# CONVERSION TECHNOLOGY EVALUATION REPORT

Prepared for:

THE COUNTY OF LOS ANGELES
DEPARTMENT OF PUBLIC WORKS
AND
THE LOS ANGELES COUNTY SOLID WASTE MANAGEMENT COMMITTEE/INTEGRATED WASTE MANAGEMENT TASK FORCE'S ALTERNATIVE TECHNOLOGY ADVISORY SUBCOMMITTEE

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# ACKNOWLEDGMENTS

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The County of Los Angeles Department of Public Works (DPW), the Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force and its Alternative Technology Advisory Subcommittee (the Subcommittee) are currently promoting the development of conversion technologies as an alternative to traditional solid waste disposal practices. As part of this effort the Subcommittee is looking for an opportunity to create a partnership between a Materials Recovery Facility (MRF) and a conversion technology supplier. The main objectives of this partnership are:

- Develop a demonstration facility in Southern California that utilizes new state-of-the-art conversion technologies and tests the feasibility of such technologies.
- Increase diversion of MRF residual solid waste from disposal at landfills. This residual solid waste is the material remaining after all recyclable materials have been removed, and is therefore destined for disposal at landfill.
- Generate marketable products, including renewable energy or green fuels.
- Generate real data for regulatory permitting pathways in California. Currently there are no commercial operating conversion technology facilities processing MSW in the United States. They are commercialized in Europe and Japan.

In order to develop the first facility of its kind, DPW and the Subcommittee have engaged URS Corporation to perform the following tasks:

- Prepare a summary of conversion technologies.
- Analyze, screen, and rank conversion technologies. This evaluation will prioritize residues from a Material Recovery Facility (MRF) or Transfer Station (TS) as the feedstock for a potential conversion demonstration facility.
- Screen and rank MRFs/TSs in Southern California.
- Analyze the most suitable combinations of MRF/TSs and technologies.
- Prepare the following supporting documents:
  - Strategic Action Plan
  - Public Outreach Plan
  - Marketing Analysis
  - Siting Analysis

The results of this study including supporting documents are presented as a Final Report. The content of this Conversion Technology Evaluation Report prepared by URS Corporation is briefly described in this executive summary and consists of the following sections:

## 1. SUMMARY OF CONVERSION TECHNOLOGIES

This section provides descriptions of thermal and biological/chemical conversion technologies. The following technologies are described:

- Thermal Conversion
    - Pyrolysis
    - Pyrolysis/gasification
    - Pyrolysis/steam reforming
    - Conventional gasification (fixed bed and fluid bed)
    - Plasma gasification
    - Thermal depolymerization
- Biological/Chemical and Other Conversion
    - Anaerobic Digestion
    - Aerobic Digestion
    - Catalytic Cracking of Plastic
    - Syngas to Ethanol

The following issues are discussed for each of the above conversion technologies:

- Process Description
- Throughput
- Feedstock Characteristics
- Byproducts
- Environmental Issues

## 2. EVALUATION, SCREENING, AND RANKING OF TECHNOLOGIES

In this section conversion technologies were ranked and screened following these steps:

- Screen potential conversion technologies. The following technologies passed the screening process and are recommended for consideration in the next phase of this process:

  - Thermal conversion including pyrolysis, gasification, plasma gasification, and thermal depolymerization
  - Biological/Chemical conversion including anaerobic digestion, and gasification with fermentation to ethanol

- Screen and rank conversion technology suppliers, which included the following steps:
  - Prepare a long list of technology suppliers
  - Prepare a questionnaire for technology suppliers, distribute the questionnaire, and evaluate the responses
  - Develop screening criteria for technology suppliers
  - Screen technology suppliers
  - Develop ranking criteria for technology suppliers
  - Rank technology suppliers
  - Select preferred technologies for consideration in the next phase of the process

Ranking of the technology suppliers is based on information provided by the technology suppliers in their responses to the questionnaire, based on the foregoing criteria established by the Subcommittee, without an independent verification of this information. The technology suppliers passing the screening criteria can be grouped into three general categories: thermal technologies, biological technologies, and emerging technologies. The results of the conversion technology ranking indicated that the top ranking screened technologies are thermal technologies such as gasification and pyrolysis. These technologies are well known and have been widely used overseas for MSW processing. These technologies generate electricity as their primary product and create only small quantities of residue. Four technology suppliers of this group ranked higher than any other technologies. The following thermal technology suppliers received ranked scores of more than 75%:

- Interstate Waste Technologies (IWT) – Pyrolysis/Gasification
- Primenergy LLC – Gasification
- Ntech Environmental – Gasification
- GEM America – Flash Pyrolysis

IWT, Ntech Environmental, and GEM America have operating facilities overseas. Primenergy has a commercial facility in the United States processing rice hulls. Also, Primenergy has an alliance with CR&R MRF and Community Recycling, and tested Refuse Derived Fuel (RDF) from these facilities.

The capital and operational costs for a demonstration facility using the IWT system are higher than the other three pyrolysis and gasification technologies in this group ($186/ton processing 300 tons/day). However, IWT has a number of commercial operating facilities overseas processing MSW, and submitted the most complete response to the questionnaire. Primenergy, Ntech Environmental, and GEM America's estimated costs are $87, $129, and $105 per ton, respectively, for processing 100 tons/day. These costs will be much lower with higher throughput in a commercial facility.

Other thermal technology suppliers ranked lower (47 to 75%). These suppliers do not have commercial facilities processing MSW, only a pilot or test unit. Additionally, their submitted information was not as complete, therefore they were not recommended to be considered in the next phase of the process.

