RDF). Refuse (solid waste) is typically burned at temperatures of about 2200 degrees Fahrenheit in waterwall boilers where thermal energy in the form of steam would be recovered. The steam is then passed through turbines where the thermal energy is converted to electricity. These processes can achieve a 70 percent volume reduction in the solid waste, ash being the only residue produced.

~~A transformation facility is defined in Section 18720 of the CCR as "a facility whose principal function is to convert, combust, or otherwise process solid waste by incineration, pyrolysis, destructive distillation, or gasification, or to chemically or biologically process solid wastes, for the purpose of volume reduction, synthetic fuel production, or energy recovery. Transformation facility does not include a composting facility."~~

~~Of the various transformation processes currently available or under development, waste-to-energy has been identified as an extremely effective alternative to divert the largest amount of solid waste from landfills. Waste-to-energy facilities are also subject to strict environmental standards including those mandated by the Federal Clean Air Act, Federal Clean Water Act, and other State, regional, and local laws and regulations. These facilities have been proven to be technically and environmentally feasible waste management alternatives to land disposal.~~

~~Chapter 6 and Appendix 6-A discuss in detail the siting criteria to be applied to new transformation facility sites.~~

Environmental issues associated with a combustion facility include potential impacts to air quality, water quality, traffic, aesthetics, and noise. The combustion of refuse to recover energy will generate emissions to the atmosphere which require that sophisticated control devices be employed. Controlled combustion, through the use of automated damper controls for air distribution, minimize NO_x and CO_x. In addition, it has been demonstrated that ammonia injection into the furnace is successful in further reducing NO_x emissions. Sulfur dioxide, hydrochloric acid (HCl), dioxins/furans, cadmium, and lead are removed at an efficiency of up to 99 percent through the use of lime treatment in a dry scrubber neutralizing the acid gases. The final stage in a typical air pollution control system at a combustion facility is a filter baghouse which removes up to 99.95 percent of the particulate matter.

Combustion technology has been identified as one of the most effective options currently available to reduce the need for landfill disposal. Combustion is commercially, technically, and environmentally feasible. ~~During the past two three decades, an interest in~~ From the 1970's to the 1990's combustion technology grew as a result of energy shortages and relatively high energy prices. State legislation was enacted in the 1980s which encouraged the development of combustion projects. However, political resistance and public perception have increased due to environmental and safety concerns. At this time no new combustion facility is proposed for development. The current lack of enthusiasm for combustion facilities is also associated with economic factors such as the high capital costs involved in developing these facilities, the deregulation of the energy industry, , and other factors such as the strong public opposition encountered by previous proposals due to air quality concerns. Additionally, development has been discouraged by its current classification as disposal, rather than diversion under State law. While there are no current proposals to develop waste-to- energy facilities in Los Angeles County, this technology remains a valid disposal option. ~~, as has been demonstrated by the successful operation of the Commerce Refuse-to-Energy and the Southeast Resource Recovery Facilities in Los Angeles County. However, currentlyand the current lowhigher prices for powerfor future consideration.Other municipalities throughout the country rely on incineration facilities for management of significant amounts of their solid waste. Examples of this are the County of Fairfax, Virginia (Ogden Martin Systems of Fairfax, Inc. Owned/operated I-95 Energy/Resource Recovery Facility), and the City of Rochester, Massachusetts (Southeastern Massachusetts (SEMASS) Resource Recovery Facility), where most of the solid waste collected for disposal is incinerated.~~

Solid waste combustion systems (incinerators) can be designed to operate with two types of solid waste fuel: commingled solid waste (mass-fired) and pre-processed solid waste known as refuse-derived fuel (RDF-fired). Mass-fired combustion systems are the predominant type. Currently, there are two such facilities operating in Los Angles County: the Commerce Refuse-to-Energy Facility in the City of Commerce and the Southeast Resource Recovery Facility (SERRF) in the City of Long Beach.

5.4.1.1 Fluidized Bed Combustion

Fluidized Bed Combustion (FBC) processes include a heated bed of particles, typically sand or another type of granular media, suspended (fluidized) within a steel column through use of an upward flow of air or fluid. Oxygen is supplied more freely through the flow action of the bed media due to the turbulent contact between the bed media and the fuel media. Complete oxidation, including the production of flames maximizes thermal efficiency and minimizes the amount of char produced provided by the fuel media. FBC is best used to manage low BTU fuel media and high moisture characteristics. Several FBC systems are being used ~~and developed~~ for solid waste combustion throughout the world.

5.4.1.2 Mass-fired Combustion Systems

In a mass-fired combustion system, minimal processing is given to solid waste before it is placed in the charging hopper of the system. The crane operator in charge of loading the charging hopper manually rejects obviously unsuitable items. One of the most critical components of a mass-fired combustion system is the grate system. It serves several functions, including the movement of waste through the system, mixing of the waste, and injection of combustion air. Typical mass-fired combustion facilities are described below.

5.4.1.2.1 Commerce Refuse-to-Energy Facility.

The Commerce Refuse-to-Energy Facility (CREF) is a joint powers agency formed by the City of Commerce and the County Sanitation Districts of Los Angeles County (CSD). The CSD has operated CREF since its inception in 1987. It successfully meets the South Coast Air Quality Management District (SCAQMD) requirements and produces some of the lowest emissions from a facility of its type worldwide. The facility combusts approximately 360 tons of refuse per day, 7 days a week, and generates approximately 10 megawatts (MW) of electricity that is sold to Southern California Edison (SCE).

Residual ash is created as a result of the burning process, and an ash treatment facility is operating at the site. The ash is mixed with cement in the drums of transit mix trucks. The mix is then transferred to portable containers where it hardens into 16 to 17 ton blocks. These blocks are transported to the Puente Hills Landfill where they are crushed and recycled as a base material for roads.

5.4.1.2.2 Southeast Resource Recovery Facility.

The Southeast Resource Recovery Facility (SERRF) is a joint powers agency formed by the City of Long Beach and the CSD. The City of Long Beach employs a private contractor to operate the facility. SERRF has the capacity to ~~burn~~ process about 1,380~~50~~ tons of refuse per day.~~, 7 days a week, and~~ As an end product, the combustion process generates approximately 36 gross MW of electricity, with 30 MW of electricity that is sold to SCE.

Residual ash is created as a result of the combustion ~~burning~~process.~~, and an~~ There is an ~~-~~ash treatment facility ~~is~~operating at the site. SERRF adds cement to the ash and transports the mix to the Puente Hills Landfill where it is recycled as a base material for roads.

5.4.1.3 RDF-Fired Combustion Systems

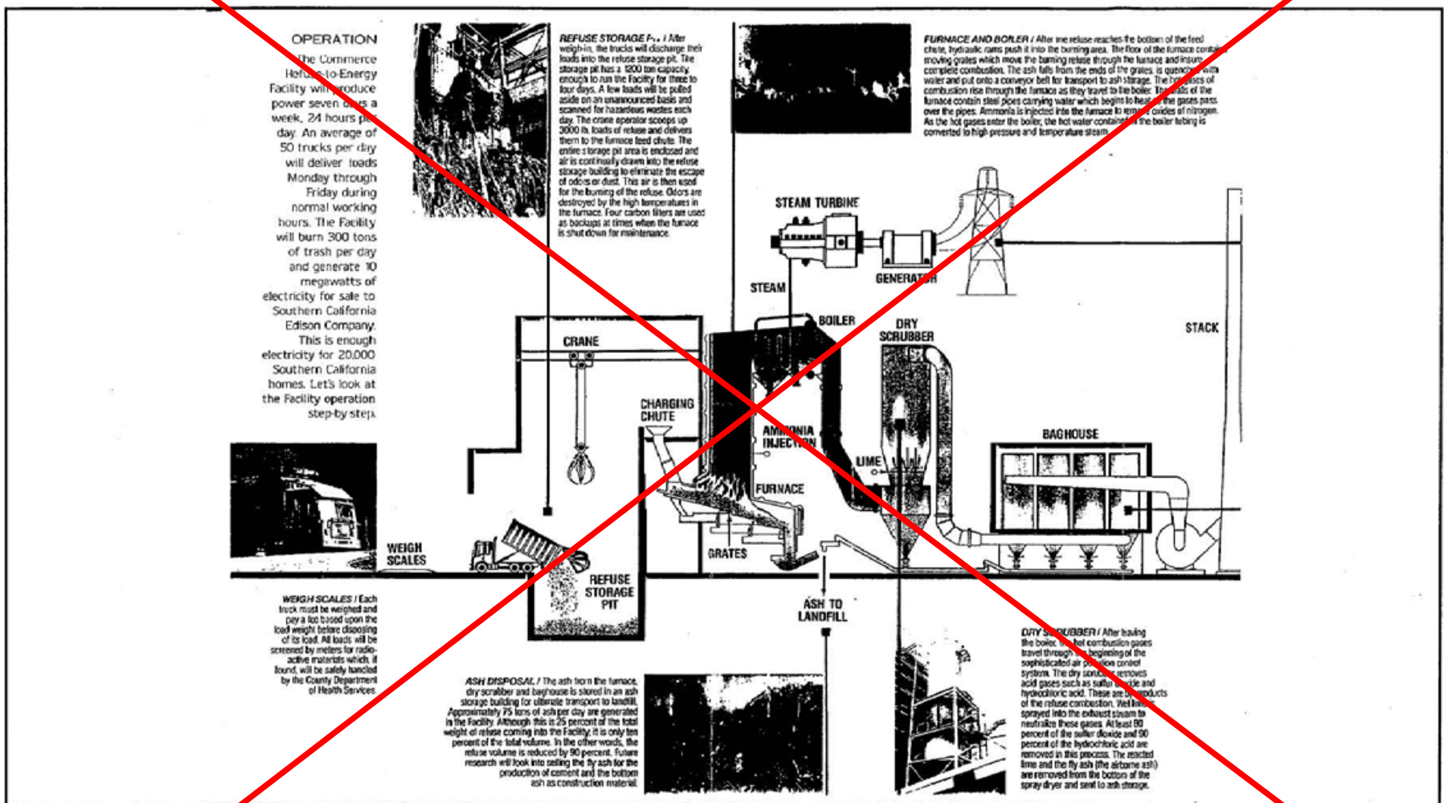
Refuse-derived fuel (RDF) is the material remaining after the selected recyclable and noncombustible materials have been removed from the waste stream. ~~The~~RDF can be produced in shredded or fluff form, or as densified pellets or cubes. Densified RDF is more costly to produce, but is easier to transport and store.

Due to the higher energy content of RDF compared to unprocessed solid waste, RDF combustion systems can be physically smaller than comparatively rated mass-fired systems. A RDF-fired system can also be controlled more effectively than a mass-fired system because of the more homogeneous nature of RDF, allowing for better combustion control and better performance of air pollution control devices. Typical RDF-fired combustors are shown below.

~~2,800 52state of the art energy/includingAn expansion of the facility was completed in 1993, increasing its capacity to over 2,800 tons per day of incoming waste. It serves over 40 communities and generates enough electricity to serve 75,000 homes. a2,800 sTotal cost to develop the facility was $300 million.~~

~~Solid waste is first sorted with ferrous, glass, and other recyclables being removed. The waste is then shredded and then blown into a burner. Fly ash is used as a mortar for landfill cover, and the bottom ash is stockpiled for further recycling. The facility has met all US EPA New Source Performance Standards air quality regulations. It recently received the 1996 Corporate Award for Resource Recycling from the Ecological Society of America.~~

~~Figure 5-2 is a schematic process diagram of the Southeastern Massachusetts (SEMASS) Resource Recovery Facility.~~



Source: Sanitation Districts

Commerce Refuse-to-Energy Facility Schematic Process Diagram **Figure 5-1**

Los Angeles County Countywide Siting Element

~~C. Fluidized Bed Combustion~~ (Moved to 5.2.1.3)

~~A fluidized bed is an alternative design to conventional combustion systems. It is a process in which a bed of particles is converted to a fluid state by means of an upward flow of gas (or liquid). In its simplest form, a Fluidized Bed Combustion (FBC) system consists of a vertical steel cylinder with a sand bed, a supporting grid plate, and air injection nozzles. When air is forced up through the nozzles, the bed of sand expands up to twice its resting volume and acts like a fluid. RDF can be injected into the reactor above or below the level of the fluidized bed. The "boiling" action of the fluidized bed promotes turbulence and mixing and transfers heat to the fuel. In operation, auxiliary fuel (natural gas or fuel oil) is used to bring the bed up to operating temperature (1,450 F to 1,750 F).~~

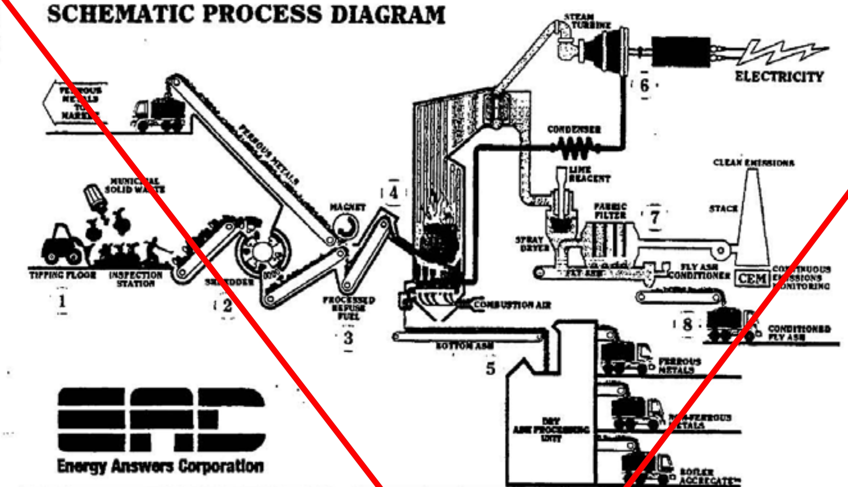
~~Fluidized bed combustors have a variety of advantages, including their simplicity of construction, their flexibility in accepting solid, liquid or gaseous fuels, and their high combustion efficiency at a low temperature minimizing NOx generation. A major advantage is the possibility of in-bed removal of~~ ~~SO_2~~ ~~using limestone or dolomite. Fluidized bed combustors are also suitable for intermittent operation as they can be started up after a nightly stop or even a full weekend.~~

~~Several FBC systems are being used for solid waste combustion throughout the world.~~

~~i. Duluth Minnesota. A fluidized bed combustion plant, currently operating at 130 tons/day with a total design capacity of 700 tons/day, was built in Duluth, Minnesota. The initial plan was to co-dispose of 300 tons/day of dewatered treatment plant sludge and 400 tons/day of solid waste. Stack emissions for the plant are 5 percent of regulated values. The management for the plant is currently considering changing the solid waste/sludge management method to the N-Viro method or land application due to economic considerations regarding the operation of the plant. If this change in disposal is made, the plant will be dismantled.~~

~~ii. Fujisawa Japan. A 390-ton/day fluidized bed combustion system is operating in Fujisawa, Japan. The system employs a proprietary fluidized bed-moving design, which allows mass firing of unprocessed solid waste.~~

SCHEMATIC PROCESS DIAGRAM



How the process works:

1.Municipal solid waste is delivered by collection trucks, transfer trailers, and rail cars to the enclosed receiving building. Here the waste is inspected, and bulky and recyclable materials are removed.

2.Refuse is pushed by front-end loaders onto conveyors which feed hammermill shredders. Waste is shredded to a size of 6" or less, then passed under magnets which remove about two-thirds of the ferrous (iron-bearing) metals for recycling.

3.This shredded material is called Processed Refuse Fuel (PRF). A ton of PRF has a heating value equal to 72 gallons of fuel oil or about one-third ton of coal.

4.The PRF is blown into specially-designed boilers. Light materials burn in suspension, while heavy portions of the fuel are burned on a traveling grate at the bottom of the boiler.

5.Dry ash from the boiler grates is conveyed to the EAC-patented bottom ash processing facility where it is processed into three components: ferrous metals, non-ferrous metals (aluminum, copper, brass, etc.), and a gravel-like material called Boiler Aggregate™. The metals are recycled through scrap dealers, and the aggregate is usable as fill material or a light-weight aggregate for concrete and asphalt products.

6.High-pressure steam produced in the boiler is passed through a turbine which drives the generator for production of electricity. The air cooled condensers convert the steam back into water for re-use in the boilers.

7.Combustion gases are passed through scrubbers where they are sprayed with a lime reagent to neutralize acid-gas constituents. Gases are then passed through either electrostatic precipitators or fabric filters (bag-house) to capture particulates. A continuous emissions monitoring system measures and records levels of regulated compounds in the flue gas.

8.Fly ash, which is made up of the fine particles removed by the sophisticated air pollution control system, is collected separately from the bottom ash, conditioned using a proprietary process, and landfilled. Research is underway to develop a use for this material as well.

Source:Resource Recovery Energy Answers Corporation Albany, New York

SEMASS Schematic Process Diagram **Figure 5-2**

Los Angeles County Countywide Siting Element

~~iii.Energy Products of Idaho (EPI) This incineration system uses a bubble-type fluid bed concept that accepts prepared 10-cm (4-inch) top-size RDF. The RDF particles are exposed to a vigorously turbulent hot environment promoting gasification and char burnout. The design provides for continuous removal of oversized, noncombustible material. Thus, the tramp material does not build up enough to stop fluidization and incur shutdown for clean out. The design provides for continuous removal of oversized noncombustibles. The waste gases then pass through a waste-heat boiler to generate high pressure, superheated steam for electrical generation. The combustion system offered by EPI is at the stage of commercial availability. EPI has installed five furnaces in the US with capacities of up to 600 tons/day using RDF. Examples of this plants are located in Brevard, NC; Tacoma, Washington; and Lacrosse, Wisconsin.~~

5.4.1.4~~D.~~ Rotary Cascading Bed Combustion

The Rotary Cascading Bed Combustion (RCBC) is a robust solid-fuel burner and heat recovery system, a form of Fluidized Bed Combustion (FBC) system. It can burn solid waste, RDF, wood chips, etc. The system consists of a rotating horizontal cylindrical chamber with bundles of boiler tubes projecting into the end of the chamber. The rotational speed of the chamber is high enough to keep the bed material continually airborne, thus increasing combustion. The hot solids cycle preheats the combustion air, drying and ignites it~~. Two furnaces are now operating in the United States, a development unit at North American Rayon Corporation and a unit used by a hazardous waste firm in Houston Texas. Pedco, Inc., of Cincinnati, Ohio, has yet to develop a front end waste system to produce a sized RDF for its RCBC system~~. Almost all RDF systems have required extensive redesign to attain acceptable levels of reliability and environmental quality.

5.4.2 Biomass Combustion

State Statute (PRC 40106) defines "biomass conversion" as “the controlled combustion, when separated from other solid waste and used for producing electricity or heat, of the following materials: (1) Agricultural crop residues; (2) Bark, lawn, yard, and garden clippings; (3) Leaves, silvicultural residue, and tree and brush pruning; (4) Wood, wood chips, and wood waste; (5) Nonrecyclable pulp or nonrecyclable paper materials.” It is essentially the controlled combustion of certain biomass feedstocks. There are no biomass conversion facilities operating or planned for Los Angeles County.

~~5.3 ALTERNATIVE SOLID WASTE DISPOSAL TECHNOLOGIES~~

5.5 CONVERSION TECHNOLOGY SYSTEMS

Conversion technology systems are an array of alternatives to conventional landfill disposal. These technologies may be used in conjunction with current landfill practices to extend the life cycle of existing landfills. Conversion technologies refer to innovative technologies including pyrolysis, gasification, anaerobic digestion, and ethanol fermentation, which are capable of converting Municipal Solid Waste (MSW) into an array of high value, marketable materials and green fuels such as ethanol, biodiesel, biomethane, and hydrogen, which can be used to produce clean, renewable energy.

Conversion technologies represent the most significant opportunity for beneficial use of MSW to come along since passage of California's AB 939 in 1989. According to a Waste Board report, as of March 2005 there were approximately 140 operating conversion technology facilities utilizing MSW as a feedstock in Europe and Japan. Various studies have shown that conversion technologies employing thermal, chemical, or biological processes can be used to successfully manage MSW. Using these technologies can decrease criteria air pollutants and greenhouse gases which would ordinarily result from other waste disposal options. Moreover, conversion technologies can revolutionize the way solid waste is managed in Southern California by transforming waste that is currently an economic, environmental and political liability, and turning it into a valuable commodity and resource.

The use of residual solid waste (waste that remains after recyclables have been removed) as feedstock sent to a conversion facility can help the County lessen disposal into landfills, by diverting unrecyclable solid waste intended for disposal. This process would in turn increase landfill life and postpone the costly and arduous task of siting and permitting new waste disposal sites. The commercialization of these technologies creates a realistic potential to achieve state recycling rates beyond 75%, while complementing and reinforcing the existing recycling market and infrastructure.

Conversion technologies could accommodate a portion of the solid waste to be managed within the 15-year planning periods of the Countywide Siting Element.

The California Integrated Waste Management Board's 2001 Strategic Plan includes a goal to "Support local government efforts to use alternative means of diverting waste, including the use of conversion technology where residuals can be converted directly into electricity and actively managed to increase fuel and gas production." This section provides a description of various ~~existing and proposed transformation~~ conversion technologies that can serve as alternatives to solid waste disposal ~~technologies~~. Conversion ~~Transformation~~ technologies can be generally grouped into three~~wo~~ main categories: a) thermal conversion processes, b) biological conversion processes and c~~b~~) ~~biological/~~chemical conversion processes. Figure 5-1 shows a typical process diagram for most conversion technologies.~~The majority of the transformation processes that are currently being proposed to manage solid waste are various types of thermal conversion processes, which include waste-to-energy, pyrolysis, and gasification.~~

~~The majority of the transformation processes that are currently being proposed to manage solid waste are various types of thermal conversion processes, which include waste-to-energy, pyrolysis, and gasification.incineration processes which are not primarily used to produce marketable by-products. Conversion technologies utilize oxidation, instead of full combustion used in the transformation process, to process solid waste to derive renewable energy.~~ Conversion technologies differ from conventional combustion processes due to the capability of conversion facilities to produce marketable products, including green fuels like biodiesel and ethanol. The Department of Energy (DOE) report, "Annual Energy Outlook 2006 with Projections to 2030" noted many markets for renewable energy. These markets included fuel for automobiles to decrease dependence upon foreign oil. "Sales of advanced technology vehicles, representing automotive technologies that use alternative fuels or require advanced engine technology, reach 5.7 million per year..."

~~With the exception of waste-to-energy, these alternative disposal technologies are generally at a developmental stage. Although waste-to-energy is technically feasible and is successfully demonstrated in the United States and Europe, and specifically in Los Angeles County at facilities in Commerce and Long Beach, there are no proposed new waste-to-energy facilities in Los Angeles County at the present time.~~

~~Development of transformation facilities, even those using the proven incineration technologies, are likely to encounter strong public opposition due to concerns regarding potential environmental impacts. Also, the proponents of these technologies are generally seeking governmental agencies and municipalities to finance the development of new facilities or "proof-of-concept" facilities. Because of current fiscal constraints, few local governments may be in a position to finance the development of unproven technology and may need to rely on private sector for its development.~~

There are specific issues~~risks~~ that are associated with the development of conversion~~new~~ technologies, which must be carefully weighed by a jurisdiction when considering ~~alternative~~ conversion technologies as a part of their solid waste management strategies. Most issues with conversion technologies can be separated into four categories: regulatory, environmental/social, technical, and economic. Most of the conversion technologies available have not been permitted to process MSW or to address the emissions from the various processes. Public perception is an important aspect to implementation of these technologies due to the lack of knowledge regarding these facilities and the environmental impact due to processing. Jurisdictions would need to provide public education regarding these technologies and the specific difference from existing full combustion processes. Feedstock characteristics, process integration, and emission controls at times provide design concerns. Currently, in the United States there are no large scale heterogeneous MSW conversion technology facilities. There are smaller demonstration facilities, but most of the feedstock is homogeneous without serious consideration for large scale MSW processing. Some cost data has been generated regarding smaller demonstration facilities in the United States such as capital, operation, maintenance costs, and possible revenue generated.

~~Examples of these risks are the four facilities constructed (two in New Jersey, two in Los Angeles County) to utilize the Carver-Greenfield Process of drying wastewater treatment sludge prior to disposal, incineration, or other uses. After substantial expenditures, all four were proven ineffective and were declared “failed technology” by the U.S. Environmental Protection Agency.~~

Some of the technologies discussed below are in the construction stage of full-scale facilities. These technologies merit continued close observation of methods and costs as they mature. However, based on the above considerations and the length of time required to permit and develop these types of facilities, these technologies (with the exception of ~~waste-to-energy~~) may not be ready for large-scale commercial operation to mange a significant portion of solid waste generated in Los Angeles County within the current planning period. Nevertheless, ~~alternative~~ conversion technologies need to be continually evaluated so that in ~~a not so distant~~the future they may provide for the management of a significant share of the County’s solid waste.

Per the aforementioned URS, Conversion Technology Evaluation Report of August 18, 2005, the thermal, chemical, and biological conversion technologies will be further explained in the following sections. To simplify discussion of these technologies this report is incorporated by reference. However, it should be noted future revisions to the ~~CTE~~Conversion Technology Evaluation report does not constitute a revision to the Countywide Siting Element. Therefore, the ~~CTE~~Conversion Technology Evaluation report will not be included as an appendix within the Countywide Siting Element.

5.5~~4~~.1 Thermal Conversion Processes

There are two major~~hree~~ types of ~~systems for the~~ thermal conversion processes~~ing~~ of solid waste~~:~~; ~~combustion systems,~~ namely pyrolysis systems~~,~~ and gasification systems~~, which are described below~~. Thermal processing involves thermal degrading of solid waste through exothermic or endothermic reactions in an oxygen deprived or oxygen reduced environment. Full combustion of solid waste to the state of ash does not occur as a phase of the thermal conversion processes.

~~5.3.1.1 Combustion Systems (Waste-to-Energy)~~

(Most of the text moved to section 5.4.1.2)

~~Waste-to-energy, or "refuse-to-energy," is a term commonly used in referring to transformation process where refuse is incinerated, in compliance with strict air quality regulations and standards, with or without preprocessing to shred the incoming solid waste. Units without preprocessing are referred to as mass-fired facilities. Waste processed prior to burning is referred to as refuse-derived-fuel (RDF). Refuse (solid waste) is typically burned at temperatures of about 2200 degrees Fahrenheit in waterwall boilers where thermal energy in the form of steam would be recovered. The steam would then be passed through steam turbines where the thermal energy would be converted to electricity. Waste-to-energy processes achieve approximately a 70 percent volume reduction in the solid waste, ash being the only residue produced.~~

~~Environmental issues associated with a waste-to-energy facility include potential impacts to air quality, water quality, traffic, aesthetics, and noise. The combustion of refuse to recover energy will generate emissions to the atmosphere which require that sophisticated control devices be employed. Controlled combustion, through the use of automated damper controls for air distribution, minimize~~ NO_x ~~and~~ CO_x~~. In addition, it has been demonstrated that ammonia injection into the furnace is successful in further reducing~~ NO_x ~~emissions. Sulfur dioxide, hydrochloric acid (HCl), dioxins/furans, cadmium, and lead are removed at an efficiency of up to 99 percent through the use of lime treatment in a dry scrubber neutralizing the acid gases. The final stage in a typical air pollution control system at a waste-to-energy facility is a filter baghouse which removes up to 99.95 percent of the particulate matter.~~

~~During the past two decades, an interest in waste-to-energy grew as a result of energy shortages and relatively high energy prices. State legislation was enacted in the 1980s which encouraged the development of waste-to-energy projects. Currently, there are two such facilities operating in Los Angles County: the Commerce Refuse-to-Energy Facility in the City of Commerce and the Southeast Resource Recovery Facility (SERRF) in the City of Long Beach.~~

~~Waste-to-energy technology has been identified as the most effective option currently available to reduce the need for landfill disposal. Waste-to-energy is commercially, technically, and environmentally feasible, as has been demonstrated by the successful operation of the Commerce Refuse-to-Energy and the Southeast Resource Recovery Facilities in Los Angeles County. However, no new facility is currently proposed for development. The current lack of enthusiasm for waste-to-energy facilities is generally associated with economic factors such as~~

~~the high capital costs involved in developing these facilities, the deregulation of the energy industry, and the current low prices for power, and other factors such as the strong public opposition encountered by previous proposals due to air quality concerns. Additionally, its development has been discouraged by its current classification as disposal, rather than diversion under State law. While there are no current proposals to develop waste-to- energy facilities in Los Angeles County, this technology remains a valid disposal option for future consideration.~~

~~Other municipalities throughout the country rely on waste-to-energy facilities for management of significant amounts of their solid waste. Examples of this are the County of Fairfax, Virginia (Ogden Martin Systems of Fairfax, Inc. Owned/operated I-95 Energy/Resource Recovery Facility), and the City of Rochester, Massachusetts (Southeastern Massachusetts (SEMASS) Resource Recovery Facility), where most of the solid waste collected for disposal is incinerated.~~

~~Solid waste combustion systems (incinerators) can be designed to operate with two types of solid waste fuel: commingled solid waste (mass-fired) and pre-processed solid waste known as refuse-derived fuel (RDF-fired). Mass-fired combustion systems are the predominant type.~~

~~A. *Mass-fired Combustion Systems*~~

~~In a mass-fired combustion system, minimal processing is given to solid waste before it is placed in the charging hopper of the system. The crane operator in charge of loading the charging hopper manually rejects obviously unsuitable items. One of the most critical components of a mass-fired combustion system is the grate system. It serves several functions, including the movement of waste through the system, mixing of the waste, and injection of combustion air. Typical mass-fired combustion facilities are described below.~~

~~ii. Commerce Refuse-to-Energy Facility. The Commerce Refuse-to-Energy Facility (CREF) is a joint powers agency formed by the City of Commerce and the County Sanitation Districts of Los Angeles County (CSD). The CSD has operated CREF since its inception in 1987. It successfully meets the South Coast Air Quality Management District (SCAQMD) requirements and produces some of the lowest emissions from a facility of its type worldwide. The facility combusts approximately 360 tons of refuse per day, 7 days a week, and generates approximately 10 megawatts (MW) of electricity that is sold to Southern California Edison (SCE). Figure 5-1 is a schematic process diagram of the Commerce Refuse-to-Energy Facility.~~

~~Residual ash is created as a result of the burning process, and an ash treatment facility is operating at the site. The ash is mixed with cement in~~

~~the drums of transit mix trucks. The mix is then transferred to portable containers where it hardens into 16 to 17 ton blocks. These blocks are transported to the Puente Hills Landfill where they are crushed and recycled as a base material for roads.~~

~~ii. Southeast Resource Recovery Facility. The Southeast Resource Recovery Facility (SERRF) is a joint powers agency formed by the City of Long Beach and the CSD. The City of Long Beach employs a private contractor to operate the facility. SERRF has the capacity to burn about 1,350 tons of refuse per day, 7 days a week, and generates approximately 30 MW of electricity that is sold to SCE.~~

~~Residual ash is created as a result of the burning process, and an ash treatment facility is operating at the site. SERRF adds cement to the ash and transports the mix to the Puente Hills Landfill where it is recycled as a base material for roads.~~

~~B. *RDF-Fired Combustion Systems*~~

~~Refuse-derived fuel (RDF) is the material remaining after the selected recyclable and noncombustible materials have been removed from the waste stream. The RDF can be produced in shredded or fluff form, or as densified pellets or cubes. Densified RDF is more costly to produce, but is easier to transport and store.~~

~~Due to the higher energy content of RDF compared to unprocessed solid waste, RDF combustion systems can be physically smaller than comparatively rated mass-fired systems. A RDF-fired system can also be controlled more effectively than a mass-fired system because of the more homogeneous nature of RDF, allowing for better combustion control and better performance of air pollution control devices. Typical RDF-fired combustors are shown below.~~