The second group of technologies includes anaerobic digestion (which falls under the California Integrated Waste Management Board's (CIWMB) composting definition). These technologies are also well known, and many facilities using this process are operating overseas using MSW or source separated organics as feedstock. The primary product of anaerobic digestion is compost, along with some electricity. A considerable quantity of residue is created that must be landfilled. In addition, compost marketability is unproven/unstable. Although some suppliers from this group are ranked second to thermal technologies (50-75% ranking scores), anaerobic digestion was not recommended for consideration in the next phase of this process, for the reasons provided below and in Section 4 of this Report.

The third group of technologies includes emerging technologies such as waste to green fuel. This group of technologies includes thermal depolymerization, and gasification with fermentation to ethanol. These technologies can be termed "emerging," since there are no operating commercial facilities processing MSW, and design data is limited. While these technologies demonstrate significant promise, the development risk is significant. The suppliers of these technologies are:

- Changing World Technologies (Thermal Depolymerization) – CWT has one operating demonstration/commercial facility using turkey waste as a feedstock.
- BRI (Gasification-Fermentation) – BRI has only a pilot facility.

If green fuel production becomes an objective of the proposed conversion facility, the syngas or biogas produced by the thermal or bioconversion technologies can be used to produce green fuel. In this case, a combination of thermal, chemical, and/or bioconversion technologies may be required, and such a combination can be evaluated in the next phase of this project.

## 3. EVALUATION OF FACILITIES

All MRFs/TSs in Southern California were evaluated to find the most suitable facility for development of a conversion demonstration project. The following procedures were followed:

- Screen and rank potential facilities. This step included:
    - Prepare a comprehensive list of MRF/TSs operating in Southern California
    - Prepare questionnaire in the form of postcard and send it to all MRF/TSs in Southern California
    - Screen MRF/TSs in Southern California
    - Develop ranking criteria for MRF/TSs
    - Evaluate selected MRF/TSs by requesting more information and site visits
    - Select preferred MRF/TSs in Southern California

A detailed evaluation of Southern California MRF/TSs indicates that the following MRF/TSs made the shortlist of preferred MRF/TSs for development of a conversion demonstration facility:

- Del Norte Regional Recycling and Transfer Station operated by Republic Services (City of Oxnard, Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) operated by Burrtec Industries (City of Aqua Mansa, Riverside County)
- Perris MRF/TS operated by CR&R (City of Perris, Riverside County)
- Central Los Angeles Recycling Center and Transfer Station operated by the City of Los Angeles Bureau of Sanitation (City of Los Angeles, Los Angeles County)
- Community Recycling/Resource Recovery, Inc. MRF in Sun Valley operated by Community Recycling (City of Los Angeles, Los Angeles County)
- Santa Clarita MRF/TS (Planned MRF to be built by Burrtec Industries, likely in or near the City of Santa Clarita, Los Angeles County)

## 4. ANALYSIS OF SUITABLE TECHNOLOGY/FACILITY COMBINATIONS

In this section the most suitable combinations of conversion technologies and MRF/TSs in Southern California were analyzed and the following issues discussed:

- Preferred MRF/TS
- Preferred Conversion Technologies
- Most Suitable Technology/MRF Combinations

The most suitable combinations of conversion technology/MRF/TS were analyzed on the following bases:

- Solid Waste Suitability
- Feedstock Availability
- Preprocessing
- Space Availability
- Infrastructure Availability
- Environmental Capability

Results for the first phase of this study concluded that the most suitable conversion technology/MRF combinations are thermal conversion and waste to green fuel technologies. Anaerobic digestion was not recommended to be considered in the next phase of this process for the following reasons:

- Anaerobic digestion requires extensive preprocessing of the feedstock, therefore MRF residue may not be a suitable feedstock for anaerobic digestion.
- Anaerobic digestion requires more acreage for development because of its larger footprint.
- An anaerobic digestion technology vendor (WRSI/Valorga) is in the process of building a commercial facility in Southern California and, therefore, there is no need for a demonstration facility.
- Anaerobic digestion generates a larger percentage of residue, and therefore has a lower diversion rate.
- Anaerobic digestion generates mostly compost and soil amendment with a small amount of biogas to generate electricity. The marketability of the compost is questionable.

The six MRFs in the list of preferred facilities are the most suitable facilities. Members of the Alternative Technology Advisory Subcommittee at the June 16, 2005 meeting unanimously agreed that the short list of preferred MRFs for the first phase of development of a conversion facility should include:

- Del Norte Regional Recycling and Transfer Station (Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) (Riverside County)
- Perris MRF/TS (Riverside County)

The Community Recycling, Central Los Angeles and Santa Clarita MRF/TS should also be considered in the next phase of the project.

For the final selection of the most suitable combinations, a more detailed evaluation of MRF and technology suppliers is required, which can be included in the scope of work for the next phase of the study.

## 5. SUPPORTING DOCUMENTS

The following supporting documents were also included in the scope of work for this study:

### Strategic Action Plan

The Strategic Action Plan prepared as part of this study considers the prospective steps the County, the Integrated Waste Management Task Force and its Alternative Technology Advisory Subcommittee should take over short (6-12 month), mid (1-5 years) and long-term to satisfy the objective of this study.

The Strategic Action Plan recommends a number of specific actions for development of a conversion facility in Southern California. The following issues are discussed in this Plan:

- Environmental Issues
- Technical Challenges
- Public Outreach Issues
- Legislative Issues
- Cost and Financing Issues

A preliminary implementation schedule is presented in the Strategic Action Plan, which indicates a possible commissioning date of mid 2008, assuming CIWMB involvement in the regulatory pathway.