~~Southeastern Massachusetts (SEMASS) Resource Recovery Facility. This is a 2,800 tons per day, 52-MW waste-to-energy plant located in Rochester, Massachusetts. The plant is owned by five partners including Energy Answers Corporation, of Albany, NY, and Bechtel Corporation. SEMASS employs a shred-and-burn concept - a process somewhat in between mass-burn and more extensive refuse-derived fuel (RDF) preparation. SEMASS incorporates several engineering features that make it a state of the art energy/environmental facility as well as a good neighbor, including use of air-cooled condensers, rail loading infrastructure (delivering 10 to 20 percent of the waste by rail car) extensive bottom ash processing, stabilization of fly ash in a patented process, and an innovative contract with the local utility, Commonwealth Electric Company, Wareham, which is not based on the~~

~~Public Utility Regulatory Act (PURPA). An expansion of the facility was completed in 1993, increasing its capacity to over 2,800 tons per day of incoming waste. It serves over 40 communities and generates enough electricity to serve 75,000 homes. The average tipping fee is $25 per ton. The facility was built in 1989 with a capacity of 1,800 tons a day which has been updated to the current 2,800 tons. Total cost to develop the facility was $300 million.~~

~~Solid waste is first sorted with ferrous, glass, and other recyclables being removed. The waste is then shredded and then blown into a burner. Fly ash is used as a mortar for landfill cover, and the bottom ash is stockpiled for further recycling. The facility has met all US EPA New Source Performance Standards air quality regulations. It recently received the 1996 Corporate Award for Resource Recycling from the Ecological Society of America. Figure 5-2 is a schematic process diagram of the Southeastern Massachusetts (SEMASS) Resource Recovery Facility.~~

~~C. *Fluidized Bed Combustion*~~

~~A fluidized bed is an alternative design to conventional combustion systems. It is a process in which a bed of particles is converted to a fluid state by means of an upward flow of gas (or liquid). In its simplest form, a Fluidized Bed Combustion (FBC) system consists of a vertical steel cylinder with a sand bed, a supporting grid plate, and air injection nozzles. When air is forced up through the nozzles, the bed of sand expands up to twice its resting volume and acts like a fluid. RDF can be injected into the reactor above or below the level of the fluidized bed. The "boiling" action of the fluidized bed promotes turbulence and mixing and transfers heat to the fuel. In operation, auxiliary fuel (natural gas or fuel oil) is used to bring the bed up to operating temperature (1,450 F to 1,750 F).~~

~~Fluidized bed combustors have a variety of advantages, including their simplicity of construction, their flexibility in accepting solid, liquid or gaseous fuels, and their high combustion efficiency at a low temperature minimizing NOx generation. A major advantage is the possibility of in-bed removal of SO_2 using limestone or dolomite. Fluidized bed combustors are also suitable for intermittent operation as they can be started up after a nightly stop or even a full weekend.~~

~~Several FBC systems are being used for solid waste combustion throughout the world.~~

~~ii. Duluth Minnesota. A fluidized bed combustion plant, currently operating at 130 tons/day with a total design capacity of 700 tons/day, was built in Duluth, Minnesota. The initial plan was to co-dispose of 300 tons/day of~~

~~dewatered treatment plant sludge and 400 tons/day of solid waste. Stack emissions for the plant are 5 percent of regulated values. The management for the plant is currently considering changing the solid waste/sludge management method to the N-Viro method or land application due to economic considerations regarding the operation of the plant. If this change in disposal is made, the plant will be dismantled.~~

~~iii.Fujisawa Japan. A 390-ton/day fluidized bed combustion system is operating in Fujisawa, Japan. The system employs a proprietary fluidized bed-moving design, which allows mass firing of unprocessed solid waste.~~

~~Energy Products of Idaho (EPI) This incineration system uses a bubble-type fluid bed concept that accepts prepared 10-cm (4-inch) top-size RDF. The RDF particles are exposed to a vigorously turbulent hot environment promoting gasification and char burnout. The design provides for continuous removal of oversized, noncombustible material. Thus, the tramp material does not build up enough to stop fluidization and incur shutdown for clean out. The design provides for continuous removal of oversized noncombustibles. The waste gases then pass through a waste-heat boiler to generate high pressure, superheated steam for electrical generation. The combustion system offered by EPI is at the stage of commercial availability. EPI has installed five furnaces in the US with capacities of up to 600 tons/day using RDF. Examples of this plants are located in Brevard, NC; Tacoma, Washington; and Lacrosse, Wisconsin.~~

~~D. Rotary Cascading Bed Combustion~~

~~The Rotary Cascading Bed Combustion (RCBC) is a robust solid-fuel burner and heat recovery system, a form of Fluidized Bed Combustion (FBC) system. It can burn solid waste, RDF, wood chips, etc. The system consists of a rotating horizontal cylindrical chamber with bundles of boiler tubes projecting into the end of the chamber. The rotational speed of the chamber is high enough to keep the bed material continually airborne, thus increasing combustion. The hot solids cycle preheats the combustion air, drying and ignites it. Two furnaces are now operating in the United States, a development unit at North American Rayon Corporation and a unit used by a hazardous waste firm in Houston Texas. Pedco, Inc., of Cincinnati, Ohio, has yet to develop a front end waste system to produce a sized RDF for its RCBC system. Almost all RDF systems have required extensive redesign to attain acceptable levels of reliability.~~

~~5.4.1.1Pyrolysis~~

5.5.1.1 Pyrolyis Systems

Pyrolysis is the thermal processing of waste in the absence of oxygen. Pyrolysis systems are used to convert solid waste into gaseous, liquid, and solid fuels. Because most organic substances are thermally unstable, they can, upon heating in an oxygen-free atmosphere, be broken down into gaseous, liquid, and solid components.

Pyrolysis systems typically include kiln type structures which use external heat to process solid waste - there are no flames applied directly to the solid waste in this process. ~~In contrast to the combustion and gasification processes, the pyrolytic process requires an external heat source.~~

Typical feedstock for pyrolysis systems range from municipal solid waste (MSW) residuals to specific organic feedstocks. MSW residuals are acceptable if the non-thermally degraded materials are separated, and if the residual materials are dry.

During a pyrolysis operation, municipal solid waste is shredded, fed to a reactor vessel, where it is heated to temperatures ranging from 750°~~900~~ to ~~1400~~ 1650°F producing the following components:

- Syngas component, containing primarily hydrogen (H_2), methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), and various other gases, depending on the organic characteristics of the material being processed.

- Liquid component (Pyrolysis oil), consisting of a tar or oil-like material containing acetic acid, acetone, methanol, and complex oxygenated hydrocarbons. Additional processing of this material results in a synthetic fuel oil.

- Char or ash component, consisting of almost pure carbon plus any inert material originally present in the solid waste.

~~a combustible gas or liquid oil and char or ash.~~
The gas or oil may either be used to generate power or ~~burned immediately or~~ processed further and sold as fuel.

Since solid waste must be shredded prior to heating, potential environmental effects associated with the processing phase of a pyrolysis system are similar to those which may result from a mixed waste composting facility and include increases in noise, dust, traffic, and risk of fire and vector infestation. However, since the actual distillation step is in an enclosed environment, air quality impacts are minimal. ~~may be small~~. ~~Pyrolysis is commonly used in the petroleum industry, but has limited operational experience in handling solid waste.~~

In the United States, only a few small demonstration and commercial pyrolysis facilities have been constructed and operated, most commercial facilities ~~of which~~ have ~~been~~ shut down due to ~~operational problems~~ end product quality.

~~There are three major components resulting from the pyrolysis process. They are the following:~~

- ~~A gas stream component, containing primarily hydrogen, methane, carbon monoxide, carbon dioxide, and various other gases, depending on the organic characteristics of the material being processed.~~

- ~~A liquid component, consisting of a tar or oil-like material containing acetic acid, acetone, methanol, and complex oxygenated hydrocarbons. Additional processing of this material results in a synthetic fuel oil.~~

- ~~A char component, consisting of almost pure carbon plus any inert material originally present in the solid waste.~~

Refer to Section 1.1.2 of the ~~CTE~~Conversion Technology Evaluation Report, for specific information regarding the range of pyrolysis processes and Appendix A, within the report, for lists conversion technology distributors. More general information regarding the pyrolysis system is summarized within Table 5-1 of this chapter.

~~The following are descriptions of some of the pyrolysis systems currently being proposed to manage solid waste:~~

~~5.3.1.2.1 Examples of Pyrolysis Systems~~

~~A. *Occidental Flash Pyrolysis System*. Only one full-scale solid waste pyrolysis system has been built in the United States. Constructed in El Cajon, California, the Occidental Flash Pyrolysis System did not achieve its primary operational goal (production of a saleable pyrolysis oil) and was shut down after two years of operation. Ultimate failure of the system was due to the low marketability of a saleable pyrolysis oil which contained a moisture content of 52 percent. Per the Florida Institute of Technology report, there is an existing plant in La Verne, California which continues to processes solid waste at a rate of 4 tons/day.~~

~~B. Bal-Pac Pyrolytic Gasification System. The Balboa Pacific Corporation has developed the Bal-Pac Pyrolytic Gasification System, a solid waste conversion process which utilizes partial oxidation thermal conversion. The resulting materials are sterile ash and syngas. Balboa Pacific states that the ash can be used to produce a variety of usable products, and the~~

~~combustible gases can be used to produce electricity. Ash produced is primarily composes of carbon and stabilized (oxidized) metals. Rather than incinerating waste, the system thermally degrades organic materials at temperatures in excess of 1,200°F. Balboa Pacific has stated that emissions resulting from the process exceed all standards set by the U.S. Environmental Protection Agency and the Air Quality Management District.~~

~~There are additional examples of pyrolysis type conversion facilities and vendors within the "Conversion Technology Evaluation Report" such as Graveson Energy Management (GEM) America and Interstate Waste Technologies (IWT). Section 1.1.2 of the CTER specifically identifies the steps in the pyrolysis process in detail and provides schematic diagrams for general processes. It is noted in this section of this report that MSW feedstock material, without extensive preprocessing and sorting, is too heterogeneous for conversion technology which is strictly pyrolysis based.~~

~~C. Plasma Torch Technology. In essence, the technology harnesses the heating power of an artificial lightning bolt to produce the high temperatures that cannot be reached through any other process except through nuclear fission/fusion. A plasma is generated when gas, such as oxygen, passes through an electrical arc created by two electrodes. This results in an extremely high temperature that is reached with minimal gas flow. A plasma torch converts electrical energy into thermal energy, creating a localized area of plasma. The torch's intense heat can reach temperatures as high as 12,000 C. Waste dissociates into a solid rock, leaving an inert, gray chunk of glass-like material.~~ (This portion was moved to 5.5.1.2.3)

~~In a 1990 study funded by the Electric Power Research Institute (EPRI), workers turned a 150-kilowatt plasma torch on shredded garbage, and found it reduced the weight of trash by 80 percent and volume by 99 percent. The missing mass emerged as a fuel-grade gas composed of mostly hydrogen, nitrogen, and carbon monoxide. The slag remained was safely inert.~~

~~Research in plasma torch technology is continuing at Georgia Tech University. The University, in partnership with Westinghouse and the U.S. Department of Energy are testing hazardous waste on contaminated soil on the Savannah River. Evaluation of the test results will be completed in November 1997. Further testing will be made on nuclear waste.~~

~~A small community in northeast New Mexico has proposed the idea of acquiring a plasma torch for the disposal of waste. The torch would be capable of disposing of 20 to 40 tons of waste every eight hours. The torch would generate 25 percent more energy than it needs. The slag remained was mostly inert. Estimated cost is approximately $3 million.~~

~~i. Bordeaux, France. Several years ago, public officials from the City of Bordeaux, France, visited the Plasma Application Research Facility (PARF) at Georgia Tech University to observe a demonstration of the technology. To determine the technology's effectiveness, 5,200 pounds of Bordeaux incinerator ash were then shipped to Georgia Tech to be treated. Based on the results, the Bordeaux officials originally decided to build a plasma arc system to treat incinerator ash (France recently passed a law that banned landfilling all but inert wastes by the year 2000). However, the processing facility was built adjacent to the city's dismantled incinerator plant to instead treat the asbestos that is held there. Known as the Inertam, the asbestos treatment facility is believed to be the world's first industrial application of plasma arc technology in a waste treatment application.~~

~~The mobile furnace has been operational since the summer of 1994. It has a capacity of 10 tons per day. With the treatment of this asbestos nearly completed, the mobile plant will be dismantled and be moved to Milan, Italy, to process other materials.~~

~~ii. Matsuyama, Japan. The Japanese city of Matsuyama has a plasma arc facility to treat the 300 tons of incinerator ash that comes from a 3,000 ton-per-day transformation facility.~~

~~iii. San Diego, California. Construction of a furnace by Kaiser Permanente that could torch 12 tons of medical waste a day has been canceled due to lack of funding.~~

~~5.3.3~~5.5.1.2 Gasification Systems

Gasification is the conversion at higher temperatures of ~~Refuse Derived Fuel (RDF)~~ feedstock into combustible gases, using a limited amount of air. Additionally, ~~G~~gasification is a general term used to describe the process of partial oxidation ~~combustion~~ in which a fuel is deliberately combusted with less than the exact amount of oxygen (or air) needed for complete ~~combustion~~ oxidation.

Unfortunately, State statute (PRC 40117) defines gasification inaccurately and in a manner meant to sharply constrain the ability to develop this technology to manage MSW. State statute defines gasification and prohibits the development of a gasification facility unless the facility uses no air or oxygen in the process, produces zero air emissions, no discharges to surface or groundwaters, and processes no feedstock from jurisdictions with less than a 30% diversion rate, among other restrictions. These restrictions are unprecedented for any technology or industry and seem designed to inhibit the development of conversion technologies.

Gasification ~~is a technique for~~ effectively reduc~~ing~~es the volume of solid waste and maximizes the recovery of energy. Gasification temperatures may range from 750° to 12,000°, depending on they type of gasification system used. Typically, the feedstock used is organic or thermally degradable and usually requires preprocessing and drying. Essentially, the process involves partial oxidation~~combustion~~ of a carbonaceous fuel to generate a combustible fuel gas rich in carbon monoxide, hydrogen, and some saturated hydrocarbons, principally methane.

The combustible fuel gas can then be combusted in an internal combustion engine, gas turbine, or boiler under excess-air conditions in order to produce power. Benefits to using gasification systems to manage solid waste are increased levels of feedstock degradation, ability to accept organic and non-organic material for degradation, and production of highly marketable products such as fuel, road base material, and other chemicals.

There are ~~six~~three ~~basic~~ major types of gasific~~ers~~ation systems;~~:~~ fixed bed gasification systems, fluid bed gasification systems, plasma arc gasification systems.

~~A. vertical fixed bed~~
~~B. horizontal fixed bed~~
~~C. fluidized bed~~
~~D. circulating fluid bed~~
~~E. indirectly heated fluidized bed~~
~~F. rotary kiln~~

The following is a brief description of the basic types of gasification systems. For additional information regarding specific gasification systems and lists of various gasification technology vendors, refer to Section 1.1.3 of the Conversion Technology Evaluation Report. Also, general information regarding various gasification systems are summarized within Table 5-1 of this chapter.

5.5.1.2.1 Fixed Bed Gasification System
~~A. Vertical Fixed Bed~~

Vertical Fixed Bed

The vertical fixed bed gasifier ~~has a number of advantages over the other types of gasifiers, including simplicity and relatively low capital costs~~is characterized by the upward orientation of the gasification machinery and the stationary or moving grates within the system.. However, this type of reactor is more sensitive to the mechanical characteristics of the fuel; it requires a uniform, homogenous fuel, such as densified RDF. ~~As shown in figure 5-3,~~

~~fuel flows through the gasifier by gravity, with air and fuel flowing concurrently through the reactor.~~ The end products of the process are primarily low-Btu gas and char.

Gasifiers have the potential to achieve low air pollution emissions with simplified air pollution control devices. The emissions are comparable to or less than the emissions from excess-air combustion systems employing far more complex emission control systems.

~~Vertical fixed bed gasifiers can also be operated with pure oxygen as an oxidant instead of air. Operation with pure oxygen results in the production of a medium-Btu gas with an energy content of 270 to 320 Btu/ft^3. Such a system was developed by the Union Carbide Corporation and marketed as the Purox System. As shown below, the system consisted of the reactor, a minimal front-end system (shredding only), gas cleanup train (electrostatic precipitator, acid absorber, condenser, and water purifier), and an oxygen plant. The gasifier operated at relatively high temperatures (2,600 F to 3,000 F), producing a molten slag as a by-product. Although a pilot plant was successfully tested on a variety of wastes, including MSW and sewage sludge, the Purox System is no longer in commercial production.~~

~~B. *Horizontal Fixed Bed*~~

Horizontal Fixed Bed

~~The horizontal fixed bed gasifier has become the most commercially available type~~.Horizontal fixed bed gasification systems are characterized by horizontally configured moving grates or plates which introduce feedstock into the horizontally oriented gasification machinery. A horizontal fixed bed gasifier consists of two major components: a primary combustion chamber and a secondary combustion chamber. In the primary chamber, waste is gasified by partial oxidation~~combustion~~ under controlled conditions, producing a low-Btu gas, which then flows into the secondary combustion chamber. In the second chamber, it is combusted with excess air which produces high-temperature (1,200 ^{o}F to 1,600 ^{o}F) gases that can be used to produce steam or hot water in an attached waste heat boiler. This system produces lower particulate emissions than conventional excess-air combustors.

Horizontal fixed bed gasifiers are commercially available from several manufacturers in standard sizes ranging from 0.05 to 4.2 tons/hr in capacity.

5.5.1.2.2 Fluid Bed Gasification

~~C. *Fluidized Bed*~~

Fluidized bed gasification is a process in which a bed of particles is converted to a fluid state by means of an upward flow of gas (or liquid). In its simplest form, a ~~F~~fluidized ~~B~~bed ~~Combustion (FBC)~~ system consists of a vertical steel cylinder with a sand bed, a supporting grid plate, and air injection nozzles. When air is forced up through the nozzles, the bed of sand expands up to twice its resting volume and acts like a fluid. Refuse Derived Fuel can be injected into the gasification reactor above or below the level of the fluidized bed. The “boiling” action of the fluidized bed promotes turbulence and mixing and transfers heat to the feedstock. In operation, auxiliary fuel (natural gas or fuel oil) is used to bring the bed up to operating temperature (1,450°F to 1,750°F).

~~A major advantage is the possibility of in-bed removal of~~ SO_2 ~~using limestone or dolomite. Fluidized bed combustors are also suitable for intermittent operation as they can be started up after a nightly stop or even a full weekend.As indicated in Section 5.4.3.2.1 (C), fluidization is a process in which a bed of particles is converted to a fluid state by means of an upward flow of gas (or liquid).~~

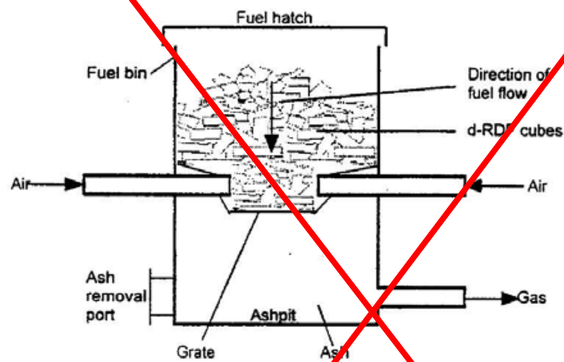
Fluidized bed gasifiers are an alternative design to conventional combustion systems. With minimal modifications, a fluidized bed combustion system can be operated as a fluidized bed gasification~~er~~ system. The major difference between combustion and gasification systems is the method of fuel media decomposition. Fluid bed combustion systems destroy fuel media through full oxidation including flames or combustion, thus producing minimal amounts of char and minimal amounts of syngas. Fluid bed gasification systems thermally decompose organic matter in a minimal oxygen atmosphere in order to produce syngas, combustible liquids, chars, and slag material. Several pilot-scale tests have been conducted with solid waste as fuel. ~~A 1-ton/hour prototype fluidized bed gasifier fueled by RDF has been demonstrated in Kingston, Ontario. A dual fluidized bed gasifier has been developed in Japan. The system employs two fluidized beds, one for fuel and one for char combustion, using the sand as a heat transfer medium between the two beds, producing medium-Btu gas. Also, a fluidized bed gasification system using RDF has been constructed in Italy. The system produces low-Btu gas, which is used in boilers for the production of steam and electricity.~~

~~Experience with full-scale and pilot-scale units has shown that reliable results with mass-fired gasifiers have not been achieved.~~

Currently, there has been some success in Europe and Japan with gasification technologies with processing MSW, with minimal preprocessing in the form of removal of large items, shredding, and sorting. Some processing to remove metals and other inert material is required, both to improve performance of the reactors and to reduce air emissions.

Refer to sections 1.1.3.1 and 1.1.3.2, of the ~~CTE~~Conversion Technology Evaluation Report provides more information regarding the current success with various gasification facilities.

~~Some form of RDF processing to remove metals and other inerts is required, both to improve performance of the reactors and to reduce air emissions. Except for the modular combustion units, gasification systems cannot be considered a viable commercial technology at this time.~~



Source: Integrated Solid Waste Management, Tchobanoglous/Theisen/Vigil

Schematic diagram of batchfed vertical fixed-bed gasifier **Figure 5-3**

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~~Several gasification systems are being used for solid waste management throughout the world.~~
~~i.~~

~~i.Energy Products of Idaho (EPI). Fluidized bed gasification bed materials are typically sand or char and the fluidizing material is air or oxygen. The fuel medium is fed into the system either above or directly into the bed. Bed media is then maintained at a temperature between 1000EF and 1800EF. When a fuel particle is introduced into this environment, its drying and pyrolysis reactions accelerate, thus driving off all gaseous components of fuel media at relatively low temperatures. Remaining char is oxidized to provide the heat source for the drying and de-volatilizing reactions to continue.~~

~~Due to large thermal capacities of inert material of portions of the fuel medium and the fluid action of the bed material, this type of system has a greater capacity for fuel media with lower quality fuel media types. Use of fuel materials which have a higher potential to produce slag through the process is possible due to the lower operating temperature in fluid bed gasification applications. Per EPI, "Energy densities in a fluid bed gasifier are dependent on the fuel characteristics and have been reported as high as four million BTU/hour/ft." The dryer the fuel media ,the higher the energy density and the better the quality of low Btu gas produced.~~

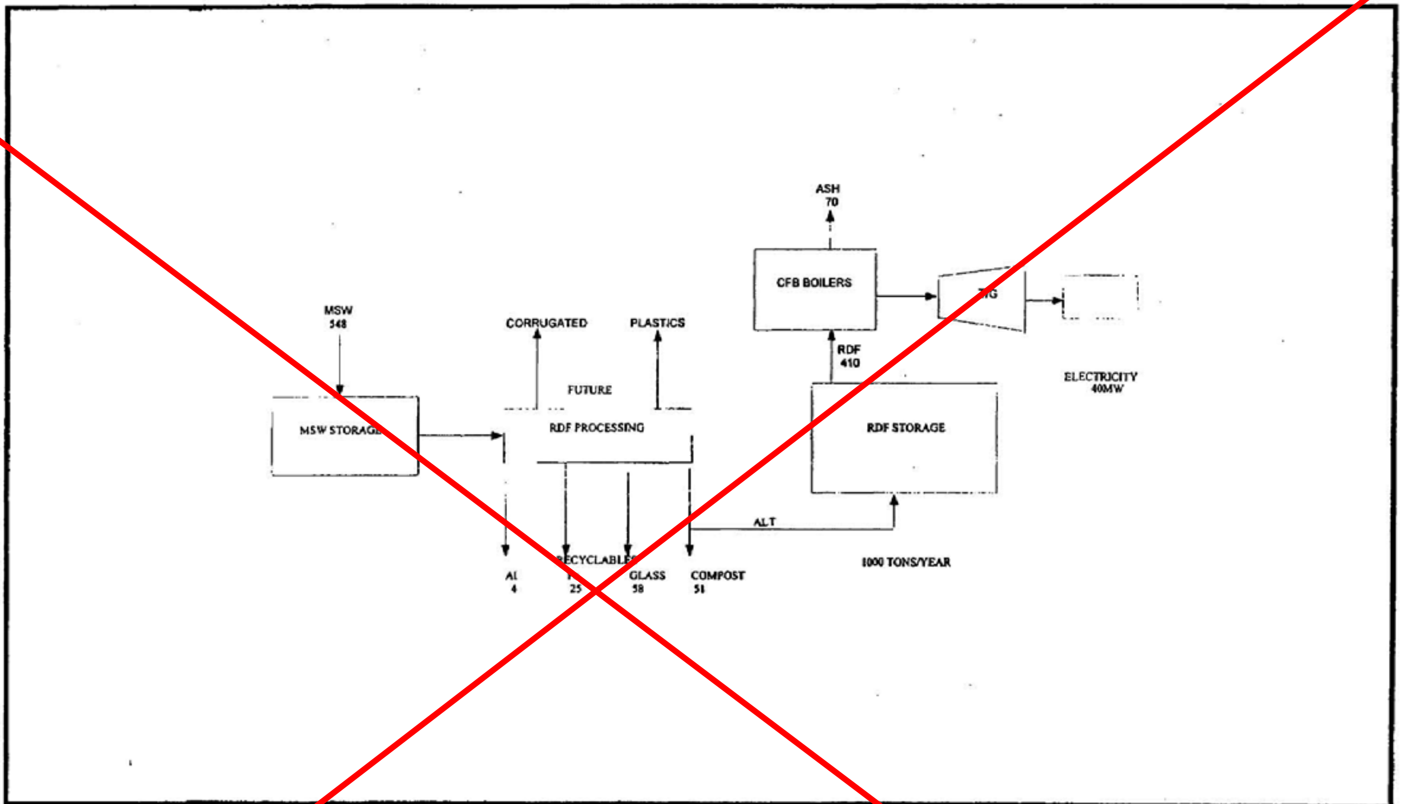
5.5.1.2.3 Plasma Arc Gasification System
~~C.~~ ~~*Plasma Arc Gasification System*~~

Plasma arc gasification systems utilize technology which harnesses the heating power of an artificial lightning bolt, to produce the high temperature gases that cannot be reached through any other process except through nuclear fission/fusion, to process solid waste. A plasma is generated when gas, such as oxygen, passes through an electrical arc created by two electrodes. This results in an extremely high processing temperature that is reached with minimal gas flow.

Hot ionized gas (plasma) is used to heat air or oxygen to high temperatures typically in excess of 7,000°F and use the resulting plasma for treating Municipal Solid Waste. Plasma gasification processes occur in a closed , pressurized reactor and the air/oxygen introduced is controlled for promotion of gasification reactions.

A plasma torch converts electrical energy into thermal energy, creating a localized area of plasma. The torch's intense heat can reach temperatures as high as 12,000 °C. Typical feedstock for this type of gasification are any organic or thermally degradable materials, including MSW. Waste feedstock is thermally processed until it dissociates into a solid rock, leaving an inert, gray chunk of glass-like material.

Refer to section 1.1.4 of the ~~CTE~~Conversion Technology Evaluation Report for more information on plasma arc gasification. In Japan this technology is used to treat wastewater products, processing hazardous or medical waste, and incinerator ash. The aforementioned section of the "Conversion Technology Evaluation Report" describes in detail the total process for this type of conversion technology.



Source: Heat Engineering Spring 199[illegible]

Robbins Flow Diagram **Figure 5-4**

Los Angeles County Countywide Siting Element

~~*D.Circulating Fluidized Bed Gasification*~~

i. ~~Termiska Processer of Sweden (TPS). The manufacturer of this technology, indicates that the process converts solid waste into a clean fuel gas which can either be burned locally or piped to a variety of users. Southern California Edison is working with this technology and has developed an Advanced Integrated Recycling Demonstration Project which would utilize RDF through the fluidized bed gasification process. The goal of the proposed demonstration facility is to process 200 tons per day of refuse at a Materials Recovery Facility (MRF) to yield 150 tons per day of RDF. In 1992, a commercial, two-bed unit was installed in Greve-en-Chianti, Italy. It had a combined capability of 30 MW to gasify 100 percent pelletized RDF fuel.~~

ii. ~~Robbins Resource Recovery Facility. This facility utilizes a circulating fluidized bed (CFB) system developed by Foster-Wheeler Power Systems Corporation (see **Figure 5-4**). The system burns shredded RDF to produce steam used to generate electric power. The 1600 tons/day facility is located in the Village of Robbins, in the southern suburb of Chicago. The facility began operation in January 1997.~~

~~The facility consist of two material recovery and fuel preparation processing lines, two RDF fired CFB combustion systems, two air pollution control systems and a single turbine generator designed to produce 41.5 MW (net) of electric power for sale to Com Ed. The facility is designed to operate 24 hours per day, 365 days a year, with redundancy to permit continuous processing of solid waste during periods of equipment maintenance.~~

~~The material recovery and fuel preparation system is designed to separate and recover for recycling 25 percent of the solid waste delivered to the facility. The system utilizes primary and secondary trommel screens, magnetic separators, several manual picking stations and shredders to produce an RDF of uniform size. The system is designed to remove 90 percent of the ferrous metals, 65 percent of the aluminum cans, and 90 percent of the glass from incoming waste.~~

~~In the CBF boilers, combustion air will be blown upwards through a grate of nozzles in the bottom of the vertical water cooled combustor chamber. RDF and bed material (sand) will be fed through the sidewalls of the combustor and become entrained in the upward flow of hot combustion gases. Sufficient upward air velocity will be used to insure that the fuel and air are vigorously mixed and turbulently suspended in a fluidized bed~~

~~as it burns. Energy in the form of superheated steam will be recovered in a waterwall boiler.~~

~~The system employs a fluidized bed with a cyclone separator that spins out the heavier, larger materials. These are recycled back into the system until they are reduced in size. A boiler efficiency of 81 percent is claimed with this technology. Ash will be used in the fluidized bed system. The fluidized bed allows a large thermal mass to circulate between the furnace and the cyclone. The turbulent mixing and the prolonged gas residence time should also reduce the denovo formation of dioxin and other organic compounds.~~

~~The combustor operates at 1525° to 1675 F. The lower furnace temperatures should reduce the formation of NOx emissions.~~

~~The system pretrommels the incoming waste to improve separation of glass, ferrous, and aluminum. This lowers shredding maintenance and loading on the shredder reducing power consumption. Glass is also separated out along with compostable material. The recycling front end uses electromagnets, sizing, specific gravity, and eddy currents to remove recyclables. The ash is currently landfilled.~~

~~Fifty-five megawatts of power are produced by the system, eleven of which are used in-house. The remainder is sold back to power companies. The tipping fee is approximately $55 per ton of solid waste.~~

~~The capital cost is $385 million. This is the first large scale facility using this technology in the world. As of mid-December 1996, the recycling front end was operating without incident. The boilers have been tested to 110 to 115 percent of load. The first waste burning test period has taken place. Air emissions are lower than expected. The turbine manufactured by Dresser and Rand has been tested to full load. Ash has tested below permitted levels. Final trial runs are scheduled for March 1997.~~

~~iii. Biomass Gasification/Battelle High Throughput Gasification System (BHTGS). The BHGTS is an indirectly heated , two-stage process that uses circulating fluidized bed gasifier and combustor as reactors(see **Figure 5-5**). In a high-throughput gasifier, RDF or other biomass feedstock is gasified in a CFB to a medium-heating-value gas (500 to 600 Btu/sft3) using steam without oxygen as the fluidizing medium. The biomass can be used as a feedstock for power generation systems. Currently, biomass resources include residue from the forest products industry, urban wood waste, food processing waste, and tree trimmings. Different types of biomass systems are possible and include direct combustion of the fuel, the use of gas turbines, or the use of fuel cell~~

~~high-efficiency technologies like gasification. A commercial scale two-chamber fluidized bed biogasification facility using wood is being constructed in Burlington, Vermont. The developer is Future Energy Resources Corporation, a Battelle licensee in Atlanta, Georgia. Shredded wood is volatilized in a fluidized sand bed at 1800 to 2000 F. A char is left which is used to reheat the chamber. The current system is expected to process nominal amount of 200 tons per day with maximum capacity expected to reach 800 tons per day with further testing. The total cost of the present system is about $13 to $14 million. The expected completion date for the Burlington, Vermont facility is March 1997. The initial testing and final trial runs are expected to be completed in May 1997.~~