## Public Outreach Plan

The prepared Public Outreach Plan recommends specific actions the County and its Alternative Technology Advisory Subcommittee can take for conducting a public outreach program in connection with development of a conversion demonstration facility in Southern California. This Plan recognizes the unique nature of this project, including the need for public involvement and communication at the community level. This Plan emphasizes the following:

- Why Public Outreach Is Needed
- What Is Public Outreach With Regards to Conversion Facilities
- The Public Interest In A Conversion Facility
- A Strategic Approach to Public Outreach
- Communication Strategy
- Public Involvement Methods
- Specific Recommendations

Public acceptability is a major factor for implementation of a conversion demonstration facility. An early and comprehensive public outreach program will contribute to the success of this project.

## Marketing Analysis

Conversion technologies produce marketable products and byproducts. The quality and quantity of these products depend on type and design of conversion systems, and feedstock composition. A preliminary marketing analysis for conversion products was performed as part of this study. The following issues are discussed:

- Primary End Products of Conversion Technologies
  - Electricity
  - Green Fuel
  - Compost and Soil Amendment

Other by-products such as carbon char, chemicals, inert material, and recyclable material may also be produced in small quantities. The type, quantity and quality of these by products depend on the type and design of the conversion systems, type and quality of preprocessing, MRF residual composition, and many other factors. Market analysis for these by products will be addressed in the second phase of this project.

- Market Assessment for Conversion Products
- Expected Market Prices and Volatility

Preliminary market analysis shows that electricity has the most reliable and stable local market. Green fuels are in a developing marketplace and compost market is uncertain and unpredictable. Markets for the other products can vary greatly.

**Siting Analysis**

A preliminary siting analysis for the development of a conversion demonstration facility was performed. The following issues are discussed in this analysis:

- Preferred Conversion Technologies
- Preferred MRF Locations
- Regulatory and Permitting Issues
    - CIWMB
    - Air Emissions for Thermal and Bioconversion Technologies
    - Air Permit Requirements
    - Water Discharges
    - Solid Waste
- Environmental Issues and Mitigation
    - CEQA
    - Air Quality
    - Nuisance (Traffic, Odor, Dust, and Noise)
    - Visual Impacts
    - Surrounding Land Use
- Public Acceptability

There are no currently commercial operating conversion facilities processing MSW or MRF residue in the United States. Preliminary data from Japan and Europe indicates that conversion facilities can operate within the regulatory framework in the U.S., and facilities with the most advanced environmental control systems would be able to meet regulatory requirements in California.

The actual environmental impacts of a specific conversion technology in a specific location will be evaluated as part of permitting process for the facility.

## 6. CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

The following conclusions are based on findings of this study:

I – The results of the technology evaluation indicated that the top ranking technologies are thermal technologies such as gasification and pyrolysis. The top four thermal technology suppliers according to their ranked scores are:

- Interstate Waste Technologies (IWT) – Pyrolysis/Gasification
- Primenergy LLC – Gasification
- Ntech Environmental – Gasification
- GEM America – Flash Pyrolysis

The second group of technologies includes anaerobic digestion. As discussed above and in Section 4 of this Report, anaerobic digestion vendors were not recommended for the next phase of this process.

The third group of technologies includes emerging technologies such as waste to green fuel technologies. These emerging technologies do not have commercial facilities processing MRF residue or MSW, therefore they ranked lower. However, the significantly increased development risk may be offset by the potential benefits offered by these technologies. The suppliers for these technologies are:

- Changing World Technologies (CWT) – Thermal Depolymerization
- BRI – Gasification/Fermentation to Ethanol

II – Analysis of the Southern California MRF/TS facilities concluded that the six MRF/TSs listed below are willing and capable of hosting a conversion technology demonstration facility.

- Del Norte Regional Recycling and Transfer Station operated by Republic Services (City of Oxnard, Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) operated by Burrtec Industries (City of Aqua Mansa, Riverside County)
- Perris MRF/TS operated by CR&R (City of Perris, Riverside County)

- Central Los Angeles Recycling Center and Transfer Station operated by the City of Los Angeles Bureau of Sanitation (City of Los Angeles, Los Angeles County)
- Community Recycling/Resource Recovery, Inc. MRF in Sun Valley operated by Community Recycling (City of Los Angeles, Los Angeles County)

Santa Clarita MRF/TS (Planned MRF to be built by Burrtec Industries, likely in or near the City of Santa Clarita, Los Angeles County)

III – Results of suitable technology/MRF combinations analysis concluded that the most suitable technologies are thermal conversion or waste to green fuel technologies and that any of the six MRF/TSs on the list of preferred facilities were suitable. Members of the Alternative Technology Advisory Subcommittee at the June 16, 2005 meeting unanimously agreed that the short list of preferred MRFs for the next phase of development of a conversion facility should include:

- Del Norte Regional Recycling and Transfer Station (Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) (Riverside County)
- Perris MRF/TS (Riverside County)

The Community Recycling, Central Los Angeles and Santa Clarita MRF/TS should also be considered in the next phase of the project.

IV – The Strategic Action Plan provides a “road map” for implementation of this project. The schedule indicates a possible commissioning date of mid 2008.

V – A Public Outreach Plan, which was prepared by this study, emphasized the steps that have to be taken for public outreach and education on conversion facilities. This Public Outreach Plan concludes that public acceptability is a major factor for developing a conversion demonstration facility in Southern California. An early and comprehensive public outreach program will contribute to the success of this project.

VI – The preliminary market analysis shows that electricity has the most reliable and stable local market. Green fuels are in a developing marketplace where current demand outstrips supply in California. The compost market is uncertain and unpredictable.

VII – The siting analysis conducted as part of this study indicates that co-location of a conversion demonstration facility at an existing MRF in Southern California has several advantages over current practices of residue disposal. The actual environmental impacts of a specific conversion technology in a specific location will be evaluated as part of permitting process for the facility.

## Recommendations

It is recommended to proceed with the following tasks for development of a conversion demonstration facility to process MRF residue in Southern California:

1. Acquire and confirm data provided by the top four technology suppliers in the thermal technology category through an official Request for Qualification (RFQ) or Request for Proposal (RFP). These suppliers are:

   - Interstate Waste Technologies (Pyrolysis/Gasification)
   - Primenergy LLC (Gasification)
   - Ntech Environmental (Gasification)
   - GEM America (Flash Pyrolysis)

2. Acquire and confirm data provided by the two emerging technology suppliers through an official RFQ or RFP. The suppliers for these technologies are:

   - Changing World Technologies (Thermal Depolymerization)
   - BRI (Gasification/Fermentation to Ethanol)

   These technologies do not have a commercial facility processing MSW or MRF residue. Changing World Technologies has a demonstration facility processing turkey waste, and BRI has only a pilot facility. While these technologies demonstrate significant promise, the development risk is substantial.

3. Evaluate RFQ/RFP responses and select preferred supplier(s).
4. Clarify permitting pathways and requirements for each technology.
5. Visit preferred suppliers operating facilities.
6. Conduct a detailed evaluation of preferred MRF/TSs in the shortlist.
7. Pursue and negotiate a partnership between MRFs and technology suppliers.
8. Determine the most cost effective and technically feasible throughput for the proposed conversion facility.
9. Pursue funding mechanisms.
10. Start public outreach as early as possible for the implementation of this project.

**Alternative Technology Advisory Subcommittee – Findings and Conclusions**

Based on existing published studies of conversion technologies, including but not limited to those by the University of California at Davis, University of California at Riverside, and the California Integrated Waste Management Board, as well as the findings of this conversion technology evaluation process, and the professional expertise of URS Corporation and Subcommittee Members, the Alternative Technology Advisory Subcommittee of the Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force also adopted the following preliminary conclusions. These conclusions were adopted in support of the Subcommittee's decision to recommend the development of a demonstration conversion technology facility in Southern California, and it is the intent of the Subcommittee to confirm the validity of these conclusions through the next process:

1. Utilizing conversion technologies to process MRF residues and recover energy or green fuel with marketable byproducts will increase diversion from landfills and enhance Southern California's solid waste management and recycling programs.
2. Each of the technology groups evaluated (pyrolysis-gasification, gasification and waste to green fuel) appeared to be environmentally and technically feasible for processing MRF residue or MSW.
3. Available data from Japan and Europe indicates that conversion facilities can operate within the regulatory framework in the U.S. and that facilities with the most advanced environmental control systems would be able to meet regulatory requirements in California.
4. Conversion technologies have been in successful, long-term use around the world, although they typically use more homogeneous feedstocks such as coal and biomass. While technical challenges are expected with most of these technologies, because of their relatively short operating history using MSW as a feedstock and complexity of the process, these challenges are judged to be manageable.
5. Economically, these technologies appear to have the ability to compete favorably with other solid waste disposal methods in a commercial facility.

Conversion technologies offer a new and potentially ground-breaking approach in reducing the amount of solid waste disposed at landfills. Conversion technologies are a group of technologies that convert the organic or carbon-based portion of post recycling residual solid waste into useful products. These products, in turn can be used to produce electricity, green fuels, and/or marketable chemicals and fertilizers.

On the basis of their technical definitions, conversion technologies are divided into two types:

- Thermal conversion technologies: These technologies are characterized by higher temperatures (higher than 400°F) to process residual solid waste and produce useful products.
- Biological and chemical conversion technologies: These technologies proceed at lower temperatures (lower than 400°F) to convert residual solid waste into useful products.

The following is a brief description of thermal, biological, and chemical conversion technologies that were evaluated for the Alternative Technology Advisory Subcommittee.

## 1.1 THERMAL CONVERSION TECHNOLOGIES

### 1.1.1 Introduction

The thermal processes being considered for the Los Angeles County conversion technology evaluation project are technologies that thermally convert Material Recovery Facility (MRF) residue currently disposed of in a landfill to other useful products and by-products. Unlike incineration, they do not directly burn the MRF residue.

These technologies include:

- Pyrolysis
- Pyrolysis/gasification
- Pyrolysis/steam reforming
- Conventional gasification (fixed bed and fluid bed)
- Plasma gasification
- Thermal depolymerization

This evaluation does not include “conventional” mass-burn incineration technologies that are utilized throughout the U.S. in Waste-to-Energy (WTE) plants. The following section describes thermal conversion technologies currently used to process Municipal Solid Waste (MSW).

### 1.1.2 Pyrolysis

#### 1.1.2.1 Conventional Pyrolysis

Pyrolysis has a long history of industrial use. Pyrolysis systems utilize a wide range of designs, temperatures, and pressures to initiate the pyrolysis reactions. Typically, pyrolysis systems use a drum, kiln-shaped structure, or pyrolysis tube, which is externally heated using either recycled syngas or another fuel or heat source to heat the pyrolysis tube/chamber. Essentially, the organic materials are "cooked" in an oven, with no air or oxygen present. No direct burning takes place.

Most organic compounds are thermally unstable. At high temperatures, larger (more complex) organic compounds are thermally broken down into gases and liquids composed of smaller molecules, including hydrocarbon gases and hydrogen gas. The temperature, pressure, reaction rates, and internal heat transfer rates are used to control specific pyrolytic reactions in order to produce specific products. At lower temperatures, liquid pyrolytic oils dominate; at higher temperatures, gaseous byproducts dominate. Pyrolysis reactions are endothermic, meaning that they require externally supplied heat to occur. Natural gas, propane or the Syngas produced by pyrolysis can be used as sources of external heat. If the feedstock has a high heating value (BTU/lb) the pyrolytic process becomes more self-sufficient and once the process starts uses very little fossil fuel.