~~There are several advantages to the Battelle system.~~

~~a. The medium Btu gas is directly substitutable for natural gas.~~

~~b. The gas Btu value is constant~~

~~c. The process does not need an oxygen system~~

~~d. The gas does not need to be cleaned while hot. This decreases capital investment and process complexity.~~

~~A prototype has been tested with RFD. Under sponsorship of the U.S. Department of Energy, Battelle has completed a preliminary investigation of gasification of prepared municipal solid waste RDF to produce a medium Btu gas without oxygen in its High Throughput Gasification System. A successful test program was conducted in a 12 tons/day Process Research Unit to provide data on product gas composition and production rates possible with the RDF feedstock. Data generated during the experimental program were used in the generation of a process conceptual design. A preliminary economic evaluation based on this design indicates that the Battelle process provides significant economic benefits when compared to mass burn technologies. Additionally, gasification under zero oxygen conditions produce fewer pollutants thus simplifying pollution control.~~

~~E. *Indirectly Heated Fluidized Bed*~~

~~Pulse Enhanced and Steam-reforming Technology. The Manufacturing and Technology Conversion International Inc. (MTCI) Steam Reforming Process is an indirectly heated fluidized bed reactor using steam as the fluidizing medium. MTCI has licensed Thermochem, Inc., to apply its Pulse Enhanced and steam-reforming technology to the gasification of RDF, paper mill rejects,~~

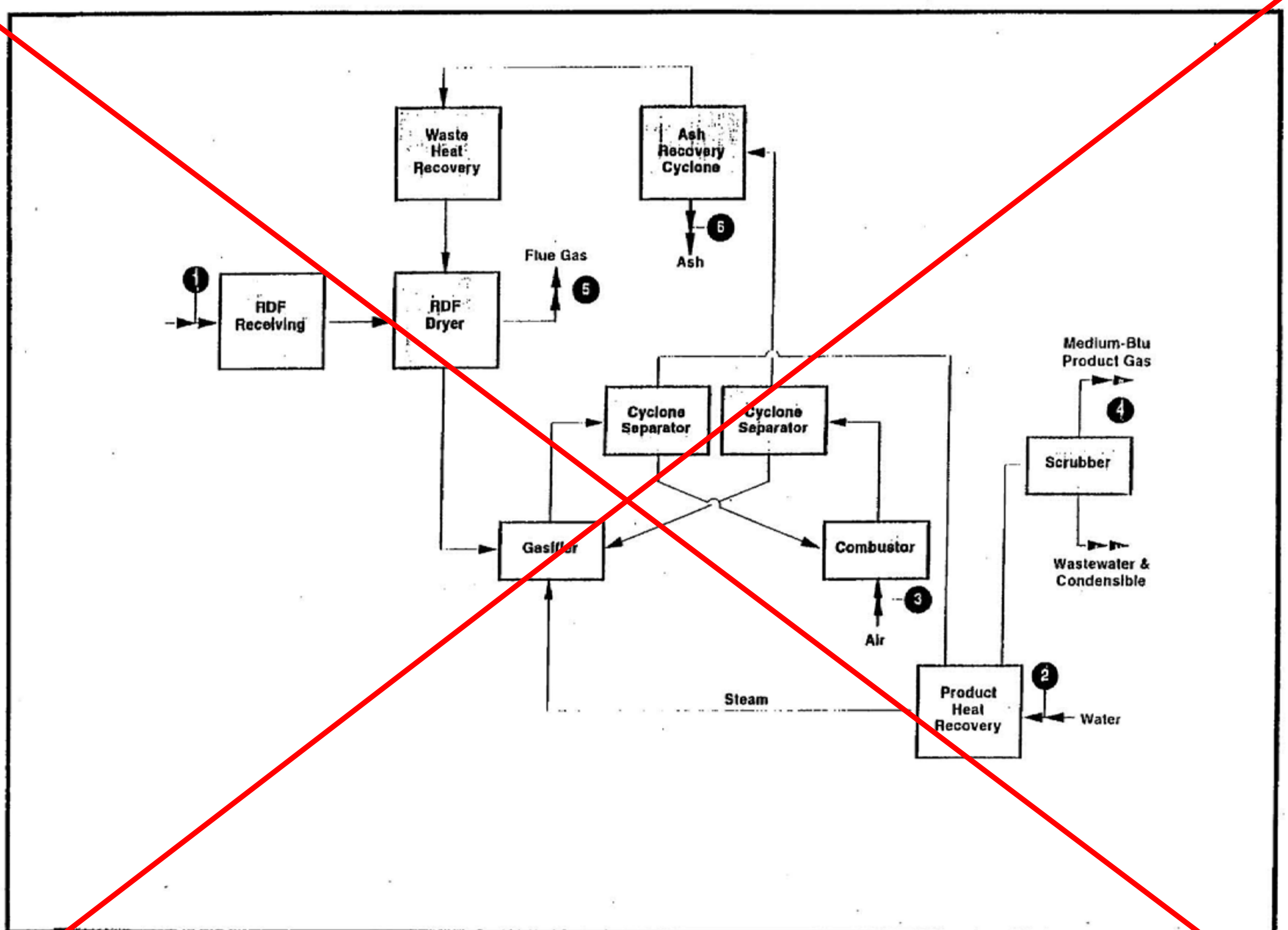
~~agricultural wastes and biomass fuels. The gas produced is a clean hydrogen rich medium with a medium heating value (374 to 448 Btu/ft). The process does not use combustion of the waste material but rather heats the waste indirectly in combination with a fluidized bed and a process of steam reforming. This results in a separation of the inorganic portion and a gasification of the organics. The organic waste fed to the fluid bed steam reformer reacts only with the steam in a reducing atmosphere, producing the fuel gas. The Pulsed Enhanced heat generates an oscillating flow of heat to a bundle of pipes that pass through the fluidized bed gasifier. It is the pulsing action that creates the turbulence to enhance the heat transfer between the gases in the tube and the RDF. As the RDF is not burned, emissions are almost negligible and it is expected the process will pass EPA New Source Performance Standards. The residue meets EPA leachability standards for disposal as a nonhazardous waste. Solid waste has also been tested in the demonstration unit.A demonstration unit was operated in Ontario, California, from 1991 to 1992 using cardboard waste from a paper mill. This unit has been relocated to Baltimore, Maryland, and has since processed coal, wood chips, and straw. A five-heater fluid bed steam-reformer has been built in New Bern, North Carolina to process black liquor from the local paper mill (120tons/day). Another pilot unit has been built in India to process black liquor.~~

~~In a recent engineering study, Thermochem, Inc., identified the major components for the steam-reformer are as follows:~~

- ~~Fluidized bed reformer with pulsed heaters to dry the RDF~~
- ~~Waste-heat recovery steam generator in the product gas stream to generate steam for fluidization~~
- ~~Feedstock dryer using heat from product gas~~
- ~~Quench system to cool the gas and remove the entrained particulates~~
- ~~Char handling system~~

~~Steam superheater and air heater installed on the pulse combuster flue gas~~

~~The system has been tested by the California EPA and the Federal EPA and has been shown to destroy dioxin and furans. NO emissions are also shown to be low. The system is modular and has low maintenance and operating costs. Total capital costs are approximately $92 million for a 650 tons/day RFD unit.~~



Source: Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste Augest 1996 National Renewable Energy Laboratory TP-43021612 U.S. Dept. of Energy, Golden Colorado

Biomass Gasification/Battelle High Throughput Gasification System Process Diagram **Figure 5-5**

Los Angeles County Countywide Siting Element

~~F. *Rotary Kiln*~~

~~i. The Proler SynGas Process. This is a patented gasification technology that reforms hydrocarbon-containing wastes into a reactor gas(see **Figure 5-6**). It requires no processing before loading. A 50 tons/day demonstration plant has been built in Houston, Texas. Although the process was originally developed for gasification of automobile shredder waste, limited runs have demonstrated its suitability for gasifying solid waste. The process accepts pre-shredded material and produces a fuel gas suitable for power generation. The residue is discharged in the form of commercially useful vitrified by-products as well as wastes acceptable for landfills. A commercial plant is proposed for large scale gasification of solid waste. The present demonstration plant feeds pre-shredded waste into a kiln-like reactor. A two-stage process is used to produce a gas from the solid waste.~~

~~In the first stage, the waste is fed into a rotary kiln with a bed depth of about two feet and a retention time of about one hour. Here the water and hydrocarbons are devolitilized at a temperature of 650 C to 850 C in a reducing atmosphere. As the feed material is heated and gasified, the raw gas and solids are discharged into the Hot Pneumatic Separator (HPS). The larger solid constituents are removed here by a series of baffles. The raw gas is cleaned in the hot cyclone followed by a baghouse and scrubber. In the second stage, the fines are separated out and the synthetic gas is used to vitrify the minerals and oxidize the carbon. The reactor is fired with the exhaust from a vitrifier that uses fuel gas, char carbon, and oxygen to melt the mineral residue. Fuel gas is produced with a medium heat content which can be used for power generation. The residue is a product that can be used by the tile industry.~~

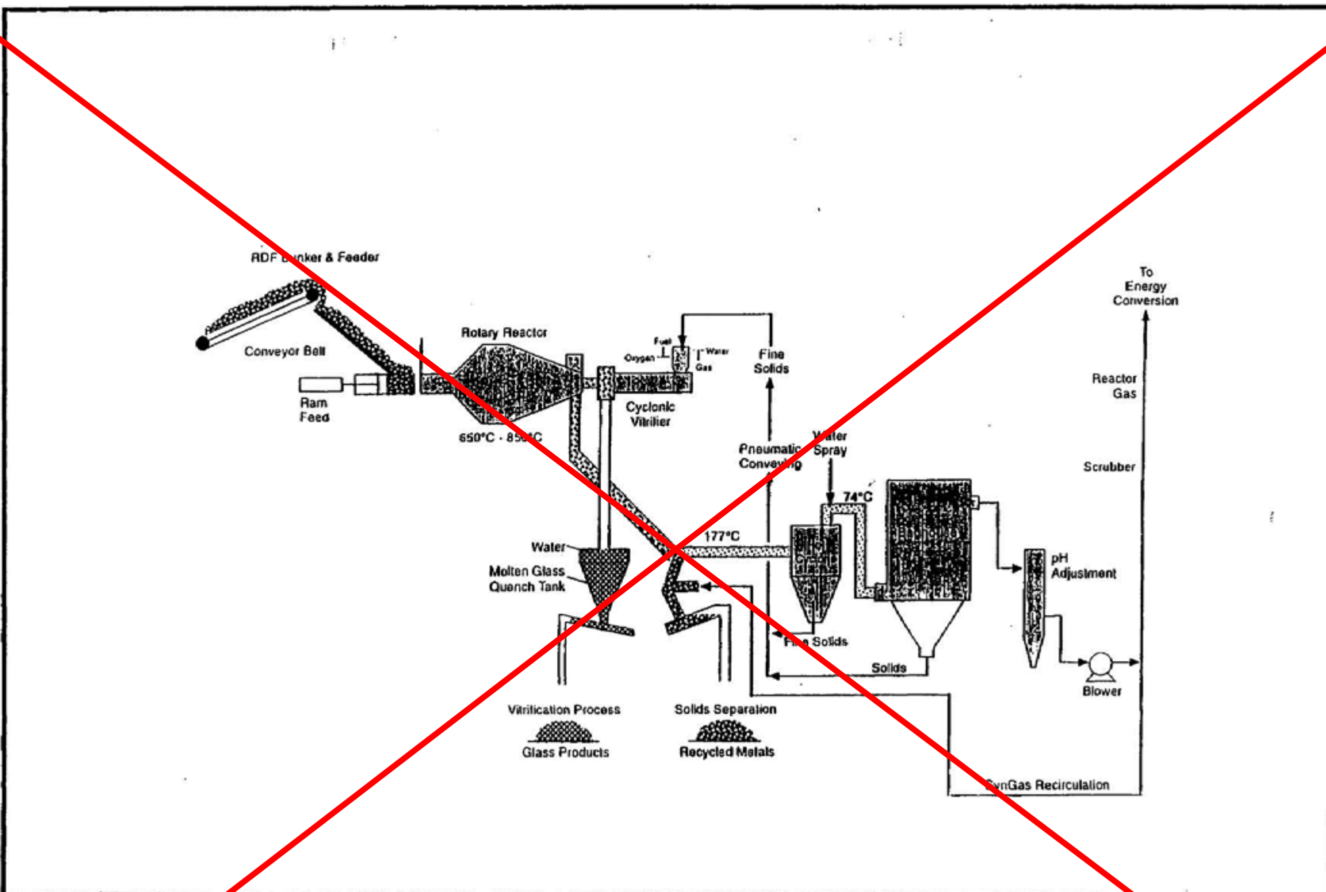
~~ii. The synthetic gas produced by this process can also be made into several other products. If the gas is used to make electricity, then one has produced a gas with the same value as methane. But the synthetic gas can also be made into several other products with technology that is commonly in use today, for example ethanol, methanol, acetic acid, and ammonia. **Thermoselect Inc.** The Thermoselect process is a method of gasifying solid waste and industrial raw wastes (see **Figure 5-7**). The Thermoselect system uses commingled solid waste and "selected" industrial waste to produce reactor gas, vitrified soil granules, elemental sulfur and sodium salts. No liquid effluent is discharged into the environment. Process water is treated and recycled. In addition, the process is intended to minimize both the formation and emission of particulates, nitrogen oxides, and other pollutants.~~

~~Gasification is achieved at a high temperature. The mixture of solid refuse and char reaches 800 C (1472 F) during the end of the first discharge period known as the degasification period. The gasification products are then retained in a reactor at 1200 C (2192 F) for more than 4 seconds. The resultant gas is then quenched to 90 C(194 F). This combination of time and temperature is sufficient to destroy complex organic compounds produced by the gasification process. The raw gas is then cleaned in a gas purification system that uses an iron chelator to remove the hydrogen sulfide. The system is a closed loop system and does not release refuse-developed gases into the environment. The only emissions released are from the combustion of the synthetic gas. The manufacturer claims no ash residue is produced. The heavy metals are separated and removed by a vapor quench hydrolyzing the heavy metals. The resulting metal hydroxides are then precipitated out using sodium sulfite. The metal residues are very high in zinc which can be smelted out and sold.~~

~~The demonstration plant is located at Fondotoce, Italy, in the southern foothills of the Alps. The operating capacity is 106 tons/day with an average tipping fee estimated to be $97.15 per ton. Test results indicate only minute amounts of organic compounds in the reactor gas. Dioxin levels in this process are controlled by keeping oxygen levels low during the quenching process and allowing the chlorine to react with the water. Only trace amounts of polychlorinated p-dioxin and polychlorinated dibenzo furan were detected. The system is expected to comply with U.S. Environmental Protection Agency regulations. The demonstration plant has gone through 15,000 hours of operation 5 days a week processing unshredded municipal and industrial wastes. The system is stated to be very efficient, with efficiency rates of 38 to 40 percent compared to incineration rates of 28 percent.~~

~~Typical U.S. tipping fees are estimated to be $65 to $80 per ton. A 10-ton per hour unit is the only size currently produced and multiples of this are then built to required capacities. Two units producing 500 tons/day are estimated to cost $100 million with a six- unit facility estimated to cost $250 to $275 million. A 2400-ton/day operation is currently in the design and construction stage and is estimated to cost $350 million. Construction of a commercial plant has begun in Karlsruhe, Germany and is expected to be completed in December, 1998.~~

~~**Kocee Waste-to-Energy Gasification System**: The Kocee gasification system is an integrated approach to waste resource recovery utilizing~~



Source: Evaluation of Gasification and novel Thermal Processes for the Treatment of Municiple Solid Waste Augest 1996 National Renewable Energy Laboratory TP-43021612 U.S. Dept of Energy, Golden Colorado

Proler SynGas Schematic Process Diagram **Figure 5-6**
Los Angeles County Countywide Siting Element

~~iii.recycling, composting, and waste-to-energy or gasification technologies. Global Waste and Energy, Inc., of Alberta, Canada, produces a gasification system using RDF. A 50-ton a day demonstration unit is in operation in Alberta, Canada. The company is starting construction of a 1,500-ton-a-day facility in El Salvador with contracts pending in Guatemala, China, and France.~~

~~The process includes a material handling (presorting) front end used for recycling incoming waste stream and an optional composting or thermophilic digestive unit, a RDF shredding unit and a dual stage gasification and burning system. Shredded RDF is fed into the primary gasification chamber, a circular inverted cone at 1600 F. This is turned slowly at 4 revolutions per hour with an air supply at 50 percent of stochiometirc requirements. This produces a low Btu gas containing 15 to 20 percent CO, 30 percent hydrogen, 10 to 15 percent methane ethane and propane (Btu content 350 Btu/cubic foot). This gas is sent to the secondary stage where it is burned. Dioxin and furans are degenerated by the hydrogen in the primary stage to methane. This phenomena is particular to gasification systems and is well documented. Dioxin and furans are said to be ½ of German limits without further abatement. The secondary chamber burns the fuel at 40 percent in excess of stoichiometric requirements to bring CO levels to non detect levels (<3 my per cubic meter). The energy from the secondary chamber is used to turn turbines on for boiler heat.~~

~~The bottom ash goes through a sintering process which bonds heavy metals to aluminum and silica to prevent leaching. This allows the process to meet German requirements for use as cement and road paving. The bottom ash remaining is 9 percent by weight of the total incoming waste. Fly ash after scrubbing is treated with a molecular bonding technique to bond the heavy metals as insoluble sulfide.~~

~~Tipping fee is estimated to be $30 to $35. A 1,500-ton-per-day plant is estimated to cost $125 million with a 10 to 12 acre-footprint.~~

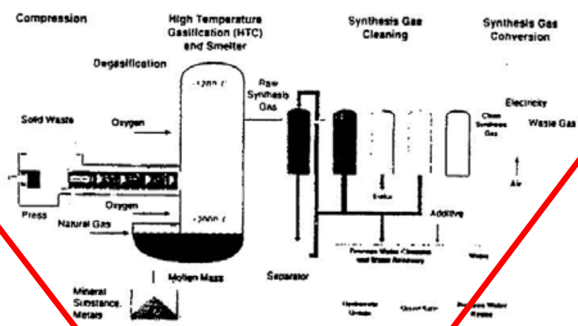
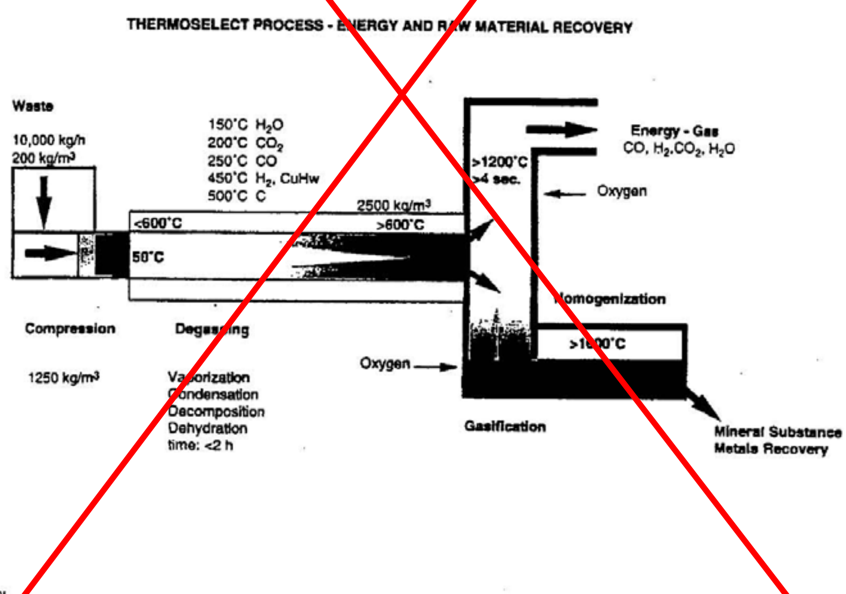


Figure 2: Process Flow



Source: The Thermoselect Solid Waste Treatment Process Thermoselect Inc Troy, Michigan.

Thermoselect Schematic Process Diagram **Figure 5-7**

Los Angeles County Countywide Siting Element

~~5.3.2 Biological/Chemical Conversion Processes~~
5.5.2 Biological Conversion Process

Biological conversion processes are designed for biodegradable organics only and require an extensive amount of pre-processing. Typically, the major end product is compost (a minimally marketable product). The feedstocks are those which include food waste, agricultural waste, biosolids, and various other organics and biodegradable materials. Table 5-1 in this chapter further specifies feedstock types and benefits of anaerobic and aerobic digestion.

~~5.3.2.1 Biosolids Injection Technology~~
5.5.2.1 Anaerobic Digestion

Anaerobic digestion (AD) is a process in which biodegradable organics are converted into compost, methane, and carbon dioxide. A typical AD process for MSW begins with pre-processing in the form of separation of metals, plastic, and non-biodegradable residues.

Hydrolysis, acidification, and production of biogas are the main components for anaerobic digestion. Hydrolysis is the process of breaking chemical bonds of larger molecules into smaller molecules. Acidification is the subsequent process which degrades the smaller molecules into acids, hydrogen gas, and carbon dioxide.

The products from the acidification process are introduced to methane producing bacteria (methanogens) and produce biogas. Typical composition of the resulting biogas is 50 percent to 70 percent methane with medium Btu values.

Refer to section 1.2.2 of the ~~CTE~~Conversion Technology Evaluation Report for further explanation of the Anaerobic Digestion process along with general process diagrams.

~~Biosolids are primarily organic solids (treated sewage sludge) derived from a municipal wastewater treatment plant that meets the requirements specified in 40 CFR Parts 503.13(b)(1)(I), 503.33(a)(1).~~
~~Biosolids Injection Technology (BIT) is an innovation in cement kiln NOx control (see **Figure 5-8**). BIT was developed by the Cement Industry Environmental Consortium (CIEC).~~

~~The CIEC was formed to develop new and innovative NO_x control technologies which might be used to meet future California NO_x emission limitations. The basic principle of BIT technology is to utilize the natural occurring ammonia content of dewatered biosolids, which are generated at municipal wastewater treatment plants, as a reagent to effect selective non-catalytic reduction (SNCR) of NOx. Dewatered biosolids are injected into the kiln system at a location where~~

~~SNCR reaction is favorable. It appears that preheater/precalciner kiln design are best suited for BIT application.~~

~~BIT development has progressed through the initial feasibility study and two phases of demonstration testing. Phase I demonstration testing was completed in 1994 and was designed to prove the concepts and principles on which BIT is based. Phase II testing began in early 1995 and is still underway. All demonstration testing was performed at Mitsubishi Cement Corporation's Cushenberry plant in Lucerne Valley, California. Based on favorable results generated thus far, the CIEC has filed BIT patent applications.~~

~~Biosolids used in the process are from wastewater treatment plants after dewatering (in~~

~~The principle of NOx reduction is the reaction between the~~ $\cancel{NO_X}$ ~~in the flu gas with the ammonia~~ ($\cancel{NH_3}$) ~~present in the biosolids. The chemical reaction is as follows:~~

$$\cancel{NO_X + NH_3 + O_2 \rightarrow N_2 + H_2O}$$

~~The following conditions affect BIT's performance~~

~~-Temperature (1700°F)~~
~~-Residence time (greater than 0.5 seconds)~~
~~-Inlet~~ $\cancel{NO_X}$ ~~concentration~~
~~-Inlet CO concentration~~
~~-Molar ration of~~ $\cancel{NH_3/NO}$
~~-Mixing effectiveness~~

~~Although the equipment installed at the Mitsubishi Cushenberry Plant is temporary, that is, for demonstration only, operating experience has been satisfactory.~~

~~**5.3.2.2 Hydrocarb Gasification**:~~

5.5.2.2 Aerobic Digestion

Aerobic digestion is a biological conversion process in which microbial oxygen dependant bacteria, degrade solid waste. Aerobic digestion feedstock must contain homogeneous biodegradable organic material. Typical feedstock includes food, agricultural, and biosolids wastes.

Aerobic microorganisms in the reactor oxidize biodegradable material and produce large amounts of heat. Renewable energy in the form of synthesized biogas and ethanol are not products of this type of process. The aerobic digestion process predominantly produces compost as well as solid and liquid fertilizers. Residue from the aerobic process is used to produce liquid and solid fertilizers.

Refer to section 1.2.4.3 of the ~~CTE~~Conversion Technology Evaluation Report contains more information regarding the aerobic digestion technology vendors. Also, refer to Table 5-1 of this chapter for more information regarding aerobic digestion.

~~The Hydrocarb process was originally conceived at the Brookhaven National Laboratory and further developed by the Hydrocarb Corporation. The process involves three steps: the hydrogasification of biomass; the pyrolysis of methane into hydrogen and carbon; and the catalytic reaction of hydrogen and carbon monoxide into methanol (see **Figure 5-9**). Examples of the biomass feedstocks are wood, waste products, sewage sludge, and municipal solid waste.~~

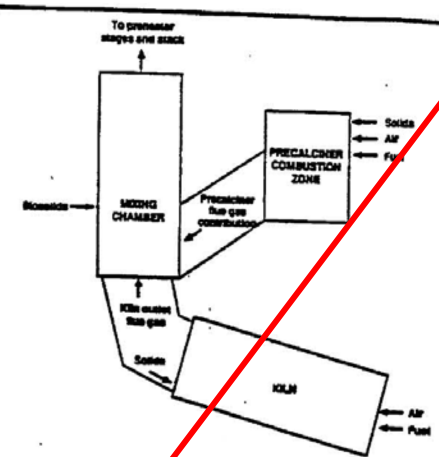


Figure 1. Biosolids Injection Location at Mitsubishi Cement

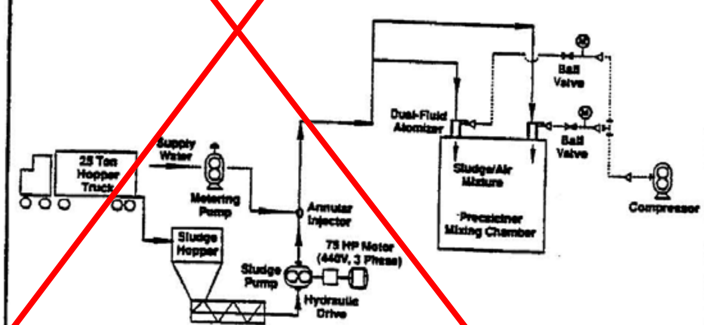


Figure 2. Biosolids Process Flowchart

Source: Biosolids Injection Technology: An Innovation in Cenent Kiln NO_x Control H. O. Biggs

Biosolids Injection Technology **Figure 5-8**

Los Angeles County Countywide Siting Element

5.5.3 Chemical Conversion Processes

Chemical conversion processes are conversion technologies which are designed to change the chemical structure of any organic fuel media. Chemical conversion processes are designed to change organic (biodegradable or inert) fuel, while biological conversion is designed to process only biodegradable organic fuel.

Table 5-1 of this chapter refers to chemical processes also.

5.5.3.1 Acid Hydrolysis

Acid hydrolysis is the process of breaking the chemical bonds of cellulose based materials and fermenting the sugar solution byproduct into ethanol. This hydrolysis of cellulose bonds within fibrous vegetable type matter specifically is called lignocellulosics. Green waste, agricultural, and paper waste are feedstock to be fed into a hydrolysis reactor and the liquid effluent from the reactor fermented and distilled into 99% ethanol.

Typical byproducts from this hydrolysis process are carbon dioxide and lignin type residue. Carbon dioxide produced is a high enough quality to be used for non-food industrial applications. Lignin and other residue which may be used for compost, gasification, combustion, or landfilling purposes.

Refer to section 1.2.3 of the “Conversion Technology Evaluation Report” for more information.

5.5.4. Other Conversion Processes

There are many emerging conversion technologies which have not yet been introduced on a full scale. These types of technologies are continuously being created and studied in order to find their potential solid waste applications. Due to the numerous technology vendors and varying levels of development, minimal discussion will be conducted regarding a national example of such a technology.

Refer to Table 5-1 of this chapter for more information.

5.5.4.1 Thermal Depolymerization (TDP)

Thermal depolymerization is a process in which the solid waste material hydrocarbons are broken into smaller chemical hydrocarbon chains. Typical feedstock for this material are animal or agricultural waste.

Feedstock is fed into a reaction chamber where it is heated to around 250 °C and subjected to 600 psi (4 MPa) for approximately 15 minutes, after which the pressure is rapidly released to boil off most of the water. The result is a mix of crude hydrocarbons and solid minerals, which are separated out. The hydrocarbons are sent to a second-stage reactor where they are heated to 500 °C, further breaking down the longer chains, and the resulting mix of hydrocarbons is then distilled in a manner similar to conventional oil refining.

Currently, there is only one full scale facility (a 250 ton/day facility located in Carthage, Missouri) which processes a highly specific feedstock, namely turkey waste. Byproduts from this process include oil, water, and carbon solids. This plant has not currently been successful in using MSW or RDF as a feedstock.

Section 1.1.5 of the “Conversion Technology Evaluation Report” specifies a conversion process for animal waste to produce renewable energy in the form of oil.