The constituents of syngas produced by pyrolysis are: methane ($CH_4$), carbon monoxide ($CO$), and hydrogen ($H_2$), which are combustible gases. They also produce oxidized compounds ($CO_2$ and $H_2O$), which have no heating value and dilute the syngas.

Pyrolysis can be run as a batch or continuous process and can reduce the volume of MSW by as much as 90%. Pyrolysis produces gases and liquids, as well as residual solids including ash and a carbon char. Some common commercial products made through pyrolysis, depending on the nature of the feedstock, are charcoal (for barbecuing) and activated carbon (for absorption of liquid and gaseous emissions).

Municipal Solid Waste (MSW) is too heterogeneous for pyrolysis and other thermal conversion technologies and, therefore requires pre-processing in most cases. Since inorganic materials such as grit, glass, and metals, do not enter into the thermal conversion reactions, energy, which could be used to produce pyrolysis reactions, is expended in heating the inorganic materials to the pyrolysis reactor temperature. Then the inorganic materials are cooled in clean-up processes, and the heat is lost. Much of the pre-processing is required to remove inorganic materials and to enhance the homogeneity of the feedstock. Depending on the specific pyrolysis process, pre-processing may include sorting, separation, size reduction, densification, etc.

Since pyrolysis occurs in the absence of oxygen, the feed system and pyrolysis chamber are sealed and isolated from outside air during the processing. This is accomplished through the use of inlet and outlet knife-gates, with ram feeders to feed one “plug” of feedstock as the next plug is being fed into the sealed environment.

In the reactor, pyrolysis may occur over a period of time (several minutes in a pyrolysis or “degassing” chamber) or very quickly, as in the case of “flash” pyrolysis, where the feedstock encounters an extremely hot internal surface and volatilizes in less than a second. Slow pyrolysis is used to maximize the production of char, as in the case of producing charcoal or activated carbon. In those cases, the volatile fraction may be vented or used elsewhere. Slow pyrolysis is used to convert low volatile coal to metallurgical grade coke for steel making. Coke is a very pure carbon product, which is then used to initiate a reducing atmosphere for converting iron ore to molten iron. Following the pyrolysis reactor, the syngas may be:

- Burned directly in a thermal oxidizer or boiler, and its heat recovered for making steam for power generation; the exhaust gases then pass through emission control systems that may include fabric filters, wet and dry scrubbers, electrostatic precipitators, and activated carbon beds.
- Quench cooled, cleaned in emission control systems, and then burned in a boiler, reciprocating engine or gas turbine for power generation.
- Quench cooled, cleaned in emission control systems, and then utilized for producing organic chemicals.

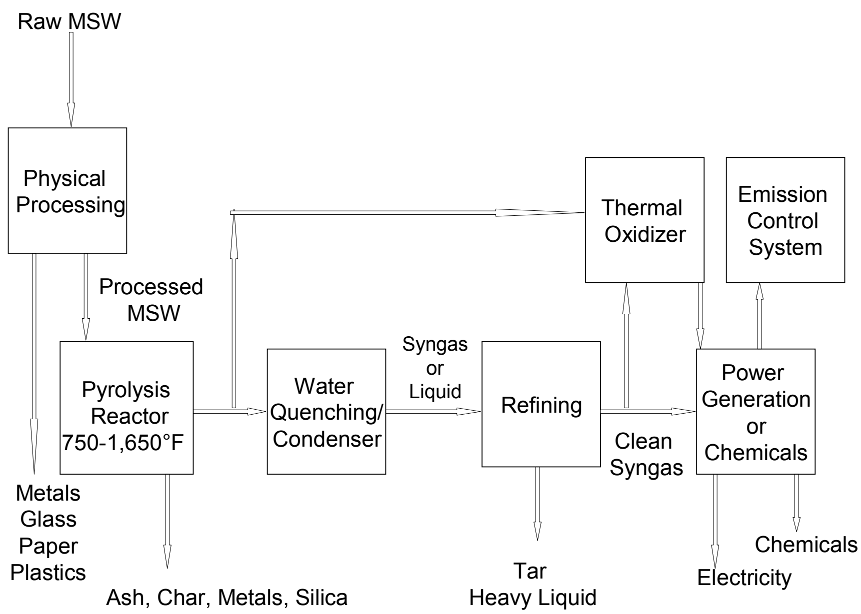
The char can be used as a commercial product, such as charcoal or coke, manufactured into graphite rods for carbon arc steel making, or further processed in gasification reactions illustrated in Figure 1-1.

The inorganic materials in the feedstock are removed as a bottom ash. It is usually combined with the char, and can be separated out for disposal (if the char is to be utilized as noted above) or used in making block materials.