~~5.3.3.3Biosolids Injection Technology~~

~~Biosolids are primarily organic solids (treated sewage sludge) derived from a municipal wastewater treatment plant that meets the requirements specified in 40 CFR Parts 503.13(b)(1)(I), 503.33(a)(1).~~

~~Biosolids Injection Technology (BIT) is an innovation in cement kiln NO_x control. BIT was developed by the Cement Industry Environmental Consortium (CIEC).~~

~~The CIEC was formed to develop new and innovative NO_x control technologies which might be used to meet future California NO_x emission limitations. The basic principle of BIT technology is to utilize the natural occurring ammonia content of dewatered biosolids, which are generated at municipal wastewater treatment plants, as a reagent to effect selective non-catalytic reduction (SNCR) of NOx. Dewatered biosolids are injected into the kiln system at a location where SNCR reaction is favorable. It appears that preheater/precalciner kiln design are best suited for BIT application.~~

~~BIT development has progressed through the initial feasibility study and two phases of demonstration testing. Phase I demonstration testing was completed in 1994 and was designed to prove the concepts and principles on which BIT is based. Phase II testing began in early 1995 and is still underway. All demonstration testing was performed at Mitsubishi Cement Corporation’s Cushenberry plant in Lucerne Valley, California. Based on favorable results generated thus far, the CIEC has filed BIT patent applications.~~

~~Biosolids used in the process are from wastewater treatment plants after dewatering (in the same form as they are shipped to landfarms and other disposal options). Since biosolids are mechanically dewatered without heat input, the solids content varies between 16 and 30 percent (moisture content of 84-70 percent). The dewatered biosolids are obtained from several wastewater~~

~~treatment facilities in the greater Los Angeles area (including the Los Angeles County Sanitation Districts' Carson plant) and are currently being disposed at the Mitsubishi Cushenberry plant in Lucerne Valley to reduce Nitrogen Oxide emissions.~~

~~The Bit technique has resulted in a 50 percent reduction in smog-producing Nitrous Oxide, while consuming approximately 500 tons of biosolids a day. On an annual basis, the Mitsubishi Cement Corporation's Cushenberry plant can consume about 155,000 tons of sewage sludge, equivalent to 10 percent of the annual wastewater sludge generated by Southern California's sewage treatment plants.~~

~~The principle of NOx reduction is the reaction between the~~ $\cancel{NO_X}$ ~~in the flu gas with the ammonia~~ ($\cancel{NH_3}$ ~~)present in the biosolids. The chemical reaction is as follows:~~

$$\cancel{NO_X + NH_3 + O_2 \rightarrow N_2 + H_2O}$$

~~The following conditions affect BIT's performance~~

~~-Temperature (1700°F)~~
~~-Residence time (greater than 0.5 seconds)~~
~~-Inlet~~ $\cancel{NO_X}$ ~~concentration~~
~~-Inlet CO concentration~~
~~-Molar ration of~~ $\cancel{NH_3/NO}$
~~-Mixing effectiveness~~

~~Although the equipment installed at the Mitsubishi Cushenberry Plant is temporary, that is, for demonstration only, operating experience has been satisfactory.~~

~~5.3.3.4Hydrocarb Gasification~~

~~The Hydrocarb process was originally conceived at the Brookhaven National Laboratory and further developed by the Hydrocarb Corporation. The process involves three steps: the hydrogasification of biomass; the pyrolysis of methane into hydrogen and carbon; and the catalytic reaction of hydrogen and carbon monoxide into methanol. Examples of the biomass feedstocks are wood, waste products, sewage sludge, and municipal solid waste.~~

~~Acurex Environmental Corporation is currently building a bench scale methanol production plant, using biomass and natural gas as feedstocks with the goal of verifying the feasibility of the Hydrocarb system at the University of California, Riverside. Completion of the project is expected in late 1997. Capacity of the U.C. Riverside system is to be 50 lbs per hour. This project is being sponsored by the US EPA and the South Coast Air Quality Management District. A pilot plant for the hydrogasification of brown coal was built and operated by Rheinbraun near~~

~~Cologne, Germany (Brungel 1988) with a capacity of 230 tons per day to convert coal into methane. A Hydrocarb plant with a capacity of 100 tons per day using biomass as feedstock is planned in Hawaii (Takahashi 1990).~~

~~The process is basically a three-step process. First, the hydrogenation of the biomass to form a methane rich gas and ash, the thermal decomposition of the methane rich gas to form carbon black and hydrogen gas and carbon monoxide, and then hydrogen and carbon monoxide are catalyzed to produce methanol. The system is run in a reducing atmosphere under pressure in a closed system. Tires, plastic, and paper can also be used as feedstock.~~

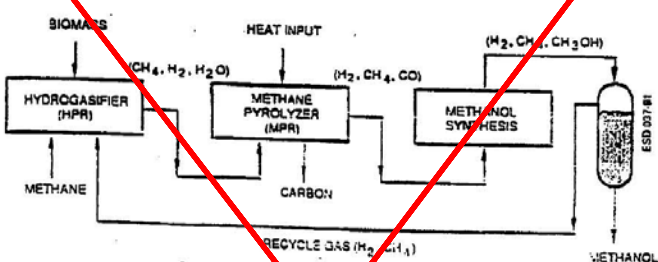


Figure 1. Hydrocarb process block diagram

Source: Treatment of Municiple Solid Waste By the Hydrocarb Process, Acurex Enviormental Corporation , Stephan Unnash

Hydrocarb Process Block Diagram **Figure 5-9**

Los Angeles County Countywide Siting Element

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~~5.3.3 ECONOMIC AND ENVIRONMENTAL ISSUES RELATING TO Transformation/Biomass TECHNOLOGIES~~

~~The emerging transformation technologies have the potential to revolutionalize the way solid waste is managed in Los Angeles County. Some of them offer the potential to substantially reduce some of the air quality impacts currently associated with transformation facilities. However, the following issues should be carefully considered when evaluating transformation tenchnologies as a part of a jurisdiction's solid waste management strategies.~~

~~Cost and environmental concerns to residents are factors which ultimately determine where jurisdictions decide to dispose of their solid waste. Total system costs which typically include collection, transportation, processing, operating and capital investments, need to be evaluated by jurisdictions to determine the economic feasibility of using a particular disposal facility or building a particular transformation facility. A tipping fee the rate charged for each ton of solid waste disposed, is a major factor to jurisdictions or entities evaluating the option of siting facilities which utilize alternative disposal technologies. The tipping fees and revenue from the sale of energy produced must be sufficient to cover capital and operating costs. Even if tipping fees at these facilities at a given time were comparable or lower than fees charged at landfill disposal facilities, jurisdictions must consider the impact of additional costs that may be incurred if the waste stream fluctuates below the level needed to keep the plant running. Furthermore, environmental issues are recognized as critical to the viability of transformation technologies and processes. While air emissions dominate the "political" assessment of a given process, problems with all effluents and environmental consequences must be resolved as part of the permitting process.~~

~~Some of these issues regarding the effect of economic and environmental factors in alternative disposal technologies and processes for the treatment of solid waste was detailed in a report commissioned by the National Renewable Energy Laboratory, U.S. Department of Energy, located in Golden, Colorado, entitled "Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste, August 1996 (NREL/TP-430-21612)". According to the report, low energy prices affect transformation technologies by reducing the flow of revenue from the sale of electricity or stream. During the 1980's and up to the present, the trend in energy prices has been downward. Consequently, the effective break-even tipping fee for proposed facilities which utilize alternative disposal technologies has increased, making financing and community acceptance more difficult.~~

~~Environmental issues have also affected solid waste combustion. Initially, pressure was focused on visible emissions. The Clean Air Act and its Amendments drove the industry away from simple refractory enclosures and~~

~~toward water wall boiler and combustion industry, and to the solid waste incineration market. In 1977 the pollutant "dioxin" emerged as a new issue. Admissions of acid gases-HCL and SO_2, nitrogen oxides (NO_x) and toxic elements also became of increasing concern. Other interests focused on ash.~~

~~Although environmental concerns have not driven thermal processing out of business, they have resulted in significantly higher costs, increased system complexity and long delays in moving projects through the public review and regulatory approval processes. Interestingly, the situation in Europe is similar to that in the United States, but the result is different. Recent legislation in Germany, France, and the Netherlands has mandated an end to raw solid waste landfilling. This legislation will help to further emphasize the role of thermal processing in solid waste management, where solid waste turned into energy has already assumed an important position. However, driven by stringent air emissions limits in some European nations, waste management costs in Europe are very much higher in the United States.~~

~~Several new or enhanced technologies to thermal processes of solid waste are now well established. One class, commonly referred to as Waste-to energy plants, burns waste in the same physical form as it is generated (mass-burn incinerators), which is coupled with elaborate back-end air and residue treatment. Another burns wastes alone or with fossil fuels after preprocessing of the waste to a refuse-derived fuel (RDF).~~

~~Waste-to-energy plants are well-proven combustion processes, and beyond these, a new technology class has emerged – refuse gasification. During this process, the organic fraction of solid waste is heated to drive off a gas with a substantial fuel value. This gas can be cleaned and burned in a gas engine or gas turbine to generate electricity. Emissions data generally show very low rates for dioxins, acid gases, and problematic pollutants.~~

~~The processes studied in detail in the report, identified by the name of the developer, are:~~

- ~~Energy Products of Idaho (EPI)~~
- ~~TPS Termiska Processer AB~~
- ~~Proler International Corporation~~
- ~~Thermoselect Inc.~~
- ~~Batelle~~
- ~~Pedco, Inc.~~
- ~~ThermoChem, Inc.~~

~~Of these seven emerging technologies, two-Energy Products of Idaho and Pedco, Inc., use full combustion, but in innovative ways. The other five processes – TPS Termiska Processor AB, Proler International Corporation, Thermoselect Inc. ,~~

~~Battelle, and ThermoChem Inc. – use gasification methods followed by cleanup and use of the fuel gas. In niche market sectors and in the broader market, the five gasification technologies studied during this project are emerging as "commercially-ready" alternatives.~~

~~The penetration of the thermal processing market by advanced technologies is driven by their environmental, economic, and performance acceptability. From an environmental viewpoint, the report's project team saw the seven technologies as a sound response to the regulatory challenges of the revised New Source Performance Standards (NSPS) and the Maximum Achievable Control Technology (MACT) rules under the federal Clean Air Act. The environmental characteristics of the seven processes are summarized in Table 5-1.~~

~~In the United States, economics has always been a critical and probably driving factor affecting the penetration of thermal processing technology in solid waste practice. Tables 5-2a and 5-2b summarize, in metric and English units respectively, the economic data collected and developed in the report's study. Capital costs of most of these processes are comparable to the $110,000/Mg/day ($100,000/ton/day) typical of contemporary mass burn systems. The net operating costs for the gasification technologies, which are equivalent to the break-even tipping fee, are comparable to those for owner-operated mass burn facilities. The revenue stream from selling energy continues to be critical to overall economic acceptability.~~

~~Results are less clear concerning "performance acceptability." Most, except for the EPI and Thermoselect processes, require an RDF feed. Historically, most RDF facilities have incurred substantial post-construction rework, capital investment, capacity down rating, etc., and landfills are still required. Many systems in this study have significant development tasks ahead of them. Unfortunately, the catalyst of vigorous market activity to push this development and to foster risk-taking is weak. Further, many systems are quite complex. This complexity presents some problems when seeking acceptance by client communities, by regulatory authorities, and from financial and engineering entities involved in concept selection and project implementation.~~

~~5.4 ALTERNATIVE METHODS FOR EXTENDING THE LIFE OF EXISTING CLASS III LANDFILLS~~ (To be relocated to another chapter within the Countywide Siting Element per Facility and Plan Review Subcommittee/ Los Angeles County Solid Waste Management Committee/ Integrated Waste Management Task Force)

~~This section provides a description of various measures that could be used to optimize the use of existing Class III landfills, and thus extend their life. These measures include, but not limited to, the use of alternative materials for daily cover, landfill mining, baling, biostabilization, and shredding of waste, etc.~~

~~5.4.1 Use of Alternative Daily Cover Materials~~

~~Current Federal Subtitle D (40 CFR Part 258 Section 258.21) and State regulations (Title 14, CCR Section 17682) require owners or operator of all solid waste landfills to cover disposed solid waste with at least six (6) inches of earthen materials at the end of each operating day. Additionally, the city or County in which the landfill is located may expand on these minimum requirements. Daily cover is used to control potential for vectors, fires, odors, blowing litter, and scavenging. In California, use of any material other than earthen material, for use as daily cover at a Class III landfill requires approval by the Local Enforcement Agency (LEA), and concurrence with the California Integrated Waste Management Board (CIWMB). Approval by the LEA is granted after a demonstration period (generally six months), during which time the landfill operator must demonstrate adequacy of the proposed materials for use as landfill cover.~~

~~The CIWMB, through the Local Enforcement Agencies, has the sole authority to approve the use of any form of ADCM (i.e., green waste, foam, or geosynthetic blanket) which is granted (or denied) on a case-by-case basis. Currently, the only form of daily cover authorized by statute and the CIWMB is soil. The performance criteria for ADCMs, as required by Subtitle D are contained in CFR 40, and in regulations adopted by the CIWMB. The regulations do not specify ADCMs, instead they establish the performance criteria for soil substitutes.~~

~~Alternative daily cover materials (ADCMs) commonly in use in 1996 include green waste, tarps (geosynthetic blankets), chemical and/ or foam compounds as daily cover at landfills to reduce the amount of soil currently being used for cover purposes. It is reported that the use of tarps, foam, or other types of ADCMs provides the same benefits as soil in controlling potential for odors, vectors, fires and litter by covering the waste as it is disposed at the landfill face but consuming less volume than soil. Therefore, disposal capacity is conserved and the life of the landfill is extended. Based on current estimates, the landfill waste disposal capacity can be increased by as much as 17 to 22 percent through the use of ADCMs. However, actual saving achieved may be lower since soil requirements cannot be entirely eliminated due to State, Federal, and local regulations regarding daily, intermediate, and final cover. These include specific performance standards which may limit the use of ADCMs to the sloping face of the waste cell, restrictions on the use of ADCMs under heavy rain, high wind, and other climatic conditions.~~

~~In Los Angeles County, most of the major Class III landfills already are using some form of ADCM, either green waste or geosynthetic blankets or foam to conserve available air space and capacity. The Antelope Valley, Lancaster, Savage Canyon, and Bradley Landfills use geosynthetic blankets to provide daily cover to the working face of their landfills. Also, the Calabasas, Puente Hills,~~

~~Scholl Canyon, and Spadra Landfills have been approved for the use of green waste as alternative daily cover (ADC) for several years, and Lancaster Landfill has recently completed its ADC demonstration project. Based on the foregoing, there may be no significant capacity savings to be acquired in Los Angeles County through the adoption of these measures since landfill operators are already using ADC materials.~~

~~5.4.2 Biostabilization/Leachate Recirculation~~

~~Biostabilization is the process whereby preprocessed solid waste is shredded and the moisture content is adjusted (preferably between 40 to 60 percent), prior to landfilling. The shredded waste is then aerated for a period of about 60 to 90 days and then compacted with standard landfill compaction equipment. Biostabilization could also be achieved by shredding waste and recirculating leachate inside the landfill to accelerate decomposition. The increased moisture content from recirculating the leachate promotes biological activity, which results in the accelerated breakdown of organic materials, increased landfill gas generation, and volume reduction. The rapid loss of solids from decomposition process in the landfill accelerates the consolidation of the landfill materials. The resultant settlement is reported to lead to increased disposal capacity but also additional operational costs. These methods have been tested in Southwest Landfill, Alachua County, Florida, and in the City of Albany in New York.~~

~~According to the Deputy Commissioner of the City of Albany, New York, biostabilazation was discontinued at their landfill in 1995 due to the cost of shredding. The City of Albany also felt that heavy compaction equipment could achieve a comparable rate of compaction.~~

~~Modern Class III landfills are designed to, among other things, minimize adverse environmental impacts on water and air resources. To achieve this goal, Class III landfills incorporate into their design composite liner systems, leachate collection and removal systems, landfill gas control and monitoring systems, and an effective drainage/storm water management system. In California, leachate production is strongly discouraged in Class III landfills as exemplified by the requirements for landfill gas condensate collection, prohibition of liquids disposal, interception of surface water run-on, and the use of cover material to control infiltration. These controls are employed to reduce the production of leachate and landfill gas at landfills. Since these methods may increase gas and leachate generation, the potential for adverse impacts on air and water resources would also increase.~~

~~5.4.3 Landfill Mining/Reclamation~~

~~Landfill mining/reclamation is a process by which solid wastes previously landfilled are excavated and processed. It is the excavation and mechanical processing of~~

~~previously landfilled materials or landfill airspace, to reduce the size of a landfill, to recover airspace at operating landfills, to recover recyclable materials, or to transfer material from an unlined to a lined landfill. It is a management technology that employs conventional surface mining techniques to dig up and sort buried waste materials. However, the feasibility of mining/reclamation is site specific, depending upon local technical, economic, and regulatory factors.~~

~~One of the earliest applications of landfill mining was the mining project conducted by the Collier County (Florida) Solid Waste Management Department at the Naples Landfill. The mined area contained municipal solid waste that had been landfilled for 10 to 15 years. Between 1986 and 1992, Collier County mined more than 70,000 tons of solid waste and cover material, averaging 40 to 80 tons per hour during processing. Since Collier's application of the technology, few other domestic and international communities have applied the concept, partially because the landfill mining technology is new, and there was no well established body of experience on which solid waste planners could rely (U.S. Environmental Protection Agency, EPA/600/R-93/163, September 1993).~~

~~Landfill mining/reclamation has been used to recover recyclable material, soil, combustibles, and landfill space, as well as remediating and/or upgrading of older, substandard or poorly designed landfills and extend landfill life. Using conventional surface mining techniques and specialized separation equipment, the previously landfilled material may be separated into recyclable material, combustible material, and soil/compost fraction and residual waste.~~

~~The potential environmental and economic benefits of landfill reclamation include the recovery of ferrous metal, tires, and other recyclables; the recovery of combustible material for energy generation; the reduction of impacts associated with closed landfills, the reduction in size or elimination of a landfill's footprint and the avoidance of costs associated with conventional closure and post-closure activities.~~

~~Limiting factors in landfill mining operations appear to be the cost of operation, the depth of excavations, and the geologic conditions. Sandy soil is easier to work with and thus less costly than cohesive soil. Excavations usually continue to within 3 to 4 feet of the liner if the liner is to remain in place. If the landfill is to be completely upgraded, the complete drainage system will be removed. Odor is also a major concern especially if the landfill is five to ten years old. Foam is commonly applied to the working face to keep the odor under control. Masking agents are also commonly used for odor control. The estimated cost of the operation ranges between $4 to $6 per cubic yard.~~

~~The major difficulty in marketing mined materials is the quality of the recyclable material. Recycling of any of the material beyond the soil and the ferrous material is usually difficult and expensive. The soil encountered usually represent 25 to 60~~

~~percent of the total excavated material. Access to a waste-to-energy facility can also limit where excavated materials will be disposed.~~

~~The feasibility of mining or reclamating a landfill is site specific, depending upon local technical, economic, and regulatory factors. Although this an evolving technology, it is unknown whether this method will be accepted for general use in Los Angeles County due to public perception and opposition to landfills, air quality concerns, and State regulatory standards.~~

~~5.4.4 Balefills~~

~~Baling is a process where municipal solid waste is compacted under high-pressure into bales prior to landfilling. Typically, balefills are not operated as canyon fills, but rather as shallow trench fills. Waste is fed into baling machines and compacted into bales, then the bales are loaded onto flat bed trucks and transported to the balefill, unloaded and stacked at the working face, and finally covered. Heavy duty compaction equipment is not needed at a balefill. Balefills require only a forklift for stacking the bales and a wheel or crawler loader for placing the cover material. Because the unit volume of the baled waste is less than the volume of the waste, the amount of cover material is significantly reduced (50 to 60 percent is typical). Reported benefits include reduced transportation costs (long-haul distances), increased landfill life (9 to 23 percent), improved landfill operation (reduces need for on-site equipment and cover material requirements).~~

~~Densities typically achieved in mechanically baled waste range from 1,300 to 1,700 lbs. per cubic yard. Balefills appear to have reduce litter control problems under high wind conditions; may be more resistant to burning than uncompacted waste; may have less odor problems; and in the event of smoldering fires, these would not be as severe due to the reduced presence of oxygen. However, it should be noted that environmental controls are still needed to control drainage as well as gas and leachate generation.~~

~~Fly emergence studies indicate that baling alone without cover soil will not significantly reduce fly emergence (the balefill studied had a weekly soil cover placement frequency and no cover was applied during winter periods when the ground was frozen). Also, one of the studies indicated that placing daily or other cover on the vertical working face of a balefill is not feasible.~~

~~There are currently several large scale balefill operations in the United States. One is the Meadlowland Landfill in Hudson County New Jersey. Another is the North Cook County facility in Chicago. The balers in place at the Hudson County facility have three-ram balers that were originally designed as car crushers. The costs for each of these were approximately $2.3 million. Balers used at recently built balefills use smaller balers costing about $700,000 each. Redundancy is~~

~~highly recommended as maintenance and downtime are significant. Maintenance is required every six months at the Hudson County facility. According to the management at the Hudson County facility, wire is considered the weakest link in the balefill operation. A typical balefill analysis is shown in Table 5-3.~~

~~In Los Angeles county, Class III landfills, using conventional compaction methods, typically achieve densities which range from 900 to 1,400 lbs. per cubic yard, with an average of 1,200 lbs. per cubic yard. These initial average densities are not significantly lower than the reported densities typically achieved in mechanically baled waste, which range from 1,300 to 1,700 lbs. per cubic yard, since the overburden of successive layers of solid waste material, especially in deep canyon fills, results in similar in-place densities for much of the fill. Only the uppermost lifts may benefit from mechanical baling prior to disposal. Since most major landfills in Los Angeles County are deep canyon fills, the density benefits afforded through implementation of baling prior to landfilling may be very limited. Due to the comprehensive control programs currently employed, baling would not be expected to result in substantial improvements over existing dust and litter control measures. Although decomposition of baled waste may be slower than that of unbaled waste, the inherent composition of the waste would not be altered by baling and thus, the potential for gas and leachate production over time may not be less than for unbaled waste..~~

~~Table 5-3: Baling Analysis Procedure~~

~~Disposal Cost Comparison:~~

~~Baler Costs:~~

~~Step 1. Determine number, size and cost of balers needed (approximately 1 baler per 300 to 400 tpd @ $500,000/baler up to 1,200 tpd).~~

~~Step 2. Calculate building size and cost needed (between 12,000 sq. ft for 100 tpd and 40,000 sq. ft for 1,200 tpd @ $35 per sq. ft and site improvements).~~

~~Step 3. Determine personnel/equipment needs and costs.~~

~~Step 4. Calculate operational (wire, power, maintenance) costs.~~

~~Step 5. Calculate yearly amortized costs plus operations.~~

~~Landfill Costs:~~

~~Step 1. Calculate landfill development costs for a landfill and a balefill.~~

~~Step 2. Calculate landfill closure costs for a landfill and a balefill.~~ ~~Step 3. Determine landfill operations costs for a landfill and balefill.~~ ~~Step 4. Calculate yearly amortized costs plus operations for a landfill and a balefill.~~
~~Compare Costs:~~ ~~Step 1. Add baler and balefill annual costs.~~ ~~Step 2. Divide landfill and baler/balefill costs by tons received per year.~~ ~~Step 3. Compare costs per ton.~~

~~**Source**: "Baling out" of the Landfill Crisis by Jeffery Crate, World Waste, October 1992 (page 56).~~

~~In evaluating the feasibility of using baling operations at landfills in Los Angeles County, it is important to note that, since most of the major metropolitan landfills are deep canyon fills, and while baling technology appears to be an appealing way to optimize the use of existing landfill capacity, it has not been demonstrated to be technically and environmentally feasible on a large-scale in an urban setting. Also, additional land requirements and high costs compared to conventional methods may hinder its widespread acceptance and use at landfills in Los Angeles County. Overall tipping fees for balefills, may still be substantially higher than conventional landfills.~~

~~5.4.5 Shredfills~~

~~A shredfill is a sanitary landfill in which solid waste is shredded before landfilling. Shredded solid waste can be compacted to a density greater than 1,200 pounds per cubic yard (pcyd) with the proper equipment, which may result in an increase up to 20 percent in landfill capacity, not including the space saved due to reduced cover requirements. A shredfill in Lewistone Maine attributes a 35 to 40 percent reduction in waste volume at the city landfill because of shredding. In place densities of 1,600 have been achieved during tests with special compactors and operator care. It is not known whether these types of densities or volume reductions are applicable to deep fill sites.~~

~~The economics of shredfills versus conventional landfills does not appear to be attractive at this time. The benefits of conserved densities have not been shown to offset the costs of the shredding operation. A case in point is the San Marcos landfill in San Diego. This landfill was converted back to a conventional landfill in~~

~~1982, because its operation as a shredfill was not economical. The shredding was accomplished at the Palomar Transfer Station. It was determined that shredding and transfer haul cost $8 to $10 per ton. In view of these costs, the Palomar Transfer Station and shredding operation was closed, and direct haul to San Marcos Landfill as a conventional landfill resumed.~~

~~5.4.6 Waste Compaction~~

~~Waste compaction is a method whereby waste is packed more densely in the Landfill. By packing the waste more densely, the life of the landfill is extended since more waste can be placed in a given volume. The CIWMB has conducted tests to compare in-place densities of waste using the conventional crawler tractor and the compactor. The tests were conducted using waste hauled by transfer vehicles on a 5 to 1 slope and on flat ground. The crawler achieved in-place waste densities ranging between 900 and 1,050 pounds per cubic yard (pcyd). The compactor achieved densities between 1,250 and 1,400 pcyd (approximately 35 percent higher than the conventional crawler tractor). The actual conservation of the landfill space will be somewhat less, however, since in-place waste densities from a crawler tractor would increase somewhat over time due to landfill overburden and waste decomposition. Cover requirements will also influence the actual amount of landfill capacity conserved.~~

~~The compactor has other advantages compare to the crawler tractor. The initial cost is less, it consumes less fuel, it lasts longer, and less cover is required with its operation because the waste surface is more uniform after compaction. However, the optimum situation is to use the crawler tractor and compactor in combination. The crawler tractor would push the waste to location, rip and break it up, and spread it. The compactor would compact the waste. Many landfill operators are converting to this combination of equipment recognizing the benefit of conserving landfill space with this method.~~

~~5.4.7 Exclusion of Inert Waste From Class III Landfills.~~

~~One suggested method of conserving Class III landfill capacity is to prohibit disposal of inert waste at these facilities, unless the waste is needed for the operation and/or maintenance of the landfill. In 1990, approximately 7 to 8 percent of the waste received at Los Angeles County Class III landfills was inert waste. The percentage of inert waste received at these landfills has dropped substantially since then, due to the significantly lower tipping fees charged at unclassified (inert waste) landfills. Currently, practically all of the inert waste received at Class III landfills is either contaminated soil that cannot be disposed at unclassified landfills or material that is needed to satisfy daily cover requirements or used for access road maintenance purposes.~~

~~At best, exclusion of inert waste from Class III landfills would have a limited effect on the County's disposal capacity or on the life of existing disposal sites.~~

~~5.4.8 Exclusion of Biosolids (sewage sludge) from Class III Landfills~~

~~Domestic wastewater treatment plants produce large volumes of sludge. Typically, the sludge is either anaerobically or aerobically stabilized. Stabilized sludge are referred to as biosolids. Biosolids are produced at various collection networks of wastewater treatment/reclamation facilities operated by the CSD and the City of Los Angeles Bureau of Sanitation, as well as the Cities of Burbank and Avalon, the Las Virgenes Municipal Water District and the Los Angeles County Department of Public Works.~~

~~In 1995, Los Angeles County residents generated an average of approximately 2,400 wet tons per day (wtpd) of biosolids (treated sewage sludge). Of this amount, 15 percent was managed on-site at various wastewater treatment facilities for purposes such as energy recovery and composting. Approximately 26 percent (600 wtpd) was managed off-site at in-County landfills for landfill co-disposal. The remaining 59 percent is shipped off-site to locations generally outside Los Angeles County for composting and land applications to grow crops such as sudan hay, alfalfa, barley, wheat, and cotton.~~

~~There are alternative disposal technologies in the developmental stages that may be capable of using all the biosolids currently being landfilled in Los Angeles County. Biosolids Injection Technology (BIT) is an innovation in cement kiln~~ ~~NO_x~~ ~~control (see Section 5.3.2.1, Biosolids Injection Technology).~~

~~BIT technology development has progressed through initial feasibility study and two phases of demonstration testing. Phase I demonstration testing was completed in 1994 and was designed to prove the concepts and principles on which BIT technology is based.~~
~~Phase II testing began in early 1995 and is still underway. All demonstration testing was performed at Mitsubishi Cement Corporation's Cushenberry plant in Lucerne Valley, California. Based on favorable results generated thus far, the CIEC has filed BIT technology patent applications.~~

~~On an annual basis, the Cushenberry plant can consume about 155,000 tons of biosolids/sewage sludge, equivalent to 10 percent of the annual wastewater sludge generated by Southern California's sewage treatment plants. When fully operational, it is expected that the plant will be capable of using all the biosolids currently being landfilled in Los Angeles County.~~

~~As various alternative disposal technologies are explored and/or patented, the exclusion of biosolids from Class III landfills would be effective only as a stopgap measure. Its effect on the County's disposal capacity would be limited and would not increase the life of existing disposal sites.~~

5.6 ALTERNATIVE TECHNOLOGY DEVELOPMENTS IN LOS ANGELES COUNTY

5.6.1 Los Angeles County Efforts

As previously mentioned in section 5.3.1, the Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force has vigorously supported increased study and facilitation for conversion technologies within Los Angeles County. ~~In addition to creating the Alternative Technology Advisory Subcommittee, the Task Force has also created the Facility and Plan Review, and Public Education and Information Subcommittees in order to further assist in addressing solid waste management issues in the County of Los Angeles. These three subcommittees work in conjunction to do the following:~~

- Scientifically evaluating the technical, economic and environmental feasibility of conversion technologies
- Promoting the development of conversion technologies by advocating for changes in legislation and regulations
- Acting as a regional resource, disseminating accurate information regarding conversion technologies and urging stakeholders throughout the State to get involved in the development of these technologies

The County and the Task Force have been strong advocates of alternative technology to manage solid waste. Many efforts to promote different technologies have been very successful. Below are significant efforts by the County and the Task Force:

- Built coalitions with numerous government agencies, associations and other entities to promote the development of conversion technologies through policies, statements and other advocacy activities, including the Task Force, the League of Council of Governments, and many others.
- Worked with the CAO to sponsor two legislative bills in 2000 that would have provided 100% diversion credit for waste processed at conversion technology facilities in order to create an incentive for thei development. This effort created the momentum which resulted in the passage of legislation in 2003 that required the Waste Board to study these technologies and provide recommendations to the Legislature.
- Attends and participates at workshops and forums to increase our knowledge and expertise in this area as well as to affirm the County's position and support.

In 2004, the Los Angeles County Integrated Waste Management Task Force established the Alternative Technology Advisory Subcommittee as an outgrowth of its commitment to conversion technologies, supported by a condition in the CUP of the Puente Hills landfill adopted in 2003. The Subcommittee is comprised of a diverse group of professionals including representatives from local government, the Waste Board, consultants, all experts in the field of conversion technologies who are responsible for evaluating and promoting the development of conversion technologies. The ultimate goal of the Subcommittee is to facilitate the development of a demonstration conversion technology facility in Southern California, which would showcase the benefits of conversion technologies as technically, economically, and environmentally viable alternative method of managing solid waste within the County.

On August 18, 2005, the Task Force officially adopted the "Conversion Technology Evaluation Report". Research for this report was conducted which assessed the viability of various conversion technologies, with the goal of vetting technologies for a potential demonstration facility. This demonstration facility is proposed to be partnered with a Material Recovery Facility/Transfer Station, the benefits of such a pairing are significant and include readily available feedstock otherwise destined for landfill disposal, appropriate siting, preprocessing capacity, transportation (cost and pollution) avoidance, and a host of symbiotic benefits.

Los Angeles County, like many other municipalities, is proposing to exclusively site conversion technology facilities at Material Recovery Facilities or Transfer Stations. This proposed siting requirement would further ensure that the waste stream processed by conversion technology facilities are strictly residual solid waste remaining after all feasibly recoverable recyclables have been removed.

The County and the Task Force are committed to promoting solutions that address the solid waste management issues of Los Angeles County.

5.6.1.1 Southern California Conversion Technology Development Project

The ~~CTE~~Conversion Technology Evaluation Report identified areas of solid waste management improvement within Los Angeles County. The report identified the development of a conversion technology demonstration facility to be co-located with a Material Recovery Facility (MRF). This co-located demonstration facility would be an efficient use of materials and time for the solid waste management needs of Los Angeles County.

The proposed demonstration facility is supported by the Task Force and will assist the Countywide objective to evaluate these alternative technologies. The possible benefits from conversion technologies will not only be marketable products but also, employment, improved community development, increased resource awareness and education regarding solid waste. This demonstration facility is proposed to be a better synergy between existing MRF's and TS's in an effort to comply with more stringent greenhouse gas emission laws (such as AB 32), reduce solid waste mismanagement, and support sustainable communities.

5.6.2 City of Los Angeles Alternative Technology Efforts

Concurrently, the City of Los Angeles is proposing to develop an alternative technology facility which will also utilize waste residuals as a feedstock. City of Los Angeles has also created a RENEW LA (Recovering Energy, Natural Resources and Economic Benefit from Waste for Los Angeles) policy to provide resource management for a period of twenty years. City of Los Angeles is also conducting its own conversion technology studies with the goal of developing various conversion technology facilities by 2025.

City of Los Angeles' main objective is to significantly decrease the 3,600 ton/day disposal rate into the Sunshine Canyon landfill. RENEW LA policy will utilize waste residuals to produce alternative fuels and generate electricity. Many thermal, biological, and chemical alternatives to conventional landfilling will be considered in evaluating technologies to process the specified solid waste residual feedstock.

5.7 ECONOMIC AND ENVIRONMENTAL ISSUES ~~RELATING TO DEVELOPMENT OF ALTERNATIVETRANSFORMATION TECHNOLOGIES~~ (Originally Section 5.3.3)

With the trend towards closure of existing landfills, diminishing in-County disposal capacity, and no foreseeable development of new landfills, emerging ~~conversion~~ technologies have the potential to revolutionize ~~way~~ solid waste ~~is~~ managementd in Los Angeles County. ~~Some of them offer the potential to substantially reduce some of the air quality impacts currently associated with transformation facilities. However, the following issues should be carefully considered when evaluating transformation technologies as a part of a jurisdiction's solid waste management strategies.~~ However, development of alternative technologies faces economic and environmental challenges and constraints as described below, due to concerns to residents which ultimately determine where jurisdictions decide to dispose of their solid waste.

This section proposes to expand on the environmental and economic issues of various types of alternative technology. Some of these issues regarding the effect of economic and environmental factors in alternative ~~disposal~~ technologies and processes for the treatment of solid waste are detailed in a report commissioned by the National Renewable Energy Laboratory the United States Department of Energy (in Golden, Colorado) titled, "Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste, August 1996 (NREL/TP-430-21612)".