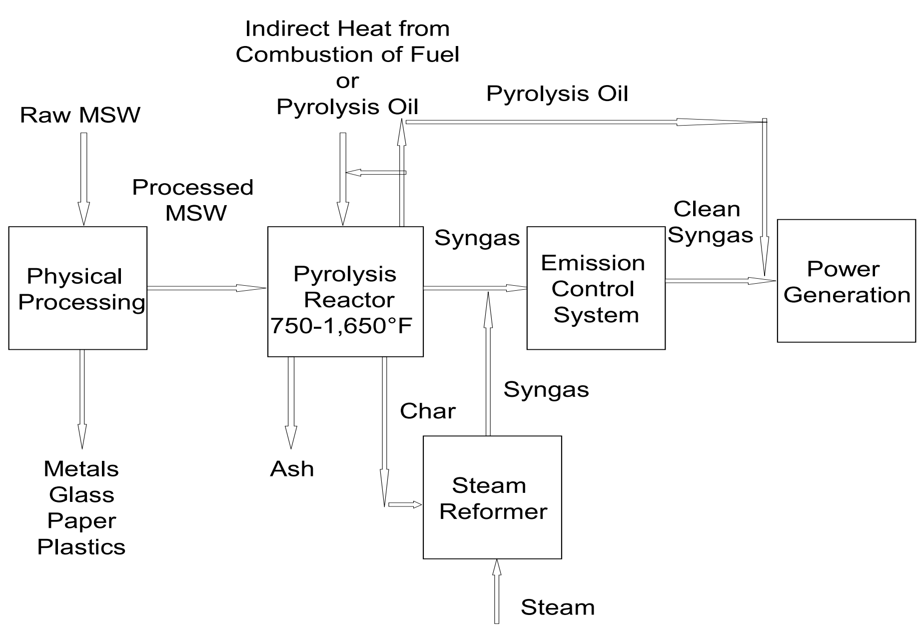
#### 1.1.2.2 Pyrolysis/Steam Reforming

Since the pyrolysis reactions result in the formation of char, liquids, and gases, additional reactions can be initiated to further the thermal breakdown of these organic compounds. One of the common reactions to follow pyrolysis is steam reforming shown in Figure 1-2. Since the water-gas reaction is used to promote the reaction of carbon and water to form syngas. In this manner, the char produced in pyrolysis is reacted with steam that is injected into the process so that:

## FIGURE 1-1
## TYPICAL PYROLYSIS SYSTEM FOR POWER GENERATION




## FIGURE 1-2
## TYPICAL PYROLYSIS/STEAM REFORMING SYSTEM FOR POWER GENERATION



$C + H_2O \rightarrow CO + H_2$ (water-gas reaction)

This reaction is endothermic, using the heat provided by the steam (and from the external source used for pyrolysis) to further this reaction. In addition, steam reforming of the methane in the syngas stream can occur, resulting in additional production of hydrogen:

$CH_4 + H_2O \rightarrow CO + 3H_2$

The syngas stream is then cooled, cleaned, and used for power generation or chemical production.

#### 1.1.2.3 Throughput

Existing pyrolysis systems treat up to 300 tons/day, with pyrolysis/steam reforming systems operating at up to 165 tons/day. Systems are modular, and can be installed in parallel to increase throughput.

#### 1.1.2.4 Feedstock Characteristics

Pyrolysis systems can process a wide range of carbon-based materials. Any organic or thermally degradable material can be processed by pyrolysis. Historically, pyrolysis was used to make charcoal from wood. Pyrolysis also is used to process used tires and produce carbon black, steel and fuel to generate power. Currently, some manufacturers are using pyrolysis to make activated carbon using coconut shells or wood as feedstock. If a homogeneous feedstock is processed by pyrolysis, it produces high quality byproducts.

MSW is not a homogenous waste stream. In order to make the pyrolysis process more efficient, pre-processing of MSW is required. The pre-processing includes the separation of thermally non-degradable material like metals, glass, and concrete debris. Also, for some pyrolytic processes, size reduction and/or densification of the feedstock may be required. If MSW has high moisture content, a dryer may be added to the pre-processing stage to lower the moisture content of the MSW to 25% or lower. Lower moisture content of the feedstock increases its heating value and the system becomes more efficient. The waste heat or fuel produced by the system can be used to dry the MSW.

#### 1.1.2.5 Byproducts

The solid byproducts from pyrolysis are mainly carbon char, silica, metals and non-thermally degradable material such as glass. In the case of low temperature pyrolysis, where liquid fuel is the byproduct, a tar or viscous material is also produced. The carbon char from processing MSW can be used as fuel, additives to construction materials or other industrial purposes. The carbon char produced by pyrolysis also can be activated using the steam generated by the pyrolysis system. The activated carbon can be used in wastewater treatment facilities or other manufacturing plants for water or air treatment and emission control. The metals can be separated and sold. The ash can be disposed of in a regular non-hazardous landfill.

#### 1.1.2.6 Environmental Issues

In all thermal conversion technologies, air emissions are a major environmental issue to be addressed. Pyrolysis uses indirect heat with the absence of free air or oxygen to process MSW, therefore the air emissions are minimized. Pyrolysis, and gasification reactors typically are closed, pressurized systems, so that there are no direct air emission points. Contaminants are removed from the syngas and/or from the flue gases prior to being exhausted from a stack. Specific design and operation characteristics of thermal conversion systems also reduce air emission significantly. These include:

- Thermal conversion technologies often incorporate pre-processing subsystems in order to produce a more homogeneous feedstock; this provides the opportunity to remove chlorine-containing plastics (as recyclables), which could otherwise contribute to the formation of trace organic constituents.
- The volume of syngas produced in the conversion of the feedstock is considerably lower than the volume of flue gases formed in the combustion of MSW in a waste-to-energy facility. Smaller gas volumes are easier and less costly to treat.
- Pre-cleaning of the syngas is possible prior to combustion in a boiler, and is required when producing chemicals or prior to combustion in a reciprocating engine or gas turbine in order to reduce the potential for corrosion in this sensitive equipment. Syngas pre-cleaning serves to reduce overall air emissions.
- Syngas produced by thermal conversion technologies is much more homogeneous and cleaner-burning fuel than MSW.

Air emission control and processing systems that are likely to be required by South Coast Air Quality Management District (SCAQMD) include some or all of the following:

- When the syngas is combusted in a boiler, reciprocating engine, or gas turbine, automated combustion controls and furnace geometry (for boilers) designed to optimize residence time, temperature and turbulence to ensure complete combustion
- For combustion of syngas in a boiler, low-$NO_x$ burners and/or a Selective Non-catalytic Reduction (SNCR) system for reduction of $NO_x$ emissions. Selective Catalytic Reduction (SCR) is typical for exhaust gases from reciprocating engines and gas turbines.
- Baghouse (fabric filter) for removal of particulate matter from flue gases.
- Activated carbon injection (followed by a baghouse) for removal of trace metals (such as mercury).