Total system costs, which typically include collection, transportation, processing, operating and capital investments, need to be evaluated by jurisdictions to determine the economic feasibility of developing a particular alternative technology facility or building a particular transformation facility.

The rate charged for each ton of solid waste received at a facility, is a major factor to jurisdictions or entities evaluating the option of siting facilities which utilize alternative technologies. Tipping fees and revenue from the sale of energy produced must be sufficient to cover capital and operating costs. Even if tipping fees at these facilities at a given time were comparable or lower than fees charged at landfill disposal facilities, jurisdictions must consider the impact of additional costs that may be incurred if the waste stream fluctuates below the level needed to keep the plant running.

According to the National Renewable Energy Laboratory report, low energy prices affected development of transformation technologies by reducing the flow of revenue from the sale of electricity or stream. For example, during the 1980's and up to the early 1990's~~present~~, the trend in energy prices was ~~has been~~ downward.

However, the since the early 1990's, the trend in energy costs has steadily increased. Consequently, the effective break-even tipping fee for proposed alternative ~~disposal~~ technology facilities has increased, thereby making financing and community acceptance of such projects more difficult. ~~In the United States, economics has always been a critical and probably driving factor affecting the penetration of thermal processing technology in solid waste practice.~~ The net operating costs for the gasification technologies, which are equivalent to the break-even tipping fee, are comparable to those for owner-operated mass burn facilities. Nevertheless, the revenue stream from selling energy continues to be critical to overall economic acceptability.

Environmental issues are recognized as critical to the viability of alternative technologies and processes. Environmental issues have affected solid waste management~~combustion~~. Initially, ~~pressure was~~ most environmental issues were focused on visible emissions. Then the Clean Air Act and its Amendments provided a catalyst ~~drove~~for the industry ~~away~~to change from simple refractory enclosures and toward water wall boiler and combustion industry, and to the solid waste combustion market. In 1977 the pollutant "dioxin" emerged as a new issue. Admissions of acid gases-HCL and SO_2, nitrogen oxides (NO_X) and toxic elements also became of increasing concern. Other interests focused on ash production and disposal. ~~transformation~~While air emissions dominate the "political" assessment of a given process, problems with all effluents and environmental consequences must be resolved as part of the permitting process.

Development of transformation facilities, even those using the proven combustion technologies are also likely to encounter strong public opposition due to concerns regarding potential environmental impacts. Moreover, the proponents of these technologies are generally seeking governmental agencies and municipalities to finance the development of new facilities or "proof-of-concept" facilities. However, due to current fiscal constraints, only few local governments may be in a position to finance the development of unproven technology and therefore need to rely on private sector for their development.

Several new or enhanced technologies to thermal processes of solid waste are now well established. One class, commonly referred to as combustion plants, burns waste in the same physical form as it is generated (mass-burn incinerators), which is coupled with elaborate back-end air and residue treatment. Another burns wastes alone or with fossil fuels after preprocessing of the waste to a refuse-derived fuel (RDF). Although environmental concerns have not driven thermal processing out of business, they have resulted in significantly higher costs due to environmental compliance, increased system complexity, and long delays in moving projects through the public review and regulatory approval processes.

Combustion plants are well-proven combustion processes, and beyond these, a new technology class has emerged – refuse gasification. During this process, the organic fraction of solid waste is heated to drive off a gas with a substantial fuel value. This gas can be cleaned and burned in a gas engine or gas turbine to generate electricity. Emissions data generally show very low rates for dioxins, acid gases, and problematic pollutants.

~~The processes studied in detail in the Conversion Technologies Evaluation Report, identified by the name of the technology developer, are:~~

- ~~Energy Products of Idaho (EPI)~~
- ~~TPS Termiska Processer~~
- ~~ABProler International Corporation~~
- ~~Thermoselect Inc.~~
- ~~Batelle~~
- ~~Pedco, Inc.ThermoChem, Inc.~~

~~The penetration of the thermal processing market by advanced technologies is driven by their environmental, economic, and performance acceptability. From an environmental viewpoint, the report's project team saw the seven technologies as a sound response to the regulatory challenges of the revised New Source Performance Standards (NSPS) and the Maximum Achievable Control Technology (MACT) rules under the federal Clean Air Act~~. ~~The environmental characteristics of the seven processes are summarized in Table 5-1.~~

~~Results are less clear concerning "performance acceptability." Most, except for the EPI and Thermoselect processes, require an RDF feed.~~ Historically, most RDF facilities have incurred substantial post-construction rework, capital investment, capacity down rating, etc., and landfills are still required. Many systems in this study have significant development tasks ahead of them. Unfortunately, the catalyst of vigorous market activity to push this development and to foster risk-taking is weak. Further, many systems are quite complex. This complexity presents some problems when seeking acceptance by client communities, by regulatory authorities, and from financial and engineering entities involved in concept selection and project implementation.

Interestingly, the situation in Europe is similar to that in the United States, but the result is different. Recent legislation in Germany, France, and the Netherlands has mandated an end to raw solid waste landfilling. This legislation will help to further emphasize the role of thermal processing in solid waste management, where solid waste turned into energy has already assumed an important position. However, driven by stringent air emissions limits in some European nations, waste management costs in Europe are much higher than in the United States. Although combustion is technically feasible and is successfully demonstrated in the United States and Europe, and specifically in Los Angeles (Commerce Refuse-to-Energy Facility and Southeast Resource Recovery Facility) County at facilities in Commerce and Long Beach, there are no proposed new combustion facilities in Los Angeles County at the present time.

5.8 TABLES, FIGURES, AND FLOWCHARTS

Additional information regarding conversion technologies may be referenced in the August 18, 2005 URS, Conversion Technology Evaluation Report. The following tables, figures, and flowcharts have been added for further information also.

Table 5-1 Environmental Comparison of Developing Technologies

Process Name	Thermal Treatment Technology	Air Pollution Control	Water Pollution Control	Residue Treatment or Disposal
EPI, Inc.	Bubbling Fluid Bed Combustor	Lime Spray Dryer Absorber, Fabric Filter, Selective Non-Catalytic Reduction, Activated Carbon Injection	None: Dry System.	Landfill
TPS Termiska AB	Circulation Fluid Bed Gasifier with Dolomite Cracker	Scrubbing of Fuel Gas to Remove Particulate Matter, Condensable Organics, and Acid gasses, NO_x[1] x1	Cleanup of Scrubber Liquor. Not specified.[2]2	Landfill
Proler International	Rotary Reactor Gasifier and Cylonic Ash Virtifier	Fabric Filter, Wet Scrubber, NO_x[1]	Cleanup of Scrubber Liquor. Not specified.[2]2	Proposed Sale as Virtified Aggregate; Otherwise Landfill
Thermoselect, Inc.	Raw Waste Gasifier	Acidic and Alkaline Scrubber, H_2S Removal, Activated Coke, NO_x[1]. x.1	pH Adjustment, Metal Precipitation, Filteration, Distillation.	Proposed Sale as Virtified Aggregate; Otherwise Landfill
Battelle	Circulating Fluid Bed Gasifier and Combustor	Wet Scrubber, NO_x.[1]	Cleanup of Scrubber Liquor. Not specified.[2]2	Landfill
Pedco Incorporated	Rotary Cascading Bed Combustor	Lime Spray Dryer/Absorber, Fabric Filter, Selective Noncatalytic Reduction, Activated Carbon Injection.	None. Dry System	Landfill
ThermoChem	Pulse-Heated Circulating Fluid Bed Gasifier	Wet Scrubber, NO_x.[1]	Cleanup of Scrubber Liquor. Not specified.[2]2	Landfill

1. NOm_x control may be required for the gas engine or turbine combustor.

2. Details of treatment were not specified by the developer.

Source: Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste, August 1996. NREL/TP-430-21612, National Renewable Energy Laboratory, U.S. Department of Energy, Golden, Colorado.

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~~Table 5-2a Summary of Statistics for Developing Technologies~~
~~(per ton quantities relate to raw MSW, metric units)~~

~~Process~~	~~Product Energy Form~~	~~Plant Size Evaluated~~	~~Capital Cost~~	~~Process Capital~~	~~Proprietary Capital~~	~~Capital Cost~~
-	-	~~(Mg/draw)~~	~~$~~	~~$~~	~~(%)~~	~~($/Mg/d)~~
~~EPI Inc.~~	~~Steam~~	~~780~~	~~79,415~~	~~28,015~~	~~35.3~~	~~101,800~~
~~TPS Termiska Processor AB~~	~~Gas~~	~~1600~~	~~170,675~~	~~58,875~~	~~33.3~~	~~106,700~~
~~Proler International Corp.~~	~~Gas~~	~~1247~~	~~153,625~~	~~57,625~~	~~37.5~~	~~123,200~~
~~Thermoselect Inc.~~	~~Gas~~	~~1440~~	~~236,790~~	~~192,790~~	~~81.4~~	~~164,400~~
~~Battelle~~	~~Gas~~	~~849~~	~~80,532~~	~~12,532~~	~~15.6~~	~~94,900~~
~~Pedco Incorporated~~	~~Steam~~	~~800~~	~~87,067~~	~~28,167~~	~~32.4~~	~~108,800~~
~~ThermoChem Inc.~~	~~Gas~~	~~849~~	~~91,733~~	~~20,983~~	~~22.9~~	~~108,800~~

~~Process~~	~~Gross Operating~~	~~Gross Power~~	~~Net Power~~	~~Net Operating Cost~~	~~Gross Heat Rate~~	~~Net Heat Rate~~
-	~~Cost ($/Mg)*~~	~~(kWh/Mg)~~	~~(kWh/Mg)~~	~~($/Mg)^~~	~~(MJ/kWh)§~~	~~(MJ/kWh)§~~
~~EPI Inc.~~	~~85.21~~	~~1088~~	~~895~~	~~52.71~~	~~9.69~~	~~11.78~~
~~TPS Termiska Processor AB~~	~~71.84~~	~~1230~~	~~1024~~	~~38.91~~	~~8.57~~	~~10.29~~
~~Proler International Corp.~~	~~99.15~~	~~1281~~	~~1091~~	~~59.47~~	~~8.23~~	~~9.67~~
~~Thermoselect Inc.~~	~~135.31~~	~~1083~~	~~778~~	~~106.95~~	~~9.74~~	~~13.55~~
~~Battelle~~	~~79.37~~	~~1001~~	~~871~~	~~47.63~~	~~10.53~~	~~12.11~~
~~Pedco Incorporated~~	~~78.87~~	~~886~~	~~868~~	~~52.29~~	~~11.89~~	~~12.15~~
~~ThermoChem Inc.~~	~~81.17~~	~~1149~~	~~1004~~	~~44.56~~	~~9.17~~	~~10.5~~

~~***Gross operating cost/ton raw refuse** - total of capital charges, insurances, labor, maintenance, and supplies before energy credits.~~

~~**^Net operating cost/ton raw refuse** - gross operating cost less energy credit.~~

~~**§Heat rate** - factor relating the fuel value in the raw refuse (assumed at 11.6 MJ/kg as RDF) to the gross or net generation.~~

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~~Table 5-2b — Summary of Statistics for Developing Technologies~~
~~(per ton quantities relate to raw MSW, English units)~~

Process	Product Energy Form	Plant Size Evaluated (t/draw)	Capital Cost $0	Process Capital $0	Proprietary Capital (%)	Capital Cost ($/t/d)
-	-					
EPI Inc.	Steam	860	79,415	28,015	35.3	92,343
TPS Termiska Processor AB	Gas	1760	170.675	58,875	33.3	96,974
Proler International Corp.	Gas	1370	153,625	57,625	37.5	112,135
Thermoselect Inc.	Gas	1585	236,790	192,790	81.4	149,394
Battelle	Gas	935	80,532	12,532	15.6	86,130
Pedco Incorporated	Steam	880	87,067	28,167	32.4	98,940
ThermoChem Inc.	Gas	935	91,733	20,983	22.9	98,110

Process	Gross Operating Cost ($/t)*	Gross Power (kWh/t)	Net Power (kWh/t)	Net Operating Cost ($/t)^	Gross Heat Rate (Btu/kWh)§	Net Heat Rate (Btu/kWh)§
-						
EPI Inc.	77.46	899	740	47.88	11,117	13,522
TPS Termiska Processor AB	65.31	919	748	35.37	10,879	13,362
Proler International Corp.	90.12	1059	901	54.06	9,445	11,094
Thermoselect Inc.	122.91	895	643	97.06	11,176	15,549
Battelle	71.6	827	720	42.81	12,087	13,896
Pedco Incorporated	85.16	879	717	56.47	11,376	13,938
ThermoChem Inc.	73.6	950	830	40.41	10,529	12,052

~~***Gross operating cost/ton raw refuse** - total of capital charges, insurance, labor, maintenance, and supplies before energy credits.~~

~~**^Net operating cost/ton raw refuse** - gross operating cost less energy credit.~~

~~**§Heat rate** - factor relating the fuel value in the raw refuse (assumed at 5000 Btu/lb, 6050 Btu/lb as RDF) to the gross or net generation.~~

~~Table 5-3: Baling Analysis Procedure~~

~~Disposal Cost Comparison~~
~~Baler Costs:~~ ~~Step 1. Determine number, size and cost of balers needed (approximately 1 baler per 300 to 400 tpd @ $500,000/baler up to 1,200 tpd).~~ ~~Step 2. Calculate building size and cost needed (between 12,000 sq. ft for 100 tpd and 40,000 sq. ft for 1,200 tpd @ $35 per sq. ft and site improvements).~~ ~~Step 3. Determine personnel/equipment needs and costs.~~ ~~Step 4. Calculate operational (wire, power, maintenance) costs.~~ ~~Step 5. Calculate yearly amortized costs plus operations.~~ ~~Landfill Costs:~~ ~~Step 1. Calculate landfill development costs for a landfill and a balefill.~~ ~~Step 2. Calculate landfill closure costs for a landfill and a balefill.~~ ~~Step 3. Determine landfill operations costs for a landfill and balefill.~~ ~~Step 4. Calculate yearly amortized costs plus operations for a landfill and a balefill.~~
~~Compare Costs:~~ ~~Step 1. Add baler and balefill annual costs.~~ ~~Step 2. Divide landfill and baler/balefill costs by tons received per year.~~ ~~Step 3. Compare costs per ton.~~

~~Source: "Baling out" of the Landfill Crisis by Jeffery Crate, World Waste, October 1992 (page 56).~~

Table 5-1 – Conversion Technology Comparison

Category	Type	Typical Temp. Range	Typical Feedstock	Byproducts/Residuals	Benefits/Advantages
Thermal	Pyrolysis	750°-1650°	Any organic or thermally degradable materials. MSW acceptable if separation of non-thermally degraded material included, and drying material.	Byproducts are: carbon char, silica, slag, ash, metals, non-thermally degradable material, tar, and viscous material Contaminants removed from syngas/flue gases prior to being exhausted from stack. Syngas cleaned through use of a boiler, scrubbers, low-NOx burners, and activated carbon injection. All syngas cleaning will provide a clean burning syngas for power generation per South Coast Air Quality Management District (SCAQMD) acceptable limits.	No direct burning in oxygen starved atmosphere. Carbon char produced can be used to produce diesel fuel for vehicles. Other byproducts may be used in a number of ways including road base and construction material. This process typically produces the highest amount of energy per ton of feedstock.
Thermal	Pyrolysis/ Gasification	750° - 2500°	Any organic or thermally degradable materials. MSW acceptable if significant separation and drying included. Byproducts of pyrolysis process.	Byproducts produced: carbon char, silica, slag, ash, metals Pre-cleaning of the syngas is necessary prior to being utilized for production of chemicals, or as a fuel for gas turbines or reciprocating engines, which require clean fuels to minimize corrosion and emissions.	Produce clean syngas which can then be converted into chemicals or power generation through an IC engine or gas turbine. This process typically produces high amounts of energy per ton of feedstock, with the least amount of solid residuals.

Source: Conversion Technology Evaluation Report, August 18, 2005
*N/A – Not Applicable

Table 5-1 – Conversion Technology Comparison

Category	Type	Typical Temp. Range	Typical Feedstock	Byproducts/Residuals	Benefits/Advantages
Thermal	Fixed/Fluid Bed Gasification	1400° - 2500°	Any organic or thermally degradable materials. MSW acceptable if preprocessed to separate significantly large items, shredded, and sorting.	Byproducts produced: carbon char, silica, slag, ash, metals The gasification process has no outlet or stack. Pre-cleaning of the syngas is necessary prior to being utilized for production of chemicals, or as a fuel for gas turbines or reciprocating engines, which require clean fuels to minimize corrosion and emissions.	Produce clean syngas which can then be converted into chemicals or power generation through an IC engine or gas turbine. Fixed bed technology allows for larger items of MSW to be thermally processed, along with lees preprocessing of feedstock material. Fluid bed technology allows for most solid waste to be processed, however larger bulky items are not fully processed.
Thermal	Plasma Arc Gasification	7000°	Any organic or thermally degradable materials. MSW acceptable if preprocessed to separate significantly large items, shredded, and sorting.	Byproducts produced: carbon conversion, molten ash, slag, metals Air emissions are a major environmental issue to be addressed. Contaminants are removed from the syngas and/or from the flue gases prior to being exhausted from a stack.	Volume of syngas produced is lower than the volume of flue gases formed in the combustion of MSW in a waste-to-energy facility. Syngas is costs less to treat due to smaller volume. Syngas is more homogeneous and cleaner-burning fuel than MSW.

Source: Conversion Technology Evaluation Report, August 18, 2005
*N/A – Not Applicable

Table 5-1 – Conversion Technology Comparison

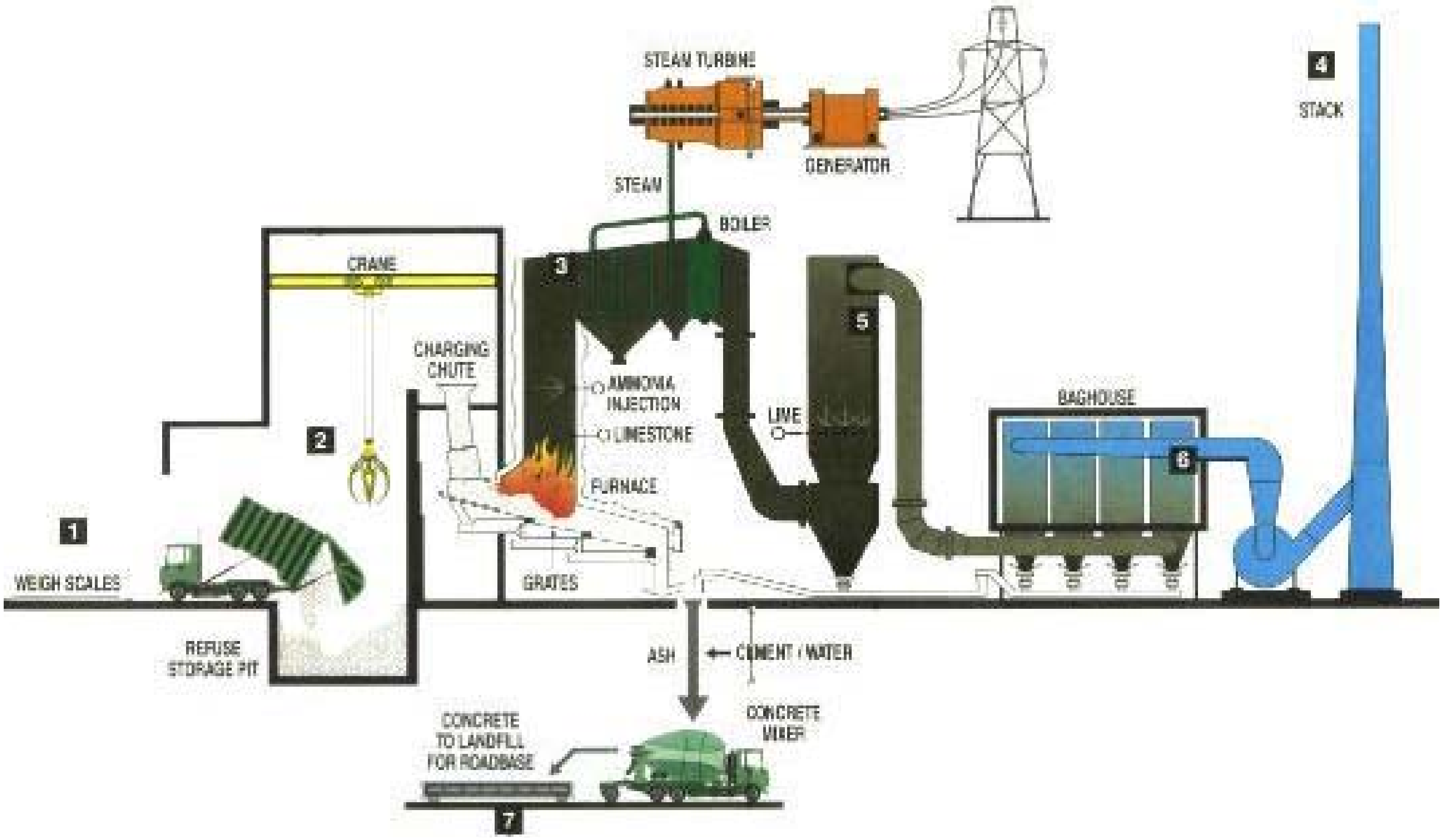
Category	Type	Typical Temp. Range	Typical Feedstock	Byproducts/Residuals	Benefits/Advantages
Biological	Aerobic Digestion	N/A*	Food waste, agricultural waste, sewage biosolids	Byproducts: Residue processed to produce liquid and solid fertilizers. This process is different from anaerobic digestion in that no fuel is produced. Contaminants from leachate and gases produced are captured and not released into adjacent area.	Aerobic microorganisms in the reactor oxidize biodegradable material and produce large amounts of heat.
Chemical	Acid Hydrolysis	N/A*	Lignocellulosics, paper, wood, yard waste, vegetal biomass	Byproducts produced: Carbon dioxide produced may be used for non-food industrial applications. Lignin and other residue which may be used for compost, gasification, combustion, or landfilling purposes Due to the dryers, furnaces, fermentation units, boilers, and handling of hazardous chemical particulants and dangerous compounds must be taken care of. Production of VOC's, NOx, SO2, CO, and PM, PM10. These compounds and particulate matter are produced by dryers, carbon furnaces, fermentation units, boilers, and ethanol load-out systems.	Fuel grade 99% ethanol. Process may be fully enclosed to minimize odor and provide dust control.
Chemical/ Other	Thermal Depolymer-ization	N/A*	All organics or biodegradable materials.	Byproducts produced : oil, water, fertilizer Tipping hall contains an odor control system. Most process water is recycled, vacuum/recompression system to be utilized to minimize wastewater discharge.	Essentially 100% diversion rate for processed MRF residuals. Direct products are fuel, residue for fertilizer, biogas, power generation and carbon.

Source: Conversion Technology Evaluation Report, August 18, 2005
*N/A – Not Applicable

Byproducts for Various Conversion Processes

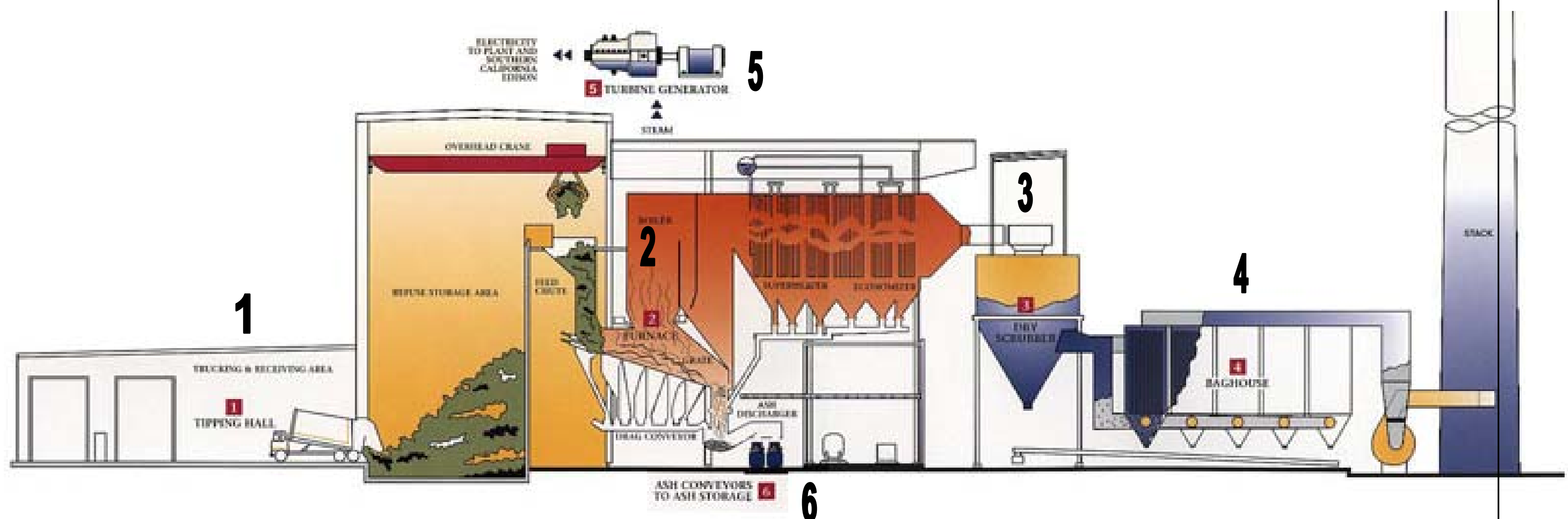
Conversion Technology	MSW component processed	Energy Efficiency	Products Mole %	Scale – Commercialization (energy output)
Partial oxidation gasification air-feed	All organics low moisture <50% wet basis depending on reactor type	75% (cold gas)	29% CO 3% CO_2 15% H_2 3% CH_4 50% N_2	0.5 to 5 MWt
Partial oxidation gasification oxygen-feed	All organics low moisture <50% wet basis depending on reactor type	90% (cold gas)	18% CO 30% CO_2 40% H_2 9% CH_4 1% N_2	5 to 150 MWt
Indirectly fired gasification	All organics high moisture or dry	85% (cold gas)	15% CO 9% CO_2 59% H_2 14% CH_4 3% N_2	10 to 25 MWt
Hydro-gasification with steam pyrolysis	All organics high moisture or dry	90% (cold gas)	11 % CO 24 % H_2 6 % CO_2 49 % CH_4	Pre-commercial
Indirectly fired Pyrolysis with drier & gasifier	All organics high moisture or dry	65% (cold gas)	7% CO 40% CO_2 5% H_2S 32% H_2 15% *HCs*	0.5 to 5 MWt
Indirectly fired Pyrolysis with drier	All organics high moisture or dry	55% (cold gas)	5% CO 36% CO_2 3% H_2S 19% H_2 36% *HCs*	0.5 to 2 MWt
Anaerobic Digestion	Biodegradable Components	30-60% (cold gas)	40-60% CH_4 60-40% CO_2	0.1 to 10 MWt
Fermentation	Biodegradable Components	30-70% (liquid)	Ethanol	0.1 to 10 MWt
Aerobic Digestion (Composting)	Biodegradable Components	N.A.	Soil amendment	N.A.

Source: Evaluation of Conversion Technology Processes and Products
University of California Riverside & University of California Davis



1. Weigh Scales
2. Refuse Storage Pit
3. Furnace & Boiler
4. Turbine – Generator, Stack
5. Dry Scrubber
6. Baghouse
7. Ash Treatment and Recycling

Commerce Refuse-to-Energy Facility Schematic Process Diagram **Figure 5-1**



*See schematic notes on next sheet for further information.

SERRF Refuse to Energy Facility Schematic Process **Figure 5-2**
Los Angeles County Countywide Siting Element

SERRF Schematic Notes

1. **Tipping Hall -** Solid waste delivered by trucks, screened for radioactive material, weighed by computerized scale, drive into enclosed tipping hall, discharging their load. Refuse inspected for unprocessible waste, pushed into refuse storage pit by front end loader. Storage pit area is enclosed, air continuously drawn from pit area, sent through boilers removing dust/odor, destroyed by high temperatures. Carbon filters used for odor control when boilers shut down for maintenance.

2. **Furnace -** Waste lifted out of storage pit by cranes, dropped into refuse feed hopper. At bottom of feed chute, hydraulic rams push refuse into boiler, and combusted under controlled conditions. Heat generated converts water flowing through tubes into steam. Floor of furnace has moving grates pushing refuse through boiler. Refuse passes through boiler, ash discharged into quench tank. Quench tank cools and eliminates dispersion of the ash. Thermal $DeNo_x$ system, injects ammonia into boiler's chamber, used to control nitrogen oxides.

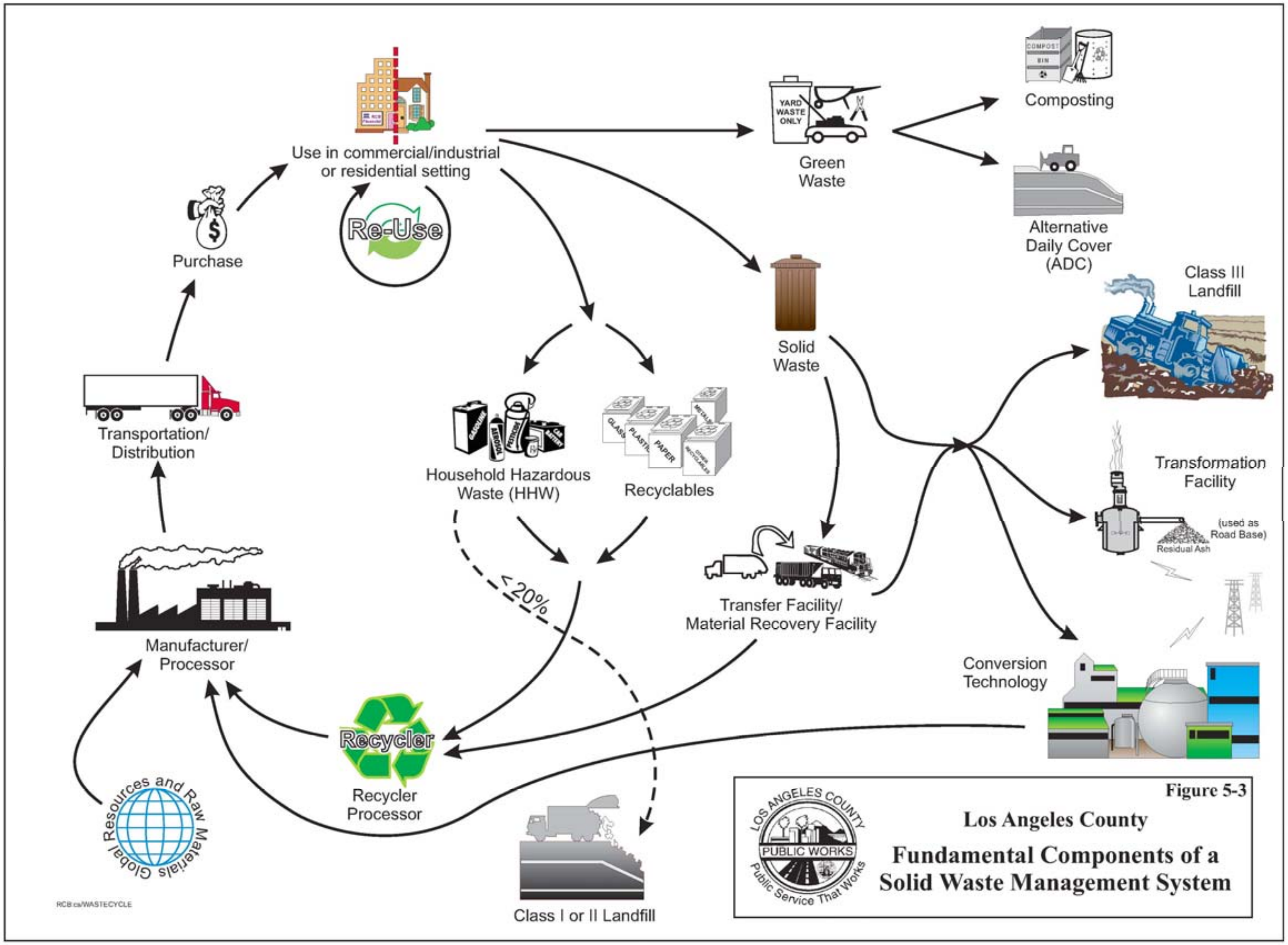
3. **Dry Scrubber -** After leaving boiler, combustion gases travel through pollution control system. Dry scrubber neutralizes acid gasses by spraying lime slurry into exhaust stream. Excess of 95% SO_2 and HCl removed in process. Reacted lime/ash removed from bottom of scrubber.

4. **Baghouse** - Baghouse operates like gigantic vacuum cleaner. Air drawn through baghouse, particulate matter/fly ash trapped in bags. Each boiler has baghouse containing ten modules with bags made of fiberglass. Baghouse cleaned by blowing air, in reverse direction, through the bags. Particulate and fly ash removed from bottom. Process removes 99.5% of particulate matter in air stream down to sub-microscopic levels. After leaving baghouse, cleaned exhaust gases exit through a 265 foot tri-flue stack. Emissions monitored by combination of continuous monitors and periodic stack sampling.

5. **Generator -** Steam generated from refuse used to drive turbine-generator producing electricity. Some electricity produced used to operate facility and remainder is sold to SCE for distribution. Steam used to drive turbine-generator then sent to condenser, converted into water, and recycled back through boilers.

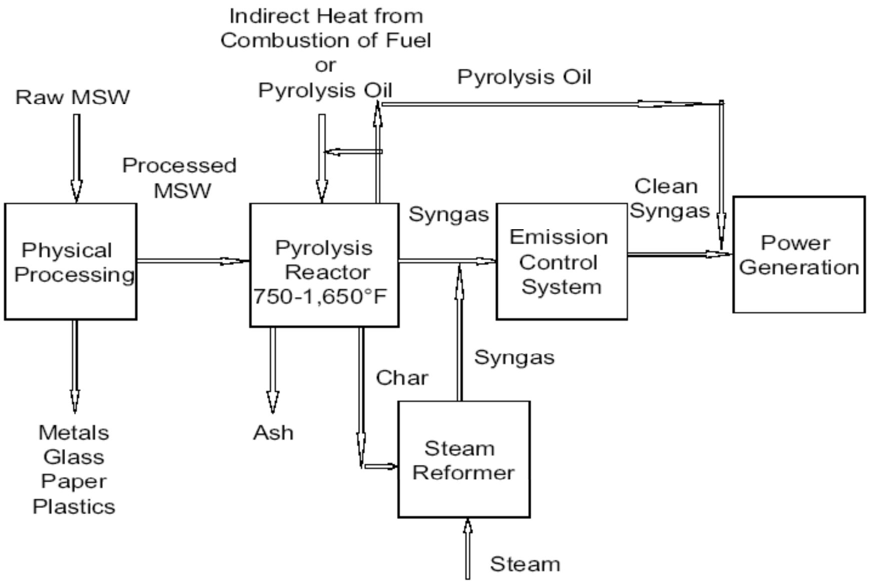
6. **Ash Conveyors** - The ash from the furnace, dry scrubber, and baghouse is treated and transported to the landfill where it is used as road base material.

SERRF Refuse to Energy Facility Schematic Process **Figure 5-2**
Los Angeles County Countywide Siting Element

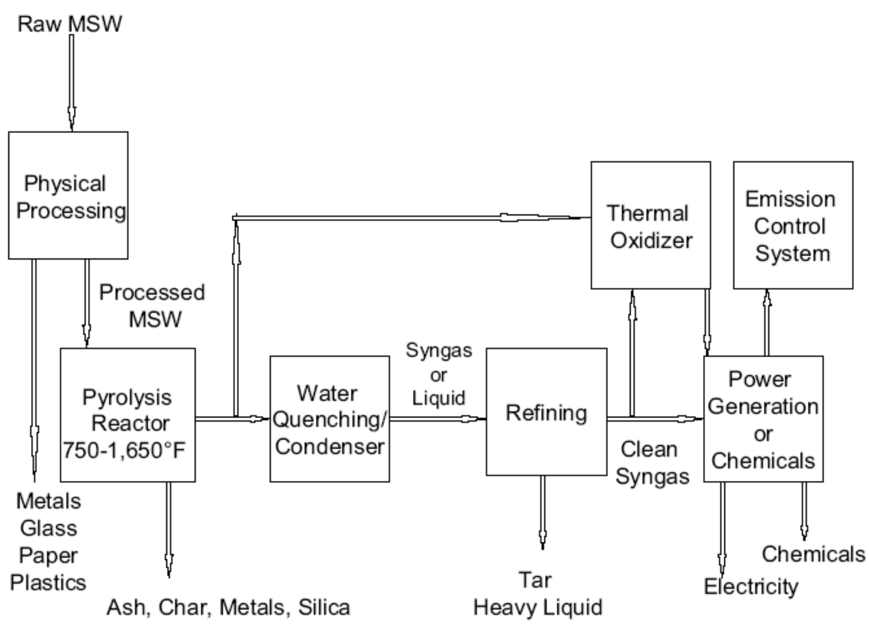


Typical Conversion Technology Procedural Flowchart **Figure 5-3**
Los Angeles County Countywide Siting Element

TYPICAL PYROLYSIS/STEAM REFORMING SYSTEM FOR POWER GENERATION

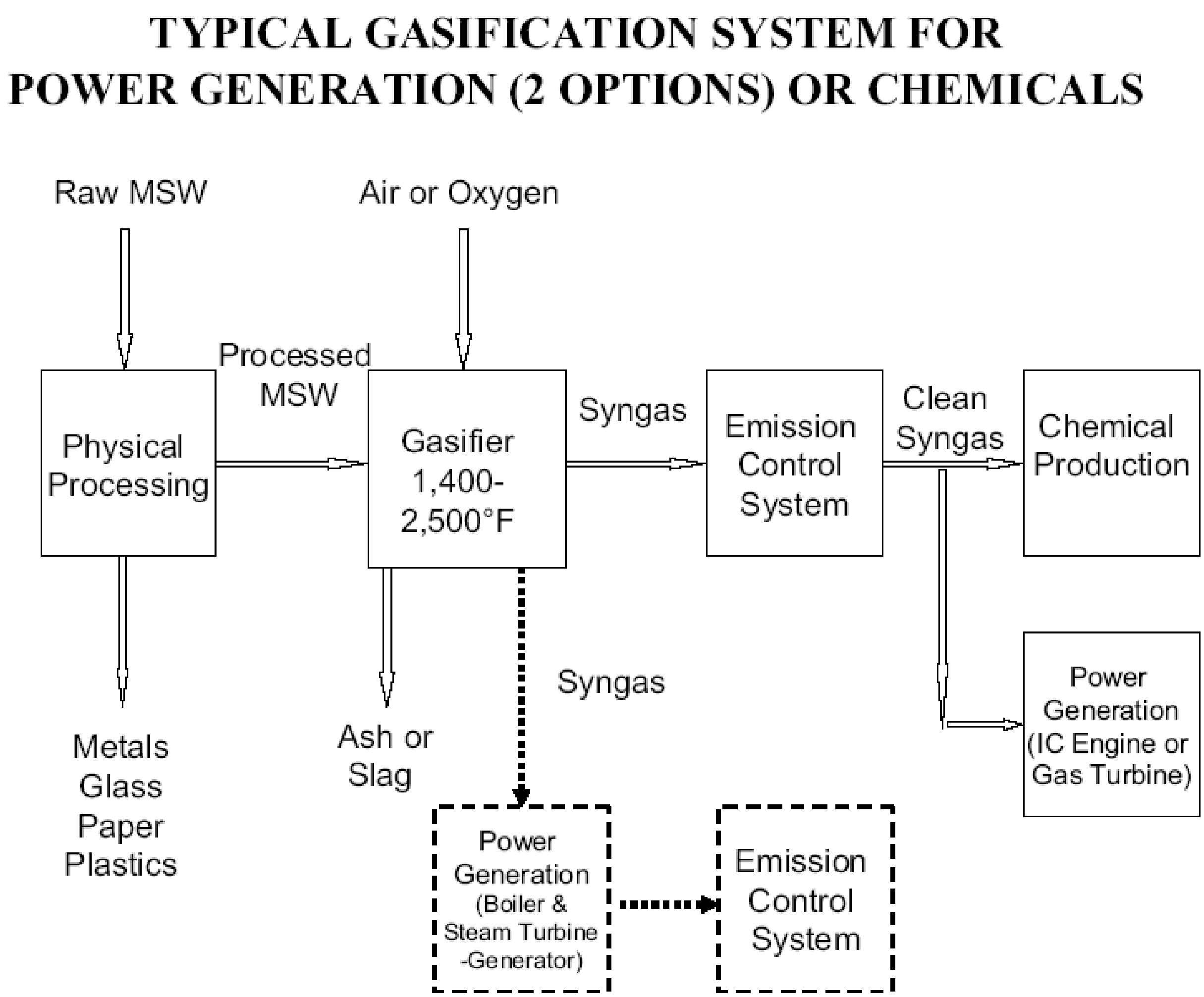


TYPICAL PYROLYSIS SYSTEM FOR POWER GENERATION



General Pyrolysis System Process Flowchart **Figure 5-4**

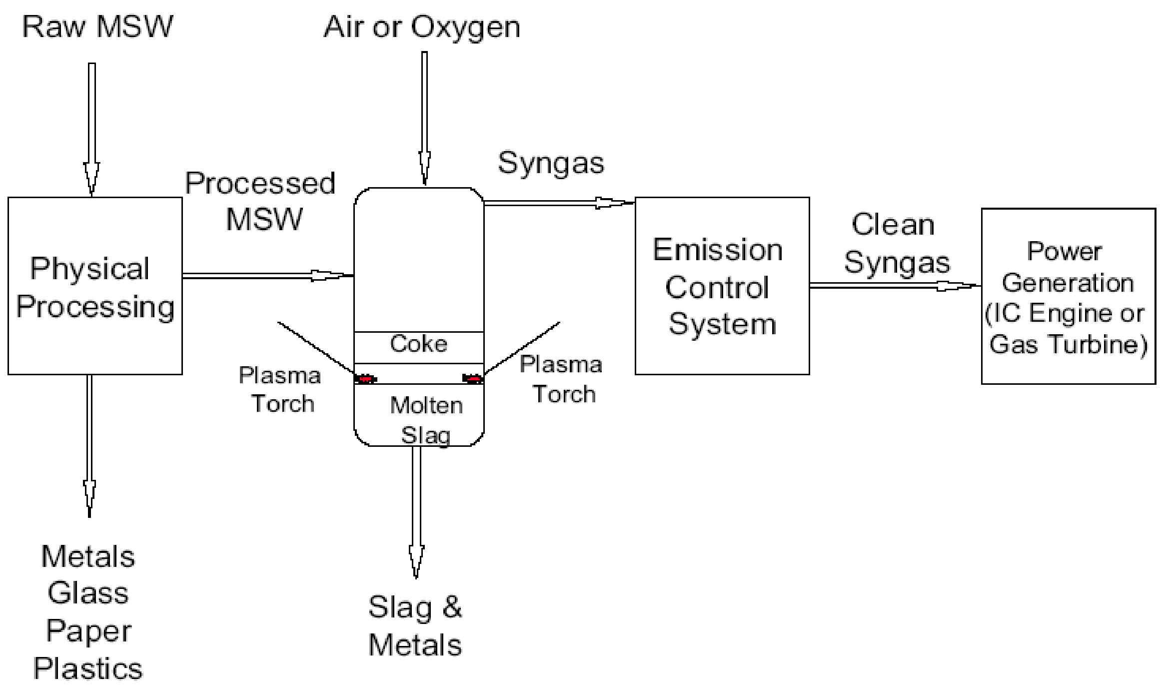
Source: URS Conversion Technology Evaluation Report, August 18,2005



General Gasification System Process Flowchart **Figure 5-5**

Source: URS Conversion Technology Evaluation Report, August 18,2005

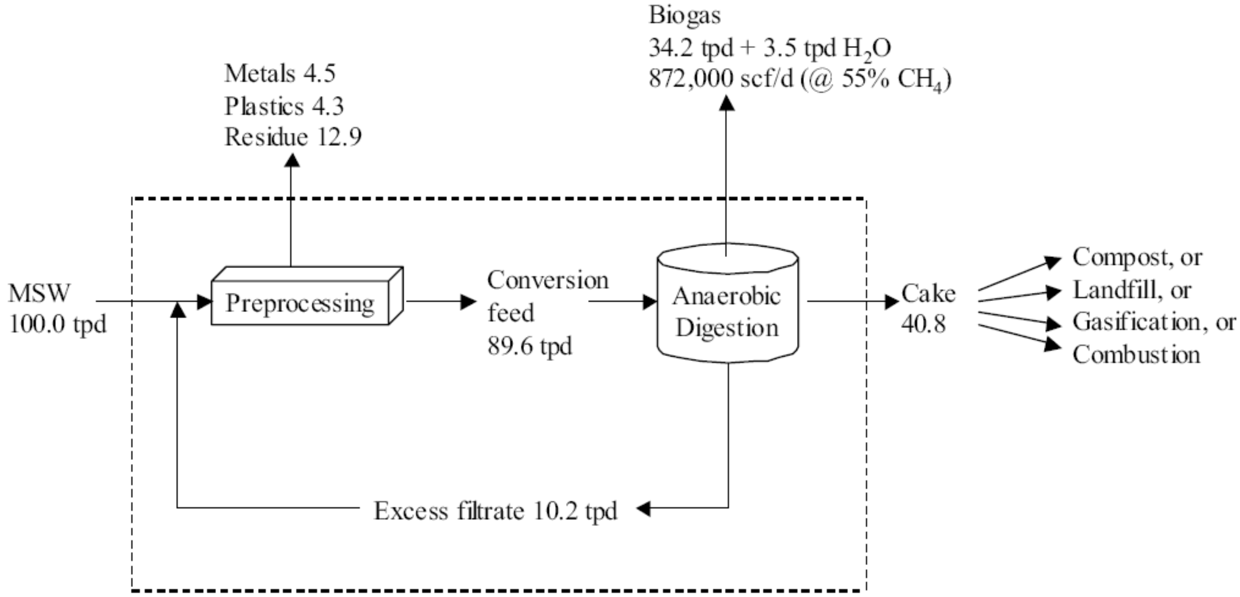
TYPICAL PLASMA GASIFICATION SYSTEM FOR POWER GENERATION



General Plasma Arc Gasification System Process Flowchart **Figure 5-6**

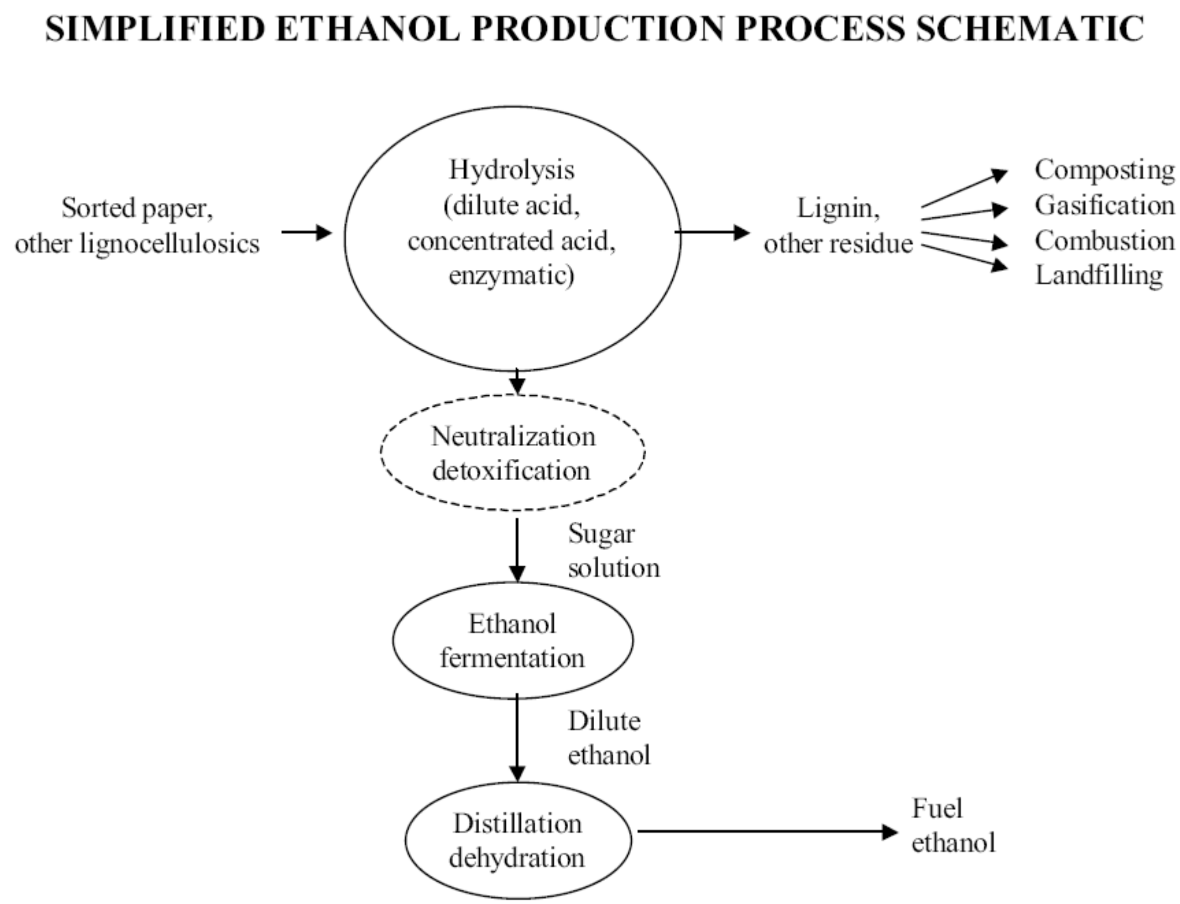
Source: URS Conversion Technology Evaluation Report, August 18,2005

SIMPLIFIED TYPICAL MSW ANAEROBIC DIGESTION PROCESS SCHEMATIC (after Legrand et al. 1989)



General Anaerobic Digestion Process Flowchart **Figure 5-7**

Source: URS Conversion Technology Evaluation Report, August 18,2005



General Acid Hydrolysis Process Flowchart **Figure 5-8**

Source: URS Conversion Technology Evaluation Report, August 18,2005

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ATTACHMENT II

Chapter 5 – Preliminary Draft (Clean Version)

CHAPTER 5 – ALTERNATIVE TECHNOLOGIES

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CHAPTER 5
ALTERNATIVE TECHNOLOGIES

5.1 PURPOSE

The purpose of this chapter is to describe technologies which provide an alternative to existing solid waste disposal technologies and to provide a brief assessment on their current state of development. This chapter also describes a number of benefits, advantages, and environmental and constraints, regarding the identified alternative technologies.

This chapter will explore various alternative technologies which divert waste from landfills and be used to generate energy, produce "green" fuels and other products. Alternatives, such as conversion technologies, are beginning to be considered viable alternatives for solid waste management in the United States. Due to current concern regarding the permitting, siting, and environmental development of conversion technologies, the County of Los Angeles has studied challenges and benefits to these technologies. These challenges and benefits are also considered within the chapter text and in the technology summary Table 5-1.

5.2 DEFINITION OF TERMS

Due to increased interest in development of alternative technologies in the United States and the evolution of thermal technologies, there has been some confusion among widely used and overlapping terms. Section 5.2 defines a variety of terms and their application to alternative technologies. For clarity, select terms will be used throughout the Chapter.

Currently, California law does not properly define these alternative technologies. One term (transformation) is used to include both incineration (mass-burn) and some conversion (non-burn) technologies, while other technologies are not defined at all. Gasification is singled out, however the definition currently incorporated into State statute for gasification is technically and scientifically inaccurate.

The Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force (Task Force) has been lobbying the State Legislature to revise California law so that it accurately reflects the scientific distinctions among these technologies, and regulates them rationally based on their relative environmental benefits and impacts compared with other solid waste management options. To date, the Legislature has been reluctant to address this issue in any way; therefore the following definitions are offered to provide a clearer distinction between the various terminologies currently in use.

5.2.1 Combustion

Combustion refers to an oxidation process - a reaction between a fuel and an oxidant, typically ambient air or oxygen - producing an exothermic reaction in the form of heat. Full combustion includes complete reactions in the form of heat and a full flame.

5.2.2 Conversion Technologies

Conversion technologies refer to a wide array of state of the art technologies capable of converting post-recycled or residual solid waste into useful products, green fuels, and renewable energy through non-combustion thermal, chemical, or biological processes. Conversion technologies do not include mechanical processes. This definition is based on the Conversion Technology Evaluation Report adopted by the Task Force.

5.2.3 Incineration

Incineration refers to an oxidation reaction including heat and flame, that reduces the fuel to the state of ash. This definition is from the American Heritage Dictionary.

5.2.4 Transformation

Transformation refers to a process whose principal function is to process solid waste by incineration. Transformation does not include a composting, gasification, conversion, or biomass processing. Transformation is a term defined in California stature (PRC 40201) to currently include “incineration, pyrolysis, distillation, or biological conversion other than composting.” Because the term as defined in statute does not make a distinction between incineration and conversion technologies, this Chapter will not reference this term.

5.2.5 Waste-to-Energy

Waste-to-Energy is a generic term for a process that uses solid waste to produce energy, however this term has become synonymous with incineration that generates electricity from the waste heat. The California Integrated Waste Management Board characterizes waste-to-energy in such terms as well.

For the sake of clarity, we will use the terms “combustion” and “conversion technologies” throughout this chapter.

5.3 INTRODUCTION

As discussed in Chapter 1 (Subsection 1.4.2.4) and consistent with the goals established in Chapter 2, the primary goal of the Los Angeles County CSE is to address the solid waste disposal needs of the 88 cities in Los Angeles County and the County unincorporated communities for a 15-year planning period.

Adequate disposal capacity has been identified, discussed, and addressed in Chapters 4 and 7. Those needs are met through utilization of existing in-County solid waste disposal facilities, expansion of existing facilities, and development of new facilities. Chapter 7 confirms that no new landfills can be developed in Los Angeles County and expanding existing landfills is a long and challenging process. Currently, nearly all refuse in Los Angeles County is transported by truck to disposal sites within the metropolitan area, however that will be changing within the decade. The County of Los Angeles is in a period of transition, and by the end of this planning period will rely on facilities outside of its borders to manage most of its waste. With the closure of the Puente Hills Landfill in 2013, and other landfills closing soon after in Los Angeles County, it is estimated that as much as 12,000 tons of solid waste will be flowing out of the County by 2025, therefore it is critical to invest in alternative solid waste infrastructure that can address this need.

However, past and current experience in siting new landfills and expanding existing landfills underscores the difficulty of achieving this goal. In the last few years, proposed new landfills and expansions of existing landfills have encountered strong opposition to their development, particularly from residents living in the vicinity of those facilities and from environmental groups. This has resulted in an increasing interest in finding alternatives to landfill disposal that would have reduced negative impacts or have beneficial impacts on the environment.

Among the most promising alternatives to landfill disposal and waste exporting are conversion technologies. For nearly a decade, Los Angeles County has been a consistent supporter of conversion technologies because of their potential to manage post-recycled MSW in an environmentally preferable manner. On July 27, 1999, the Los Angeles County Board of Supervisors formally adopted a series of recommendations that included support for the development of alternatives to landfilling and combustion, such as conversion technologies.

Since then, the County has supported local research and development of conversion technologies including supporting legislation to advance conversion within the state and working with members of the California Integrated Waste Management Board (Waste Board) and other stakeholders on this matter. The County has sponsored and supported legislation that would correct erroneous definitions currently in State stature, and provide conversion technologies with “diversion credit” for the material diverted from landfill disposal. Diversion credit represents an important incentive for local jurisdictions, therefore diversion credit, could invigorate research and development of environmentally beneficial technologies that can create jobs while transforming a liability (residual solid waste) into a benefit (renewable energy, green fuels and useful products).

In 2004, the Los Angeles County Integrated Waste Management Task Force (Task Force) established the Alternative Technology Advisory Subcommittee as an outgrowth of its commitment to conversion technologies, supported by a condition in the CUP of the Puente Hills landfill adopted in 2003. The Subcommittee is comprised of a diverse group of professionals including representatives from local government, the Waste Board, consultants, all experts in the field of conversion technologies who are responsible for evaluating and promoting the development of conversion technologies. The ultimate goal of the Subcommittee is to facilitate the development of a demonstration conversion technology facility in Southern California, which would showcase the benefits of conversion technologies as technically, economically, and environmentally viable alternative method of managing solid waste within the County.

On August 18, 2005, the Task Force officially adopted the "Conversion Technology Evaluation Report". Research for this report was conducted which assessed the viability of various conversion technologies, with the goal of vetting technologies for a potential demonstration facility. This demonstration facility is proposed to be partnered with a Material Recovery Facility/Transfer Station, the benefits of such a pairing are significant and include readily available feedstock otherwise destined for landfill disposal, appropriate siting, preprocessing capacity, transportation (cost and pollution) avoidance, and a host of symbiotic benefits.

Los Angeles County, like many other municipalities, is proposing to exclusively site conversion technology facilities at Material Recovery Facilities or Transfer Stations. This proposed siting requirement would further ensure that the waste stream processed by conversion technology facilities are strictly residual solid waste remaining after all feasibly recoverable recyclables have been removed.

The development and viability of the various proposed alternative technologies, and the methods to enhance existing landfill capacity, depend on technical and economic factors, air quality standards, and public acceptance. Further studies and testing of many of these technologies may be needed to determine if they are viable. Data contained within the Conversion Technology Evaluation Report provides clearly defined information regarding all of the above mentioned areas of concern. There have been significant developments regarding the use of MSW as feedstock for alternative technologies, including conversion technologies.

5.4 COMBUSTION SYSTEMS

Combustion facilities that utilize municipal solid waste as a feedstock are currently used within the County of Los Angeles. End products for combustion facilities are typically ash, inert material, and energy generation. Energy produced from the combustion facilities is sold to power utilities, in addition to being used on-site.

Combustion systems are used to reduce the volume of solid waste, destroy pathogens, break down chemical compound structures, and produce energy. Combustion occurs at high temperatures to produce gas, ash, and inert residual material. Heat from the controlled burning process is used to produce steam, which is then used to generate power. Pollution control for gas produced is typically in the form of scrubbers and filters. The scrubbers neutralize the acid gases within the resulting gas. Filters remove minute ash particles from any gas produced due to current air quality standards. Typically the ash and minimal inert material produced from combustion is stored and used as road base material.

5.4.1 Combustion

Combustion, as defined in section 5.2.3 of this chapter, is used to manage solid waste in compliance with state and regional environmental regulations. Units without preprocessing are referred to as mass-fired or mass burn combustion facilities. Waste processed prior to burning is referred to as refuse-derived-fuel (RDF). Refuse (solid waste) is typically burned at temperatures of about 2200 degrees Fahrenheit in waterwall boilers where thermal energy in the form of steam would be recovered. The steam is then passed through turbines where the thermal energy is converted to electricity. These processes can achieve a 70 percent volume reduction in the solid waste, ash being the only residue produced.

Environmental issues associated with a combustion facility include potential impacts to air quality, water quality, traffic, aesthetics, and noise. The combustion of refuse to recover energy will generate emissions to the atmosphere which require that sophisticated control devices be employed. Controlled combustion, through the use of automated damper controls for air distribution, minimize NO_x and CO_x. In addition, it has been demonstrated that ammonia injection into the furnace is successful in further reducing NO_x emissions. Sulfur dioxide, hydrochloric acid (HCl), dioxins/furans, cadmium, and lead are removed at an efficiency of up to 99 percent through the use of lime treatment in a dry scrubber neutralizing the acid gases. The final stage in a typical air pollution control system at a combustion facility is a filter baghouse which removes up to 99.95 percent of the particulate matter.

Combustion technology has been identified as one of the most effective options currently available to reduce the need for landfill disposal. Combustion is commercially, technically, and environmentally feasible. From the 1970’s to the 1990’s combustion technology grew as a result of energy shortages and relatively high energy prices. State legislation was enacted in the 1980s which encouraged the development of combustion projects. However, political resistance and public perception have increased due to environmental and safety concerns. At this time no new combustion facility is proposed for development. The current lack of enthusiasm for combustion facilities is also associated with economic factors such as the high capital costs involved in developing these facilities, the deregulation of the energy industry, , and other factors such as the strong public opposition encountered by previous proposals due to air quality concerns. Additionally, development has been discouraged by its current classification as disposal, rather than diversion under State law. While there are no current proposals to develop waste-to- energy facilities in Los Angeles County, this technology remains a valid disposal option.

Solid waste combustion systems (incinerators) can be designed to operate with two types of solid waste fuel: commingled solid waste (mass-fired) and pre-processed solid waste known as refuse-derived fuel (RDF-fired). Mass-fired combustion systems are the predominant type. Currently, there are two such facilities operating in Los Angles County: the Commerce Refuse-to-Energy Facility in the City of Commerce and the Southeast Resource Recovery Facility (SERRF) in the City of Long Beach.

5.4.1.1 Fluidized Bed Combustion

Fluidized Bed Combustion (FBC) processes include a heated bed of particles, typically sand or another type of granular media, suspended (fluidized) within a steel column through use of an upward flow of air or fluid. Oxygen is supplied more freely through the flow action of the bed media due to the turbulent contact between the bed media and the fuel media. Complete oxidation, including the production of flames maximizes thermal efficiency and minimizes the amount of char produced provided by the fuel media. FBC is best used to manage low BTU fuel media and high moisture characteristics. Several FBC systems are being used for solid waste combustion throughout the world.

5.4.1.2 Mass-fired Combustion Systems

In a mass-fired combustion system, minimal processing is given to solid waste before it is placed in the charging hopper of the system. The crane operator in charge of loading the charging hopper manually rejects obviously unsuitable items. One of the most critical components of a mass-fired combustion system is the grate system. It serves several functions, including the movement of waste through the system, mixing of the waste, and injection of combustion air. Typical mass-fired combustion facilities are described below.

5.4.1.2.1 Commerce Refuse-to-Energy Facility.

The Commerce Refuse-to-Energy Facility (CREF) is a joint powers agency formed by the City of Commerce and the County Sanitation Districts of Los Angeles County (CSD). The CSD has operated CREF since its inception in 1987. It successfully meets the South Coast Air Quality Management District (SCAQMD) requirements and produces some of the lowest emissions from a facility of its type worldwide. The facility combusts approximately 360 tons of refuse per day, 7 days a week, and generates approximately 10 megawatts (MW) of electricity that is sold to Southern California Edison (SCE).

Residual ash is created as a result of the burning process, and an ash treatment facility is operating at the site. The ash is mixed with cement in the drums of transit mix trucks. The mix is then transferred to portable containers where it hardens into 16 to 17 ton blocks. These blocks are transported to the Puente Hills Landfill where they are crushed and recycled as a base material for roads.

5.4.1.2.2 Southeast Resource Recovery Facility.

The Southeast Resource Recovery Facility (SERRF) is a joint powers agency formed by the City of Long Beach and the CSD. The City of Long Beach employs a private contractor to operate the facility. SERRF has the capacity to process about 1,380 tons of refuse per day. As an end product, the combustion process generates approximately 36 gross MW of electricity, with 30 MW of electricity that is sold to SCE.

Residual ash is created as a result of the combustion process. There is an ash treatment facility operating at the site. SERRF adds cement to the ash and transports the mix to the Puente Hills Landfill where it is recycled as a base material for roads.

5.4.1.3 RDF-Fired Combustion Systems

Refuse-derived fuel (RDF) is the material remaining after the selected recyclable and noncombustible materials have been removed from the waste stream. RDF can be produced in shredded or fluff form, or as densified pellets or cubes. Densified RDF is more costly to produce, but is easier to transport and store.