- Wet scrubber for removal of chlorides/hydrochloric acid (may produce saleable HCl).
- Wet, dry, or semi-dry scrubber for sulfur dioxide (may produce saleable gypsum).
- Final baghouse for removal of fine particulate matter after dry or semi-dry scrubbers. Air emission control equipment to accomplish this syngas and/or flue gas cleanup is commercially available, and is able to reduce air emissions to levels well below regulatory limits in California.

It is likely that other issues will involve the following:

- Solid residual management – as stated above, pyrolysis can create several "residues", including char, silica, slag, or ash, depending upon the nature of the process. While many residues can be re-used, some small portion may be disposed in a landfill. These materials will be inert, however.
- Visual and Land Use – there may be impacts relating to the visual character of the facility, or issues relating to compatibility of the facility with surrounding land uses.
- As with other facilities handling MSW, there will be concerns about odors, litter, noise, traffic, and dust.

### 1.1.3 Gasification

#### 1.1.3.1 Conventional Gasification

Conventional gasification involves the partial oxidation of carbon-based feedstock to generate a syngas, which can be used as a fuel or for the production of chemicals. Gasification has been used worldwide for making "town gas" for street lighting and cooking for over 150 years. It played a major role in the industrial development of Europe. Since then, many gasification technologies and designs have been developed, primarily in Europe. The Fischer-Tropsch process was developed to take syngas from gasification of coal and convert it to a wide range of hydrocarbon liquids, including diesel. After WWII, the use of gasification declined as oil and gasoline became cheaper and more available.

Syngas produced by gasification is presently used for making chemicals and electricity. Examples are the gasification of coal by Eastman Chemical in their Kingsport, Tennessee, plant to make chemicals that are the precursors for the manufacture of photographic film and other products, and the gasification of coal and petroleum coke by Tampa Electric to produce syngas, which is burned in place of natural gas in a large combustion turbine to make electricity.

The use of gasification for MSW began in the 1980s, in the U.S., Europe and Japan. In these initial units, the use of unprocessed MSW resulted in many technical problems, primarily due to the heterogeneous nature of MSW. This caused handling and feeding problems, as well as issues with temperature and process control, ash removal, and overall cost. Many of these facilities were shut down. With the worldwide success in coal and petroleum coke gasification, regulatory requirements in Europe and Japan for increased diversion of MSW from landfills, and difficulties in siting and permitting of conventional incineration, gasification become a major alternative treatment technology for MSW. Most of the development has occurred in Japan and Europe, at first utilizing MSW combined with other feedstocks, such as sewage sludge and industrial wastes. In order to feed the MSW by itself, development and use of preprocessing technologies became critical.

Prior to entering the gasifier, some preprocessing will likely be required, as described above in the section on pyrolysis. Some gasification technologies (primarily fixed-bed designs) may accept a minimum amount of preprocessing, such as removal of large appliances, shredding and sorting. Others may require a significant amount of removal of recyclables, sorting, shredding, and drying, in order to provide a homogeneous feedstock.

In the gasifier, the addition of air or oxygen for gasification of the MSW leads to a small amount of combustion, forming some $CO_2$ and releasing heat:

$$C + O_2 \rightarrow CO_2$$

Depending on the gasifier design, 10-30% of the heating value of the feedstock is used in this reaction. Utilizing that heat, the organic compounds in the feedstock begin to thermally degrade, forming the pyrolysis gases, oils, liquids and char. As these products move through the bed, or downstream through the gasifier, they encounter air, oxygen, and/or steam, which are injected to further the gasification reactions. The endothermic water-gas and Boudouard reactions occur:

$C + H_2O \rightarrow CO + H_2$ (water-gas reaction)

$C + CO_2 \rightarrow 2CO$ (Boudouard reaction)

Some of the carbon may react with the hydrogen, forming additional methane gas:

$$C + 2H_2 \rightarrow CH_4$$

Carbon monoxide, hydrogen, and methane, form the primary components of syngas. If air is used instead of oxygen, the syngas will include the nitrogen gas that enters with the air, diluting the syngas and lowering its overall heating value. Gasifier designs are optimized to feedstock and to specific reaction products. Additional water or steam can be injected to initiate the water-gas shift reaction, which converts the CO formed in the water-gas and Boudouard reactions to $CO_2$, also resulting in the production of a stream higher in hydrogen concentration.

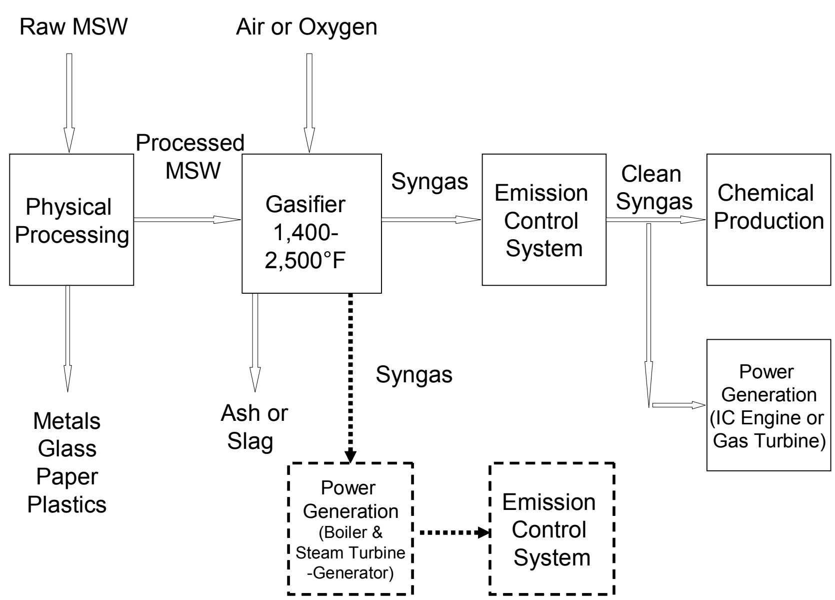
$CO + H_2O \rightarrow CO_2 + H_2$

The higher hydrogen concentration is important when the syngas will be used for chemical production. In that scenario, the $CO_2$ can be separated and removed through commercially available physical, chemical, membrane, or cryogenic processes.