Due to the higher energy content of RDF compared to unprocessed solid waste, RDF combustion systems can be physically smaller than comparatively rated mass-fired systems. A RDF-fired system can also be controlled more effectively than a mass-fired system because of the more homogeneous nature of RDF, allowing for better combustion control and better performance of air pollution control devices. Typical RDF-fired combustors are shown below.

5.4.1.4 Rotary Cascading Bed Combustion

The Rotary Cascading Bed Combustion (RCBC) is a robust solid-fuel burner and heat recovery system, a form of Fluidized Bed Combustion (FBC) system. It can burn solid waste, RDF, wood chips, etc. The system consists of a rotating horizontal cylindrical chamber with bundles of boiler tubes projecting into the end of the chamber. The rotational speed of the chamber is high enough to keep the bed material continually airborne, thus increasing combustion. The hot solids cycle preheats the combustion air, drying and ignites it. Almost all RDF systems have required extensive redesign to attain acceptable levels of reliability and environmental quality.

5.4.2 Biomass Combustion

State Statute (PRC 40106) defines "biomass conversion" as “the controlled combustion, when separated from other solid waste and used for producing electricity or heat, of the following materials: (1) Agricultural crop residues; (2) Bark, lawn, yard, and garden clippings; (3) Leaves, silvicultural residue, and tree and brush pruning; (4) Wood, wood chips, and wood waste; (5) Nonrecyclable pulp or nonrecyclable paper materials.” It is essentially the controlled combustion of certain biomass feedstocks. There are no biomass conversion facilities operating or planned for Los Angeles County.

5.5 CONVERSION TECHNOLOGY SYSTEMS

Conversion technology systems are an array of alternatives to conventional landfill disposal. These technologies may be used in conjunction with current landfill practices to extend the life cycle of existing landfills. Conversion technologies refer to innovative technologies including pyrolysis, gasification, anaerobic digestion, and ethanol fermentation, which are capable of converting Municipal Solid Waste (MSW) into an array of high value, marketable materials and green fuels such as ethanol, biodiesel, biomethane, and hydrogen, which can be used to produce clean, renewable energy.

Conversion technologies represent the most significant opportunity for beneficial use of MSW to come along since passage of California’s AB 939 in 1989. According to a Waste Board report, as of _March 2005 there were approximately 140 operating conversion technology facilities utilizing MSW as a feedstock in Europe and Japan. Various studies have shown that conversion technologies employing thermal, chemical, or biological processes can be used to successfully manage MSW. Using these technologies can decrease criteria air pollutants and greenhouse gases which would ordinarily result from other waste disposal options.

Moreover, conversion technologies can revolutionize the way solid waste is managed in Southern California by transforming waste that is currently an economic, environmental and political liability, and turning it into a valuable commodity and resource.

The use of residual solid waste (waste that remains after recyclables have been removed) as feedstock sent to a conversion facility can help the County lessen disposal into landfills, by diverting unrecyclable solid waste intended for disposal. This process would in turn increase landfill life and postpone the costly and arduous task of siting and permitting new waste disposal sites. The commercialization of these technologies creates a realistic potential to achieve state recycling rates beyond 75%, while complementing and reinforcing the existing recycling market and infrastructure.

Conversion technologies could accommodate a portion of the solid waste to be managed within the 15-year planning periods of the Countywide Siting Element.

The California Integrated Waste Management Board's 2001 Strategic Plan includes a goal to "Support local government efforts to use alternative means of diverting waste, including the use of conversion technology where residuals can be converted directly into electricity and actively managed to increase fuel and gas production." This section provides a description of various conversion technologies that can serve as alternatives to solid waste disposal. Conversion technologies can be generally grouped into three main categories: a) thermal conversion processes, b) biological conversion processes and c) chemical conversion processes. Figure 5-1 shows a typical process diagram for most conversion technologies.

Conversion technologies differ from conventional combustion processes due to the capability of conversion facilities to produce marketable products, including green fuels like biodiesel and ethanol. The Department of Energy (DOE) report, "Annual Energy Outlook 2006 with Projections to 2030" noted many markets for renewable energy. These markets included fuel for automobiles to decrease dependence upon foreign oil. "Sales of advanced technology vehicles, representing automotive technologies that use alternative fuels or require advanced engine technology, reach 5.7 million per year..."

There are specific issues that are associated with the development of conversion technologies, which must be carefully weighed by a jurisdiction when considering conversion technologies as a part of their solid waste management strategies. Most issues with conversion technologies can be separated into four categories: regulatory, environmental/social, technical, and economic. Most of the conversion technologies available have not been permitted to process MSW or to address the emissions from the various processes. Public perception is an important aspect to implementation of these technologies due to the lack of knowledge regarding these facilities and the environmental impact due to processing.

Jurisdictions would need to provide public education regarding these technologies and the specific difference from existing full combustion/combustion processes. Feedstock characteristics, process integration, and emission controls at times provide design concerns. Currently, in the United States there are no large scale heterogeneous MSW conversion technology facilities. There are smaller demonstration facilities, but most of the feedstock is homogeneous without serious consideration for large scale MSW processing. Some cost data has been generated regarding smaller demonstration facilities in the United States such as capital, operation, maintenance costs, and possible revenue generated.

Some of the technologies discussed below are in the construction stage of full-scale facilities. These technologies merit continued close observation of methods and costs as they mature. However, based on the above considerations and the length of time required to permit and develop these types of facilities, these technologies (with the exception of) may not be ready for large-scale commercial operation to mange a significant portion of solid waste generated in Los Angeles County within the current planning period. Nevertheless, conversion technologies need to be continually evaluated so that in the future they may provide for the management of a significant share of the County's solid waste.

Per the aforementioned URS, Conversion Technology Evaluation Report of August 18, 2005, the thermal, chemical, and biological conversion technologies will be further explained in the following sections. To simplify discussion of these technologies this report is incorporated by reference. However, it should be noted future revisions to the Conversion Technology Evaluation report does not constitute a revision to the Countywide Siting Element. Therefore, the Conversion Technology Evaluation report will not be included as an appendix within the Countywide Siting Element.

5.5.1 Thermal Conversion Processes

There are two major types of thermal conversion processes of solid waste; namely pyrolysis systems and gasification systems. Thermal processing involves thermal degrading of solid waste through exothermic or endothermic reactions in an oxygen deprived or oxygen reduced environment. Full combustion of solid waste to the state of ash does not occur as a phase of the thermal conversion processes.

5.5.1.1 Pyrolyis Systems

Pyrolysis is the thermal processing of waste in the absence of oxygen. Pyrolysis systems are used to convert solid waste into gaseous, liquid, and solid fuels. Because most organic substances are thermally unstable, they can, upon heating in an oxygen-free atmosphere, be broken down into gaseous, liquid, and solid components.

Pyrolysis systems typically include kiln type structures which use external heat to process solid waste - there are no flames applied directly to the solid waste in this process.

Typical feedstock for pyrolysis systems range from municipal solid waste (MSW) residuals to specific organic feedstocks. MSW residuals are acceptable if the non-thermally degraded materials are separated, and if the residual materials are dry.

During a pyrolysis operation, municipal solid waste is shredded, fed to a reactor vessel, where it is heated to temperatures ranging from 750° to 1650°F producing the following components:

- Syngas component, containing primarily hydrogen (H_2), methane (CH_4), carbon monoxide (CO), carbon dioxide (CO_2), and various other gases, depending on the organic characteristics of the material being processed.

- Liquid component (Pyrolysis oil), consisting of a tar or oil-like material containing acetic acid, acetone, methanol, and complex oxygenated hydrocarbons. Additional processing of this material results in a synthetic fuel oil.

- Char or ash component, consisting of almost pure carbon plus any inert material originally present in the solid waste.

The gas or oil may either be used to generate power or processed further and sold as fuel.

Since solid waste must be shredded prior to heating, potential environmental effects associated with the processing phase of a pyrolysis system are similar to those which may result from a mixed waste composting facility and include increases in noise, dust, traffic, and risk of fire and vector infestation. However, since the actual distillation step is in an enclosed environment, air quality impacts are minimal..

In the United States, only a few small demonstration and commercial pyrolysis facilities have been constructed and operated, most commercial facilities have shut down due to end product quality.

Refer to Section 1.1.2 of the Conversion Technology Evaluation Report, for specific information regarding the range of pyrolysis processes and Appendix A, within the report, for lists conversion technology distributors. More general information regarding the pyrolysis system is summarized within Table 5-1 of this chapter.

5.5.1.2 Gasification Systems

Gasification is the conversion at higher temperatures of feedstock into combustible gases, using a limited amount of air. Additionally, gasification is a general term used to describe the process of partial oxidation in which a fuel is deliberately combusted with less than the exact amount of oxygen (or air) needed for complete oxidation.

Unfortunately, State statute (PRC 40117) defines gasification inaccurately and in a manner meant to sharply constrain the ability to develop this technology to manage MSW. State statute defines gasification and prohibits the development of a gasification facility unless the facility uses no air or oxygen in the process, produces zero air emissions, no discharges to surface or groundwaters, and processes no feedstock from jurisdictions with less than a 30% diversion rate, among other restrictions. These restrictions are unprecedented for any technology or industry and seem designed to inhibit the development of conversion technologies.

Gasification effectively reduces the volume of solid waste and maximizes the recovery of energy. Gasification temperatures may range from 750° to 12,000°, depending on they type of gasification system used. Typically, the feedstock used is organic or thermally degradable and usually requires preprocessing and drying. Essentially, the process involves partial oxidation of a carbonaceous fuel to generate a combustible fuel gas rich in carbon monoxide, hydrogen, and some saturated hydrocarbons, principally methane.

The combustible fuel gas can then be combusted in an internal combustion engine, gas turbine, or boiler under excess-air conditions in order to produce power. Benefits to using gasification systems to manage solid waste are increased levels of feedstock degradation, ability to accept organic and non-organic material for degradation, and production of highly marketable products such as fuel, road base material, and other chemicals.

There are threemajor types of gasification systems; fixed bed gasification systems, fluid bed gasification systems, plasma arc gasification systems.

The following is a brief description of the basic types of gasification systems. For additional information regarding specific gasification systems and lists of various gasification technology vendors, refer to Section 1.1.3 of the Conversion Technology Evaluation Report. Also, general information regarding various gasification systems are summarized within Table 5-1 of this chapter.

5.5.1.2.1 Fixed Bed Gasification System

Vertical Fixed Bed

The vertical fixed bed gasifier is characterized by the upward orientation of the gasification machinery and the stationary or moving grates within the system.. However, this type of reactor is more sensitive to the mechanical characteristics of the fuel; it requires a uniform, homogenous fuel, such as densified RDF. The end products of the process are primarily low-Btu gas and char.

Gasifiers have the potential to achieve low air pollution emissions with simplified air pollution control devices. The emissions are comparable to or less than the emissions from excess-air combustion systems employing far more complex emission control systems.

Horizontal Fixed Bed

.Horizontal fixed bed gasification systems are characterized by horizontally configured moving grates or plates which introduce feedstock into the horizontally oriented gasification machinery. A horizontal fixed bed gasifier consists of two major components: a primary combustion chamber and a secondary combustion chamber. In the primary chamber, waste is gasified by partial oxidation under controlled conditions, producing a low-Btu gas, which then flows into the secondary combustion chamber. In the second chamber, it is combusted with excess air which produces high-temperature (1,200 ^{o}F to 1,600 ^{o}F) gases that can be used to produce steam or hot water in an attached waste heat boiler. This system produces lower particulate emissions than conventional excess-air combustors.

Horizontal fixed bed gasifiers are commercially available from several manufacturers in standard sizes ranging from 0.05 to 4.2 tons/hr in capacity.

5.5.1.2.2 Fluid Bed Gasification

Fluidized bed gasification is a process in which a bed of particles is converted to a fluid state by means of an upward flow of gas (or liquid). In its simplest form, a fluidized bed system consists of a vertical steel cylinder with a sand bed, a supporting grid plate, and air injection nozzles. When air is forced up through the nozzles, the bed of sand expands up to twice its resting volume and acts like a fluid. Refuse Derived Fuel can be injected into the gasification reactor above or below the level of the fluidized bed. The “boiling” action of the fluidized bed promotes turbulence and mixing and transfers heat to the feedstock. In operation, auxiliary fuel (natural gas or fuel oil) is used to bring the bed up to operating temperature (1,450°F to 1,750°F).

Fluidized bed gasifiers are an alternative design to conventional combustion systems. With minimal modifications, a fluidized bed combustion system can be operated as a fluidized bed gasification system. The major difference between combustion and gasification systems is the method of fuel media decomposition. Fluid bed combustion systems destroy fuel media through full oxidation including flames or combustion, thus producing minimal amounts of char and minimal amounts of syngas. Fluid bed gasification systems thermally decompose organic matter in a minimal oxygen atmosphere in order to produce syngas, combustible liquids, chars, and slag material. Several pilot-scale tests have been conducted with solid waste as fuel.

Currently, there has been some success in Europe and Japan with gasification technologies with processing MSW, with minimal preprocessing in the form of removal of large items, shredding, and sorting. Some processing to remove metals and other inert material is required, both to improve performance of the reactors and to reduce air emissions.

Refer to sections 1.1.3.1 and 1.1.3.2, of the Conversion Technology Evaluation Report provides more information regarding the current success with various gasification facilities.

5.5.1.2.3 Plasma Arc Gasification System

Plasma arc gasification systems utilize technology which harnesses the heating power of an artificial lightning bolt, to produce the high temperature gases that cannot be reached through any other process except through nuclear fission/fusion, to process solid waste. A plasma is generated when gas, such as oxygen, passes through an electrical arc created by two electrodes. This results in an extremely high processing temperature that is reached with minimal gas flow.

Hot ionized gas (plasma) is used to heat air or oxygen to high temperatures typically in excess of 7,000°F and use the resulting plasma for treating Municipal Solid Waste. Plasma gasification processes occur in a closed , pressurized reactor and the air/oxygen introduced is controlled for promotion of gasification reactions.

A plasma torch converts electrical energy into thermal energy, creating a localized area of plasma. The torch's intense heat can reach temperatures as high as 12,000 °C. Typical feedstock for this type of gasification are any organic or thermally degradable materials, including MSW. Waste feedstock is thermally processed until it dissociates into a solid rock, leaving an inert, gray chunk of glass-like material.

Refer to section 1.1.4 of the Conversion Technology Evaluation Report for more information on plasma arc gasification. In Japan this technology is used to treat wastewater products, processing hazardous or medical waste, and incinerator ash. The aforementioned section of the “Conversion Technology Evaluation Report” describes in detail the total process for this type of conversion technology.

5.5.2 Biological Conversion Process

Biological conversion processes are designed for biodegradable organics only and require an extensive amount of pre-processing. Typically, the major end product is compost (a minimally marketable product). The feedstocks are those which include food waste, agricultural waste, biosolids, and various other organics and biodegradable materials. Table 5-1 in this chapter further specifies feedstock types and benefits of anaerobic and aerobic digestion.

5.5.2.1 Anaerobic Digestion

Anaerobic digestion (AD) is a process in which biodegradable organics are converted into compost, methane, and carbon dioxide. A typical AD process for MSW begins with pre-processing in the form of separation of metals, plastic, and non-biodegradable residues.

Hydrolysis, acidification, and production of biogas are the main components for anaerobic digestion. Hydrolysis is the process of breaking chemical bonds of larger molecules into smaller molecules. Acidification is the subsequent process which degrades the smaller molecules into acids, hydrogen gas, and carbon dioxide.

The products from the acidification process are introduced to methane producing bacteria (methanogens) and produce biogas. Typical composition of the resulting biogas is 50 percent to 70 percent methane with medium Btu values.

Refer to section 1.2.2 of the Conversion Technology Evaluation Report for further explanation of the Anaerobic Digestion process along with general process diagrams.

5.5.2.2 Aerobic Digestion

Aerobic digestion is a biological conversion process in which microbial oxygen dependant bacteria, degrade solid waste. Aerobic digestion feedstock must contain homogeneous biodegradable organic material. Typical feedstock includes food, agricultural, and biosolids wastes.

Aerobic microorganisms in the reactor oxidize biodegradable material and produce large amounts of heat. Renewable energy in the form of synthesized biogas and ethanol are not products of this type of process. The aerobic digestion process predominantly produces compost as well as solid and liquid fertilizers. Residue from the aerobic process is used to produce liquid and solid fertilizers.

Refer to section 1.2.4.3 of the Conversion Technology Evaluation Report contains more information regarding the aerobic digestion technology vendors. Also, refer to Table 5-1 of this chapter for more information regarding aerobic digestion.

5.5.3 Chemical Conversion Processes

Chemical conversion processes are conversion technologies which are designed to change the chemical structure of any organic fuel media. Chemical conversion processes are designed to change organic (biodegradable or inert) fuel, while biological conversion is designed to process only biodegradable organic fuel.

Table 5-1 of this chapter refers to chemical processes also.

5.5.3.1 Acid Hydrolysis

Acid hydrolysis is the process of breaking the chemical bonds of cellulose based materials and fermenting the sugar solution byproduct into ethanol. This hydrolysis of cellulose bonds within fibrous vegetable type matter specifically is called lignocellulosics. Green waste, agricultural, and paper waste are feedstock to be fed into a hydrolysis reactor and the liquid effluent from the reactor fermented and distilled into 99% ethanol.

Typical byproducts from this hydrolysis process are carbon dioxide and lignin type residue. Carbon dioxide produced is a high enough quality to be used for non-food industrial applications. Lignin and other residue which may be used for compost, gasification, combustion, or landfilling purposes.

Refer to section 1.2.3 of the “Conversion Technology Evaluation Report” for more information.

5.5.4. Other Conversion Processes

There are many emerging conversion technologies which have not yet been introduced on a full scale. These types of technologies are continuously being created and studied in order to find their potential solid waste applications. Due to the numerous technology vendors and varying levels of development, minimal discussion will be conducted regarding a national example of such a technology.

Refer to Table 5-1 of this chapter for more information.

5.5.4.1 Thermal Depolymerization (TDP)

Thermal depolymerization is a process in which the solid waste material hydrocarbons are broken into smaller chemical hydrocarbon chains. Typical feedstock for this material are animal or agricultural waste.

Feedstock is fed into a reaction chamber where it is heated to around 250 °C and subjected to 600 psi (4 MPa) for approximately 15 minutes, after which the pressure is rapidly released to boil off most of the water. The result is a mix of crude hydrocarbons and solid minerals, which are separated out. The hydrocarbons are sent to a second-stage reactor where they are heated to 500 °C, further breaking down the longer chains, and the resulting mix of hydrocarbons is then distilled in a manner similar to conventional oil refining.

Currently, there is only one full scale facility (a 250 ton/day facility located in Carthage, Missouri) which processes a highly specific feedstock, namely turkey waste. Byproduts from this process include oil, water, and carbon solids. This plant has not currently been successful in using MSW or RDF as a feedstock.

Section 1.1.5 of the "Conversion Technology Evaluation Report" specifies a conversion process for animal waste to produce renewable energy in the form of oil.

5.6 ALTERNATIVE TECHNOLOGY DEVELOPMENTS IN LOS ANGELES COUNTY

5.6.1 Los Angeles County Efforts

As previously mentioned in section 5.3.1, the Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force has vigorously supported increased study and facilitation for conversion technologies within Los Angeles County.

- Scientifically evaluating the technical, economic and environmental feasibility of conversion technologies
- Promoting the development of conversion technologies by advocating for changes in legislation and regulations
- Acting as a regional resource, disseminating accurate information regarding conversion technologies and urging stakeholders throughout the State to get involved in the development of these technologies

The County and the Task Force have been strong advocates of alternative technology to manage solid waste. Many efforts to promote different technologies have been very successful. Below are significant efforts by the County and the Task Force:

- Built coalitions with numerous government agencies, associations and other entities to promote the development of conversion technologies through policies, statements and other advocacy activities, including the Task Force, the League of Council of Governments, and many others.

- Worked with the CAO to sponsor two legislative bills in 2000 that would have provided 100% diversion credit for waste processed at conversion technology facilities in order to create an incentive for thei development. This effort created the momentum which resulted in the passage of legislation in 2003 that required the Waste Board to study these technologies and provide recommendations to the Legislature.

- Attends and participates at workshops and forums to increase our knowledge and expertise in this area as well as to affirm the County's position and support.

In 2004, the Los Angeles County Integrated Waste Management Task Force established the Alternative Technology Advisory Subcommittee as an outgrowth of its commitment to conversion technologies, supported by a condition in the CUP of the Puente Hills landfill adopted in 2003. The Subcommittee is comprised of a diverse group of professionals including representatives from local government, the Waste Board, consultants, all experts in the field of conversion technologies who are responsible for evaluating and promoting the development of conversion technologies. The ultimate goal of the Subcommittee is to facilitate the development of a demonstration conversion technology facility in Southern California, which would showcase the benefits of conversion technologies as technically, economically, and environmentally viable alternative method of managing solid waste within the County.

On August 18, 2005, the Task Force officially adopted the "Conversion Technology Evaluation Report". Research for this report was conducted which assessed the viability of various conversion technologies, with the goal of vetting technologies for a potential demonstration facility. This demonstration facility is proposed to be partnered with a Material Recovery Facility/Transfer Station, the benefits of such a pairing are significant and include readily available feedstock otherwise destined for landfill disposal, appropriate siting, preprocessing capacity, transportation (cost and pollution) avoidance, and a host of symbiotic benefits.

Los Angeles County, like many other municipalities, is proposing to exclusively site conversion technology facilities at Material Recovery Facilities or Transfer Stations. This proposed siting requirement would further ensure that the waste stream processed by conversion technology facilities are strictly residual solid waste remaining after all feasibly recoverable recyclables have been removed.

The County and the Task Force are committed to promoting solutions that address the solid waste management issues of Los Angeles County.

5.6.1.1 Southern California Conversion Technology Development Project

The Conversion Technology Evaluation Report identified areas of solid waste management improvement within Los Angeles County. The report identified the development of a conversion technology demonstration facility to be co-located with a Material Recovery Facility (MRF). This co-located demonstration facility would be an efficient use of materials and time for the solid waste management needs of Los Angeles County.

The proposed demonstration facility is supported by the Task Force and will assist the Countywide objective to evaluate these alternative technologies. The possible benefits from conversion technologies will not only be marketable products but also, employment, improved community development, increased resource awareness and education regarding solid waste. This demonstration facility is proposed to be a better synergy between existing MRF's and TS's in an effort to comply with more stringent greenhouse gas emission laws (such as AB 32), reduce solid waste mismanagement, and support sustainable communities.

5.6.2 City of Los Angeles Alternative Technology Efforts

Concurrently, the City of Los Angeles is proposing to develop an alternative technology facility which will also utilize waste residuals as a feedstock. City of Los Angeles has also created a RENEW LA (Recovering Energy, Natural Resources and Economic Benefit from Waste for Los Angeles) policy to provide resource management for a period of twenty years. City of Los Angeles is also conducting its own conversion technology studies with the goal of developing various conversion technology facilities by 2025.

City of Los Angeles' main objective is to significantly decrease the 3,600 ton/day disposal rate into the Sunshine Canyon landfill. RENEW LA policy will utilize waste residuals to produce alternative fuels and generate electricity. Many thermal, biological, and chemical alternatives to conventional landfilling will be considered in evaluating technologies to process the specified solid waste residual feedstock.

5.7 ECONOMIC AND ENVIRONMENTAL ISSUES (Originally Section 5.3.3)

With the trend towards closure of existing landfills, diminishing in-County disposal capacity, and no foreseeable development of new landfills, emerging technologies have the potential to revolutionize solid waste management in Los Angeles County. However, development of alternative technologies faces economic and environmental challenges and constraints as described below, due to concerns to residents which ultimately determine where jurisdictions decide to dispose of their solid waste.

This section proposes to expand on the environmental and economic issues of various types of alternative technology. Some of these issues regarding the effect of economic and environmental factors in alternative technologies and processes for the treatment of solid waste are detailed in a report commissioned by the National Renewable Energy Laboratory the United States Department of Energy (in Golden, Colorado) titled, "Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste, August 1996 (NREL/TP-430-21612)".

Total system costs, which typically include collection, transportation, processing, operating and capital investments, need to be evaluated by jurisdictions to determine the economic feasibility of developing a particular alternative technology facility or building a particular transformation facility.

The rate charged for each ton of solid waste received at a facility, is a major factor to jurisdictions or entities evaluating the option of siting facilities which utilize alternative technologies. Tipping fees and revenue from the sale of energy produced must be sufficient to cover capital and operating costs. Even if tipping fees at these facilities at a given time were comparable or lower than fees charged at landfill disposal facilities, jurisdictions must consider the impact of additional costs that may be incurred if the waste stream fluctuates below the level needed to keep the plant running.

According to the National Renewable Energy Laboratory report, low energy prices affected development of transformation technologies by reducing the flow of revenue from the sale of electricity or stream. For example, during the 1980's and up to the early 1990's, the trend in energy prices was downward.

However, the since the early 1990's, the trend in energy costs has steadily increased. Consequently, the effective break-even tipping fee for proposed alternative technology facilities has increased, thereby making financing and community acceptance of such projects more difficult. The net operating costs for the gasification technologies, which are equivalent to the break-even tipping fee, are comparable to those for owner-operated mass burn facilities. Nevertheless, the revenue stream from selling energy continues to be critical to overall economic acceptability.

Environmental issues are recognized as critical to the viability of alternative technologies and processes. Environmental issues have affected solid waste management. Initially, most environmental issues were focused on visible emissions. Then the Clean Air Act and its Amendments provided a catalyst for the industry to change from simple refractory enclosures and toward water wall boiler and combustion industry, and to the solid waste combustion market. In 1977 the pollutant "dioxin" emerged as a new issue. Admissions of acid gases-HCL and SO_2, nitrogen oxides (NO_X) and toxic elements also became of increasing concern. Other interests focused on ash production and disposal. While air emissions dominate the "political" assessment of a given process, problems with all effluents and environmental consequences must be resolved as part of the permitting process.

Development of transformation facilities, even those using the proven combustion technologies are also likely to encounter strong public opposition due to concerns regarding potential environmental impacts. Moreover, the proponents of these technologies are generally seeking governmental agencies and municipalities to finance the development of new facilities or "proof-of-concept" facilities. However, due to current fiscal constraints, only few local governments may be in a position to finance the development of unproven technology and therefore need to rely on private sector for their development.

Several new or enhanced technologies to thermal processes of solid waste are now well established. One class, commonly referred to as combustion plants, burns waste in the same physical form as it is generated (mass-burn incinerators), which is coupled with elaborate back-end air and residue treatment. Another burns wastes alone or with fossil fuels after preprocessing of the waste to a refuse-derived fuel (RDF). Although environmental concerns have not driven thermal processing out of business, they have resulted in significantly higher costs due to environmental compliance, increased system complexity, and long delays in moving projects through the public review and regulatory approval processes.

Combustion plants are well-proven combustion processes, and beyond these, a new technology class has emerged – refuse gasification. During this process, the organic fraction of solid waste is heated to drive off a gas with a substantial fuel value. This gas can be cleaned and burned in a gas engine or gas turbine to generate electricity. Emissions data generally show very low rates for dioxins, acid gases, and problematic pollutants.

Historically, most RDF facilities have incurred substantial post-construction rework, capital investment, capacity down rating, etc., and landfills are still required. Many systems in this study have significant development tasks ahead of them. Unfortunately, the catalyst of vigorous market activity to push this development and to foster risk-taking is weak. Further, many systems are quite complex. This complexity presents some problems when seeking acceptance by client communities, by regulatory authorities, and from financial and engineering entities involved in concept selection and project implementation.

Interestingly, the situation in Europe is similar to that in the United States, but the result is different. Recent legislation in Germany, France, and the Netherlands has mandated an end to raw solid waste landfilling. This legislation will help to further emphasize the role of thermal processing in solid waste management, where solid waste turned into energy has already assumed an important position. However, driven by stringent air emissions limits in some European nations, waste management costs in Europe are much higher than in the United States. Although combustion is technically feasible and is successfully demonstrated in the United States and Europe, and specifically in Los Angeles (Commerce Refuse-to-Energy Facility and Southeast Resource Recovery Facility) County at facilities in Commerce and Long Beach, there are no proposed new combustion facilities in Los Angeles County at the present time.

5.8 TABLES, FIGURES, AND FLOWCHARTS

Additional information regarding conversion technologies may be referenced in the August 18, 2005 URS, Conversion Technology Evaluation Report. The following tables, figures, and flowcharts have been added for further information also.

Table 5-1 – Conversion Technology Comparison

Category	Type	Typical Temp. Range	Typical Feedstock	Byproducts/Residuals	Benefits/Advantages
Thermal	Pyrolysis	750°-1650°	Any organic or thermally degradable materials. MSW acceptable if separation of non-thermally degraded material included, and drying material.	Byproducts are: carbon char, silica, slag, ash, metals, non-thermally degradable material, tar, and viscous material Contaminants removed from syngas/flue gases prior to being exhausted from stack. Syngas cleaned through use of a boiler, scrubbers, low-NOx burners, and activated carbon injection. All syngas cleaning will provide a clean burning syngas for power generation per South Coast Air Quality Management District (SCAQMD) acceptable limits.	No direct burning in oxygen starved atmosphere. Carbon char produced can be used to produce diesel fuel for vehicles. Other byproducts may be used in a number of ways including road base and construction material. This process typically produces the highest amount of energy per ton of feedstock.
Thermal	Pyrolysis/ Gasification	750° - 2500°	Any organic or thermally degradable materials. MSW acceptable if significant separation and drying included. Byproducts of pyrolysis process.	Byproducts produced: carbon char, silica, slag, ash, metals Pre-cleaning of the syngas is necessary prior to being utilized for production of chemicals, or as a fuel for gas turbines or reciprocating engines, which require clean fuels to minimize corrosion and emissions.	Produce clean syngas which can then be converted into chemicals or power generation through an IC engine or gas turbine. This process typically produces high amounts of energy per ton of feedstock, with the least amount of solid residuals.

Source: Conversion Technology Evaluation Report, August 18, 2005
*N/A – Not Applicable

Table 5-1 – Conversion Technology Comparison

Category	Type	Typical Temp. Range	Typical Feedstock	Byproducts/Residuals	Benefits/Advantages
Thermal	Fixed/Fluid Bed Gasification	1400° - 2500°	Any organic or thermally degradable materials. MSW acceptable if preprocessed to separate significantly large items, shredded, and sorting.	Byproducts produced: carbon char, silica, slag, ash, metals The gasification process has no outlet or stack. Pre-cleaning of the syngas is necessary prior to being utilized for production of chemicals, or as a fuel for gas turbines or reciprocating engines, which require clean fuels to minimize corrosion and emissions.	Produce clean syngas which can then be converted into chemicals or power generation through an IC engine or gas turbine. Fixed bed technology allows for larger items of MSW to be thermally processed, along with lees preprocessing of feedstock material. Fluid bed technology allows for most solid waste to be processed, however larger bulky items are not fully processed.
Thermal	Plasma Arc Gasification	7000°	Any organic or thermally degradable materials. MSW acceptable if preprocessed to separate significantly large items, shredded, and sorting.	Byproducts produced: carbon conversion, molten ash, slag, metals Air emissions are a major environmental issue to be addressed. Contaminants are removed from the syngas and/or from the flue gases prior to being exhausted from a stack.	Volume of syngas produced is lower than the volume of flue gases formed in the combustion of MSW in a waste-to-energy facility. Syngas is costs less to treat due to smaller volume. Syngas is more homogeneous and cleaner-burning fuel than MSW.

Source: Conversion Technology Evaluation Report, August 18, 2005
*N/A – Not Applicable

Table 5-1 – Conversion Technology Comparison

Category	Type	Typical Temp. Range	Typical Feedstock	Byproducts/Residuals	Benefits/Advantages
Biological	Aerobic Digestion	N/A*	Food waste, agricultural waste, sewage biosolids	Byproducts: Residue processed to produce liquid and solid fertilizers. This process is different from anaerobic digestion in that no fuel is produced. Contaminants from leachate and gases produced are captured and not released into adjacent area.	Aerobic microorganisms in the reactor oxidize biodegradable material and produce large amounts of heat.
Chemical	Acid Hydrolysis	N/A*	Lignocellulosics, paper, wood, yard waste, vegetal biomass	Byproducts produced: Carbon dioxide produced may be used for non-food industrial applications. Lignin and other residue which may be used for compost, gasification, combustion, or landfilling purposes Due to the dryers, furnaces, fermentation units, boilers, and handling of hazardous chemical particulants and dangerous compounds must be taken care of. Production of VOC's, NOx, SO2, CO, and PM, PM10. These compounds and particulate matter are produced by dryers, carbon furnaces, fermentation units, boilers, and ethanol load-out systems.	Fuel grade 99% ethanol. Process may be fully enclosed to minimize odor and provide dust control.
Chemical/ Other	Thermal Depolymer-ization	N/A*	All organics or biodegradable materials.	Byproducts produced : oil, water, fertilizer Tipping hall contains an odor control system. Most process water is recycled, vacuum/recompression system to be utilized to minimize wastewater discharge.	Essentially 100% diversion rate for processed MRF residuals. Direct products are fuel, residue for fertilizer, biogas, power generation and carbon.

Source: Conversion Technology Evaluation Report, August 18, 2005

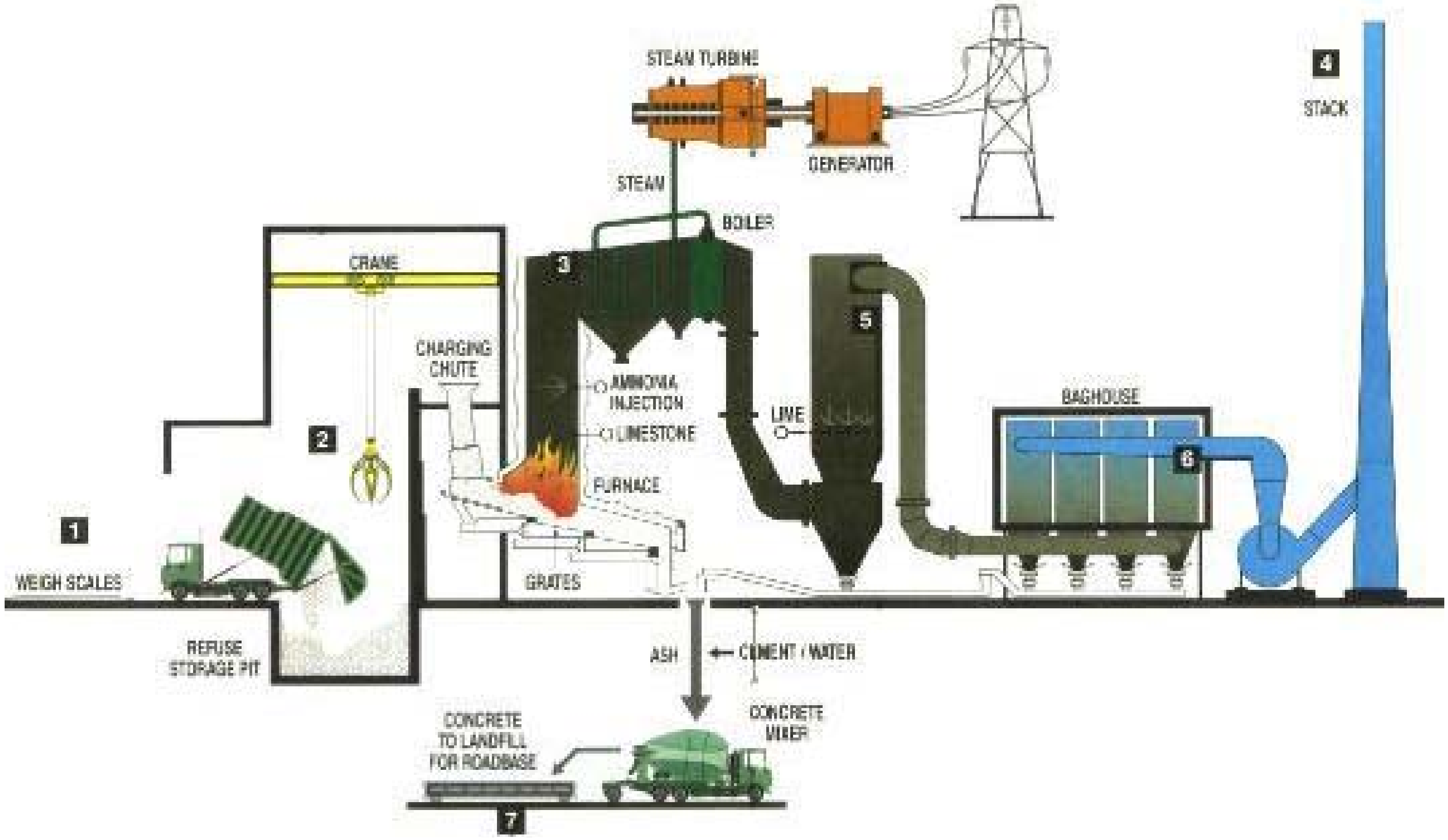
*N/A – Not Applicable

Byproducts for Various Conversion Processes

Conversion Technology	MSW component processed	Energy Efficiency	Products Mole %	Scale – Commercialization (energy output)
Partial oxidation gasification air-feed	All organics low moisture <50% wet basis depending on reactor type	75% (cold gas)	29% CO 3% CO_2 15% H_2 3% CH_4 50% N_2	0.5 to 5 MWt
Partial oxidation gasification oxygen-feed	All organics low moisture <50% wet basis depending on reactor type	90% (cold gas)	18% CO 30% CO_2 40% H_2 9% CH_4 1% N_2	5 to 150 MWt
Indirectly fired gasification	All organics high moisture or dry	85% (cold gas)	15% CO 9% CO_2 59% H_2 14% CH_4 3% N_2	10 to 25 MWt
Hydro-gasification with steam pyrolysis	All organics high moisture or dry	90% (cold gas)	11 % CO 24 % H_2 6 % CO_2 49 % CH_4	Pre-commercial
Indirectly fired Pyrolysis with drier & gasifier	All organics high moisture or dry	65% (cold gas)	7% CO 40% CO_2 5% H_2S 32% H_2 15% *HCs*	0.5 to 5 MWt
Indirectly fired Pyrolysis with drier	All organics high moisture or dry	55% (cold gas)	5% CO 36% CO_2 3% H_2S 19% H_2 36% *HCs*	0.5 to 2 MWt
Anaerobic Digestion	Biodegradable Components	30-60% (cold gas)	40-60% CH_4 60-40% CO_2	0.1 to 10 MWt
Fermentation	Biodegradable Components	30-70% (liquid)	Ethanol	0.1 to 10 MWt
Aerobic Digestion (Composting)	Biodegradable Components	N.A.	Soil amendment	N.A.

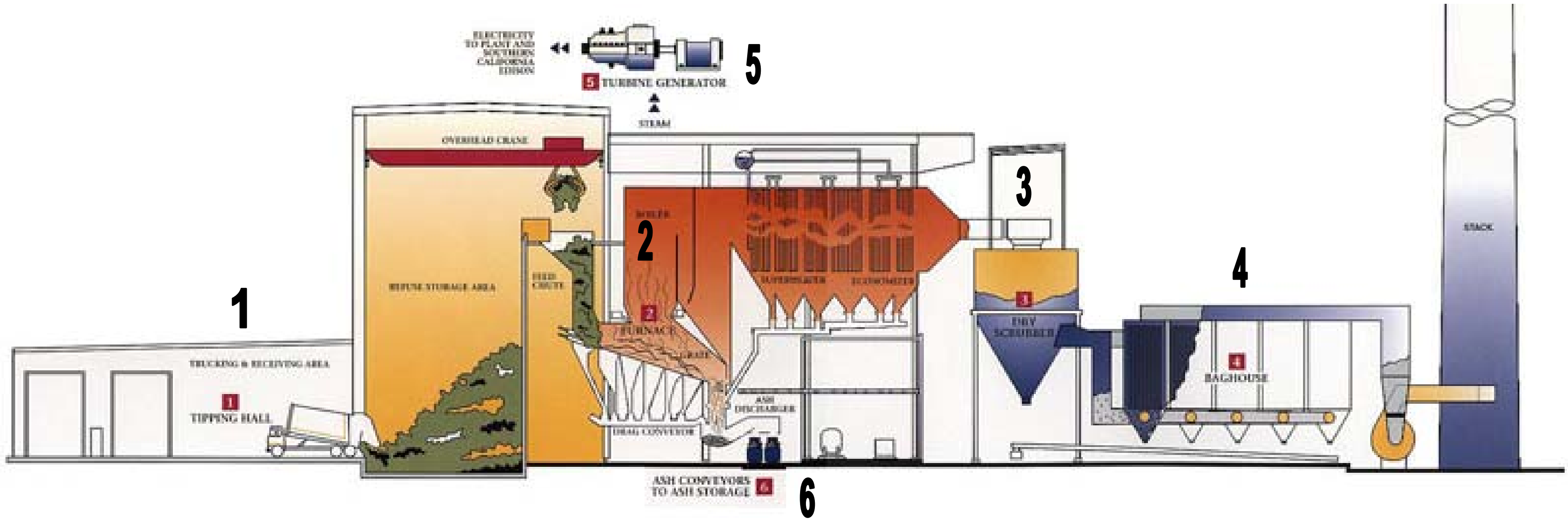
Source: Evaluation of Conversion Technology Processes and Products
University of California Riverside & University of California Davis

UC Riverside Comparison Table for Conversion Technology Table 5-2



1. Weigh Scales
2. Refuse Storage Pit
3. Furnace & Boiler
4. Turbine – Generator, Stack
5. Dry Scrubber
6. Baghouse
7. Ash Treatment and Recycling

Commerce Refuse-to-Energy Facility Schematic Process Diagram **Figure 5-1**



*See schematic notes on next sheet for further information.

SERRF Refuse to Energy Facility Schematic Process **Figure 5-2**

SERRF Schematic Notes

1. **Tipping Hall -** Solid waste delivered by trucks, screened for radioactive material, weighed by computerized scale, drive into enclosed tipping hall, discharging their load. Refuse inspected for unprocessible waste, pushed into refuse storage pit by front end loader. Storage pit area is enclosed, air continuously drawn from pit area, sent through boilers removing dust/odor, destroyed by high temperatures. Carbon filters used for odor control when boilers shut down for maintenance.

2. **Furnace -** Waste lifted out of storage pit by cranes, dropped into refuse feed hopper. At bottom of feed chute, hydraulic rams push refuse into boiler, and combusted under controlled conditions. Heat generated converts water flowing through tubes into steam. Floor of furnace has moving grates pushing refuse through boiler. Refuse passes through boiler, ash discharged into quench tank. Quench tank cools and eliminates dispersion of the ash. Thermal $DeNo_x$ system, injects ammonia into boiler's chamber, used to control nitrogen oxides.

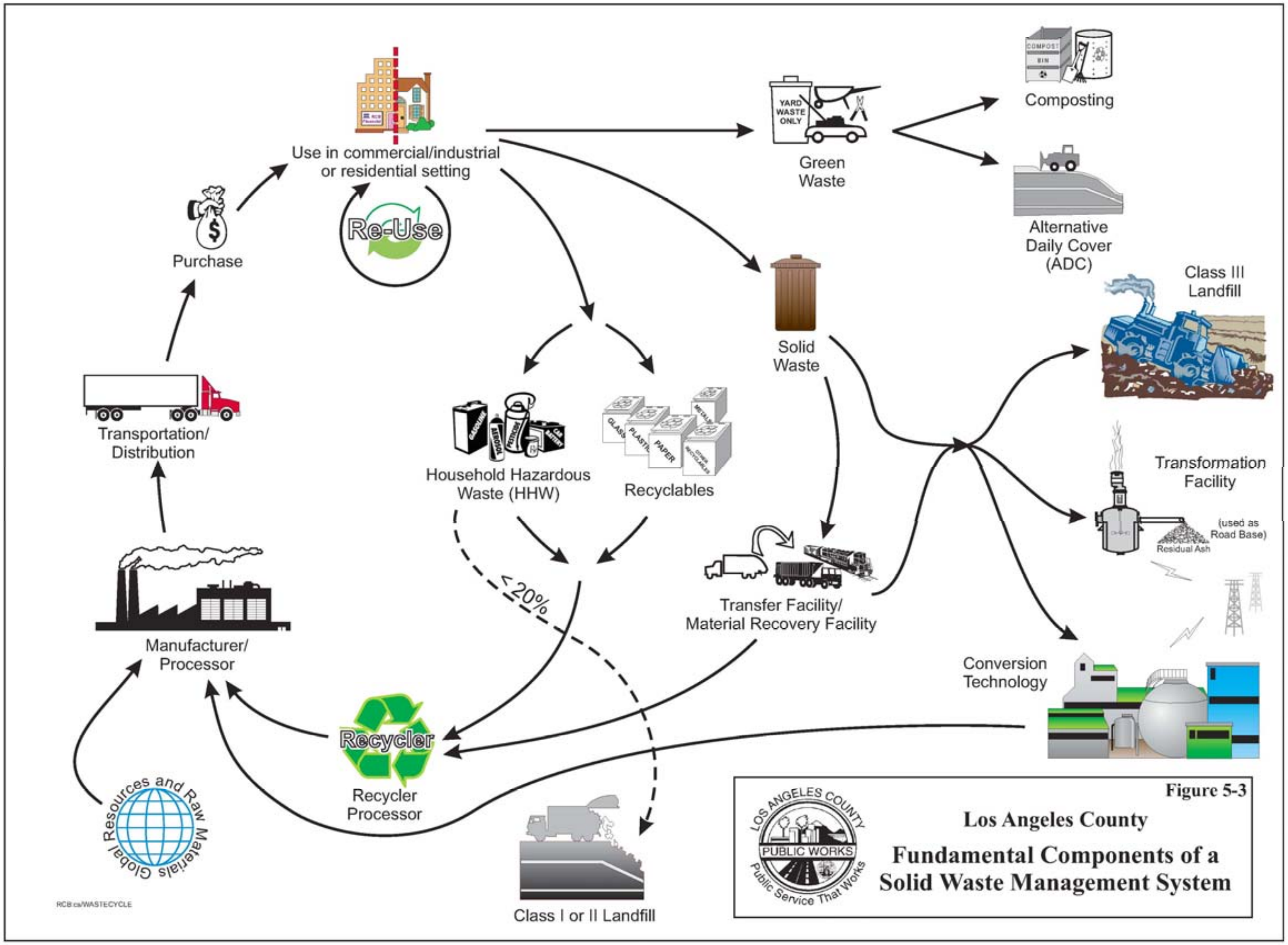
3. **Dry Scrubber -** After leaving boiler, combustion gases travel through pollution control system. Dry scrubber neutralizes acid gasses by spraying lime slurry into exhaust stream. Excess of 95% SO_2 and HCl removed in process. Reacted lime/ash removed from bottom of scrubber.

4. **Baghouse** - Baghouse operates like gigantic vacuum cleaner. Air drawn through baghouse, particulate matter/fly ash trapped in bags. Each boiler has baghouse containing ten modules with bags made of fiberglass. Baghouse cleaned by blowing air, in reverse direction, through the bags. Particulate and fly ash removed from bottom. Process removes 99.5% of particulate matter in air stream down to sub-microscopic levels. After leaving baghouse, cleaned exhaust gases exit through a 265 foot tri-flue stack. Emissions monitored by combination of continuous monitors and periodic stack sampling.

5. **Generator -** Steam generated from refuse used to drive turbine-generator producing electricity. Some electricity produced used to operate facility and remainder is sold to SCE for distribution. Steam used to drive turbine-generator then sent to condenser, converted into water, and recycled back through boilers.

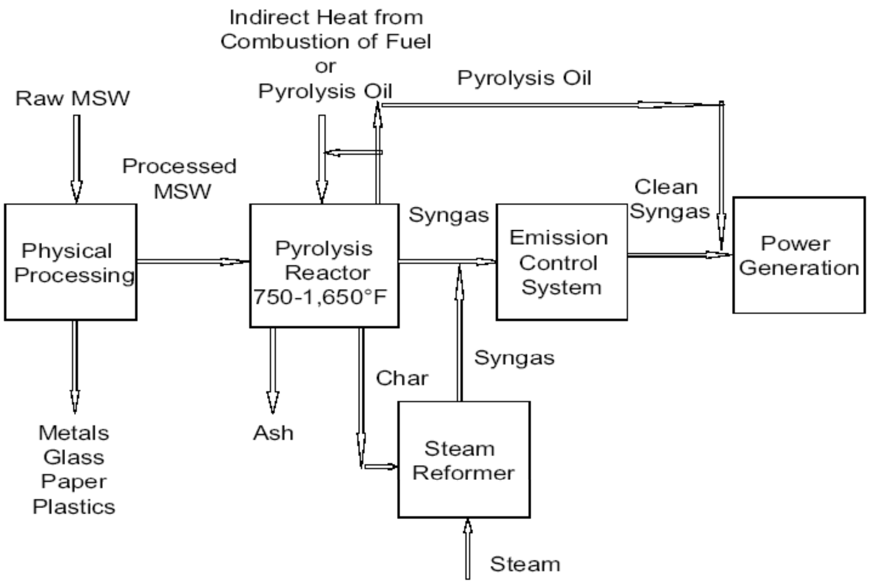
6. **Ash Conveyors** - The ash from the furnace, dry scrubber, and baghouse is treated and transported to the landfill where it is used as road base material.

SERRF Refuse to Energy Facility Schematic Process **Figure 5-2**

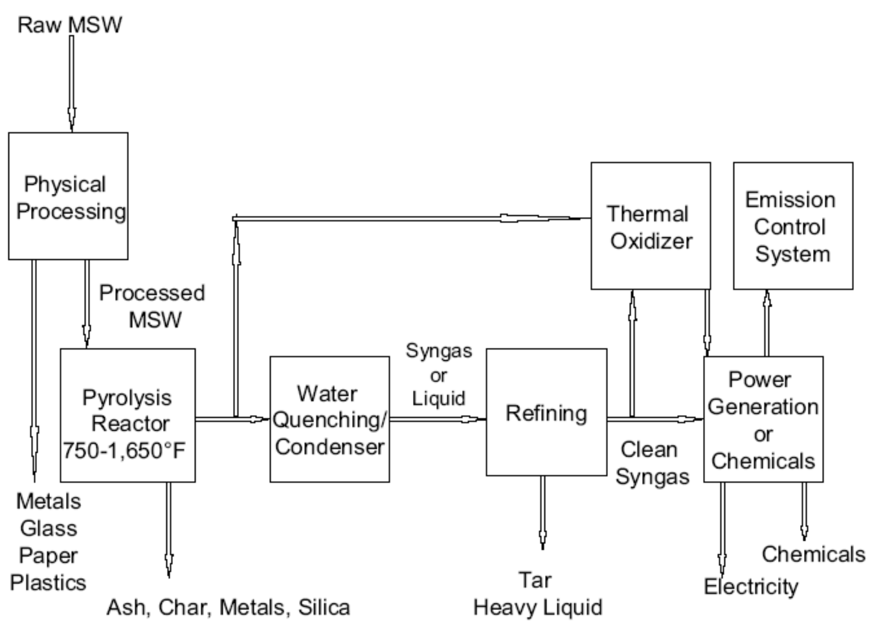


Typical Conversion Technology Procedural Flowchart **Figure 5-3**

TYPICAL PYROLYSIS/STEAM REFORMING SYSTEM FOR POWER GENERATION



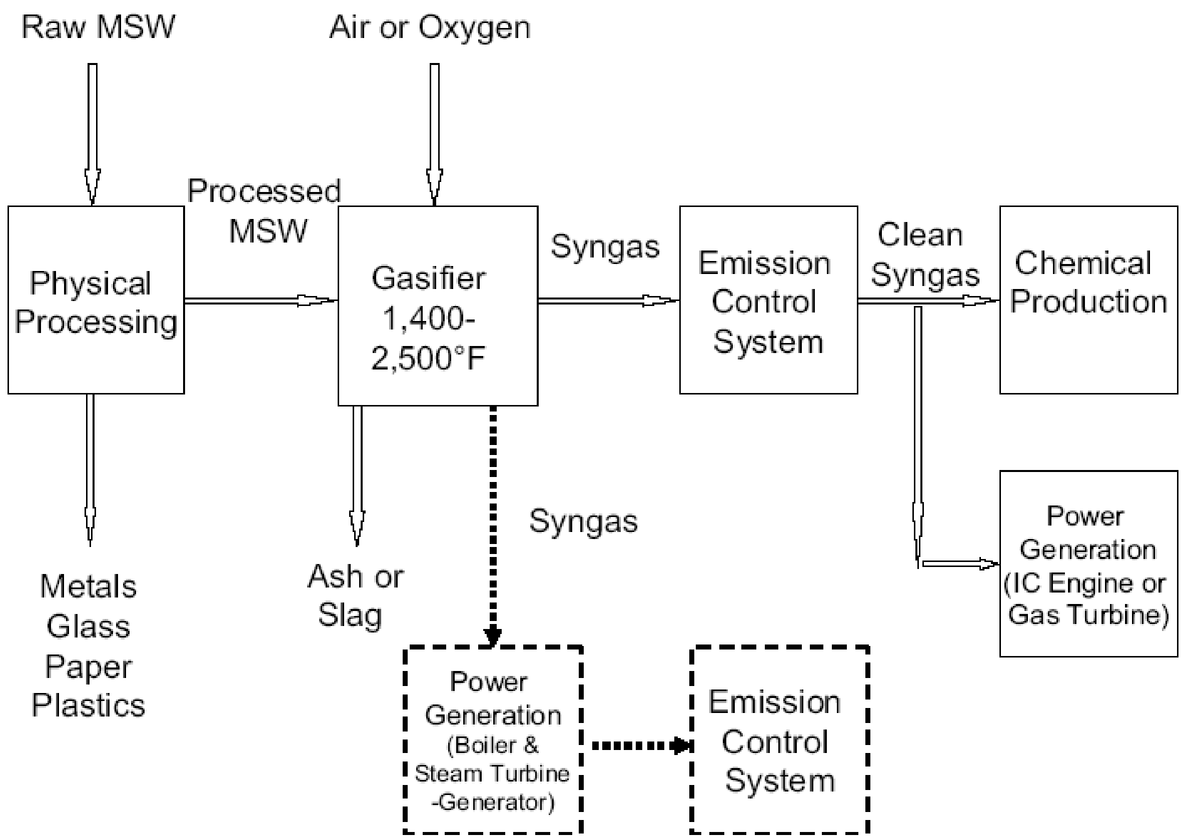
TYPICAL PYROLYSIS SYSTEM FOR POWER GENERATION



General Pyrolysis System Process Flowchart **Figure 5-4**

Source: URS Conversion Technology Evaluation Report, August 18,2005

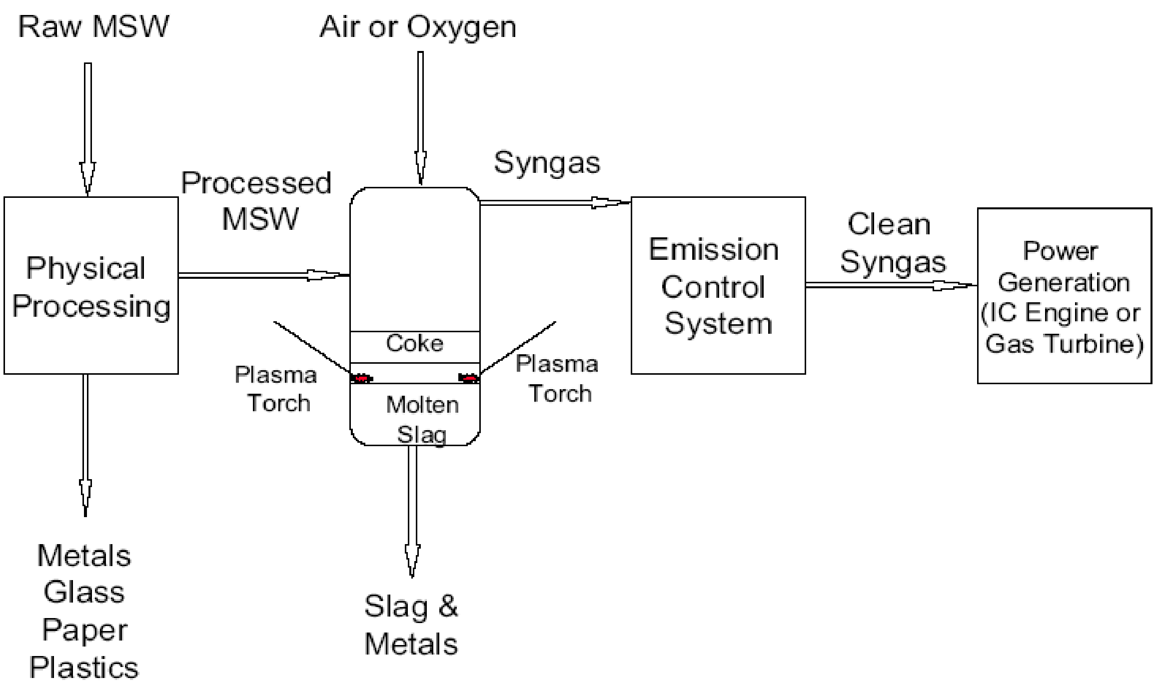
TYPICAL GASIFICATION SYSTEM FOR POWER GENERATION (2 OPTIONS) OR CHEMICALS



General Gasification System Process Flowchart **Figure 5-5**

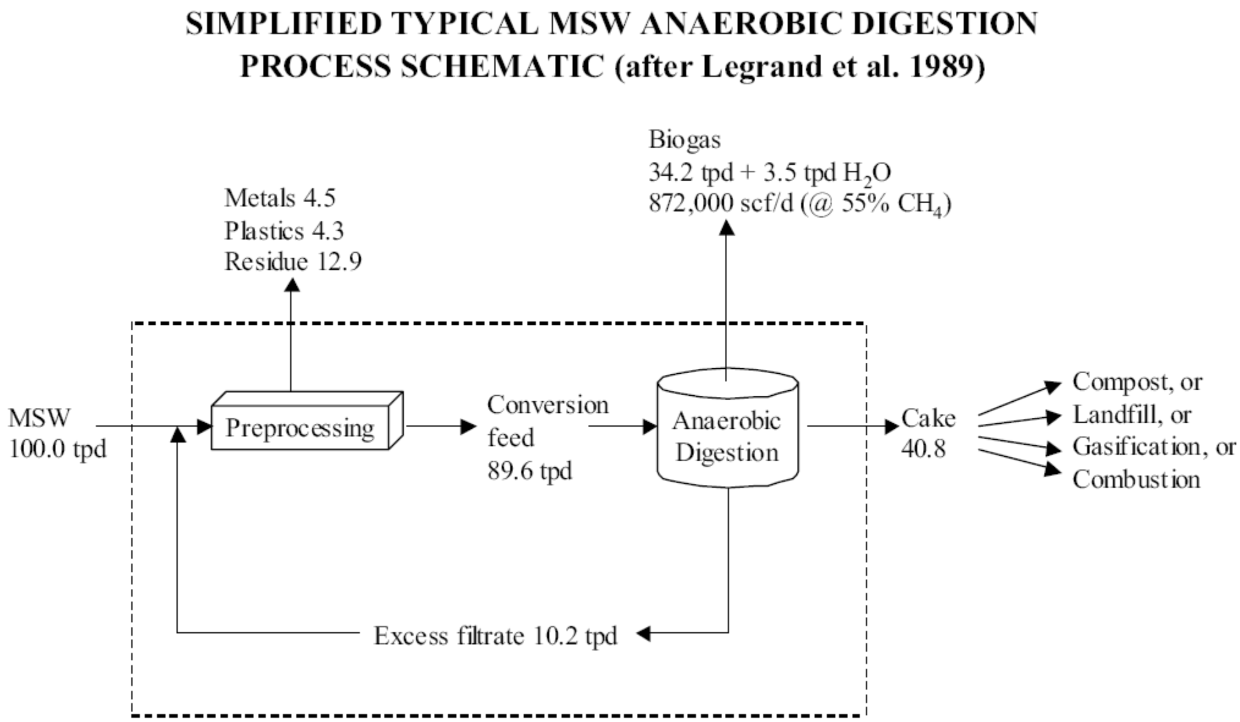
Source: URS Conversion Technology Evaluation Report, August 18,2005

TYPICAL PLASMA GASIFICATION SYSTEM FOR POWER GENERATION



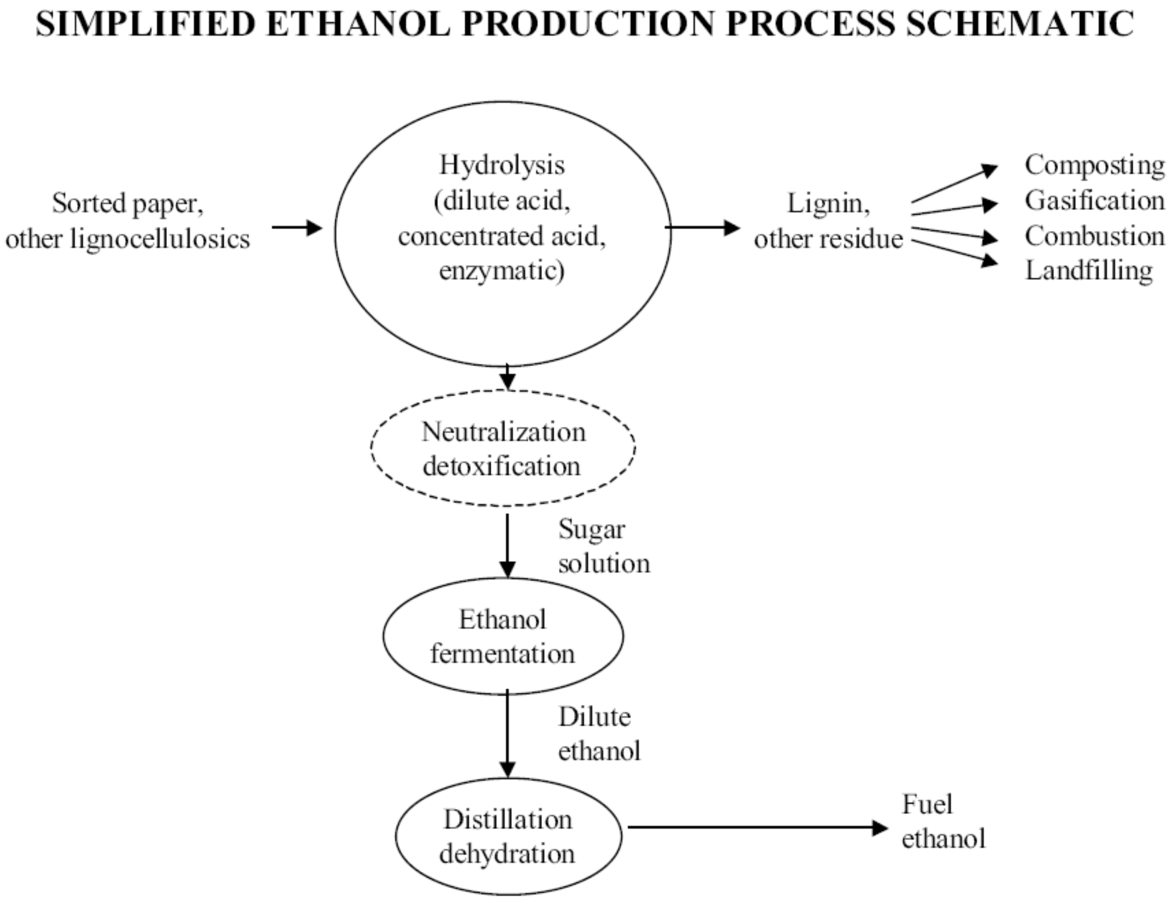
General Plasma Arc Gasification System Process Flowchart **Figure 5-6**

Source: URS Conversion Technology Evaluation Report, August 18,2005



General Anaerobic Digestion Process Flowchart **Figure 5-7**

Source: URS Conversion Technology Evaluation Report, August 18,2005



General Acid Hydrolysis Process Flowchart **Figure 5-8**

Source: URS Conversion Technology Evaluation Report, August 18,2005

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