Gasifiers are typically characterized as being horizontal or vertical, and utilize one of three specific reactor designs: 1) fixed-bed, 2) fluid bed, and 3) entrained bed. In fixed-bed gasifiers, the feedstock is usually fed through the system on a stationary or moving grate. The air or oxygen is injected either up, down, or cross draft flow. In an updraft gasifier, the air or oxygen is injected from the bottom and the syngas exits at the top.

In a downdraft design, the air enters at or near the top of the gasifier, and the syngas exits the bottom. In a fluid bed design, the gasifier is filled with inert particles (usually sand or alumina). The feedstock is fed either directly into or above the bed. High velocity oxygen, air, or other fluidizing medium is injected below the bed, causing the particles to be entrained in the flow and suspended. The feedstock and bed materials are continuously stirred, resulting in uniform temperatures, reactions, and heat transfer. Bubbling bed and circulating fluid bed designs are commonly used to enhance fluidization and turbulence. Figure 1-3 shows the process flow of typical gasification systems.

**FIGURE 1-3**
**TYPICAL GASIFICATION SYSTEM FOR**
**POWER GENERATION (2 OPTIONS) OR CHEMICALS**



Following the gasifier, the syngas may be:

- Burned directly in a thermal oxidizer or boiler, and its heat recovered for making steam for power generation; the exhaust gases then pass through emission control systems that may include fabric filters, wet and dry scrubbers, electrostatic precipitators, and activated carbon beds
- Quench cooled, cleaned in emission control systems, and then burned in a boiler reciprocating engine or gas turbine for power generation
- Quench cooled, clean in emission control systems, and then utilized for producing organic chemicals

If low temperature gasification is used, the inorganic materials in the feedstock will be recovered as a powdery to clinker-like bottom ash. This can be disposed of or used for the manufacture of block materials. If high-temperature gasification is used (above about 2,000°F), the inorganic materials will be subjected to temperatures above their melting points, forming a molten slag. The slag flows out a tap hole in the bottom of the gasifier, into a water bath. There, the slag is quench cooled, forming a glassy, non-hazardous slag material.

This can be disposed of safely, or used for the production of roofing tiles, sandblasting grit, or asphalt filler.

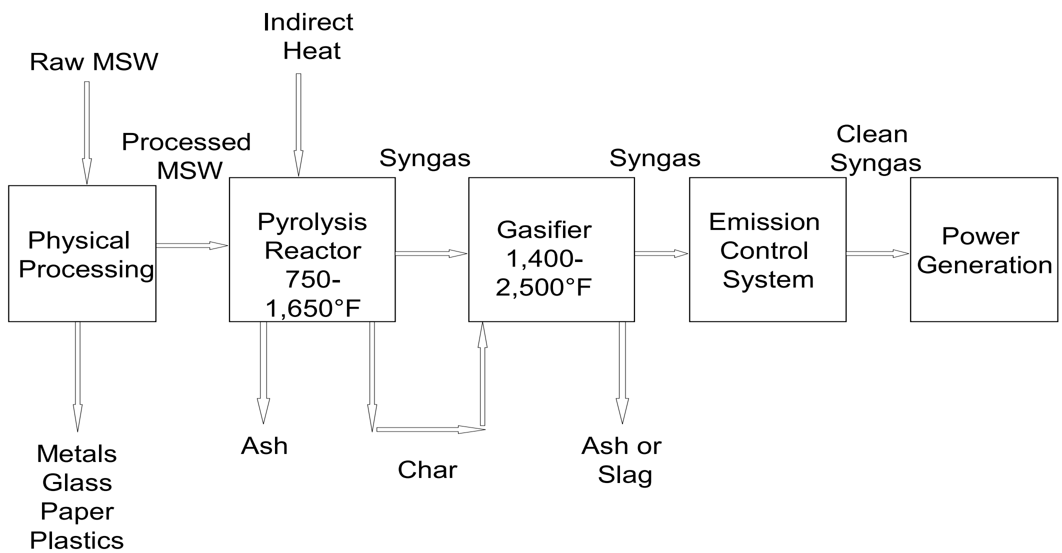
#### 1.1.3.2 Pyrolysis/Gasification

Some technologies employ a pyrolysis system close-coupled to a follow-on gasification step or separate reactor, shown in Figure 1-4. The carbon char produced in the pyrolysis or "degassing" chamber is pushed through into the gasification chamber, where the char and any pyrolysis liquids are gasified by way of additional reactions in a gasification chamber. While the pyrolysis reactor operates without free oxygen, the gasification reactor may use air, oxygen, and/or steam to provide the oxygen needed for the gasification reactions. The gasification reactions are mostly exothermic, so that once the reactions initiate, they are self-sustaining.

#### 1.1.3.3 Throughput

Existing gasification systems operate at throughputs up to 1,000 tons/day, with pyrolysis/ gasification systems operating at up to 800 tons/day. Gasifiers and the pre-processing, emission control, and power generation systems can be installed in parallel to increase throughput and power generation.

**FIGURE 1-4**
**TYPICAL PYROLYSIS/GASIFICATION**
**SYSTEM FOR POWER GENERATION**




### 1.1.3.4 Feedstock Characteristics

Gasification systems utilize a wide range of feedstocks. As noted above, gasification has a long history with coal and petroleum coke. Gasification has also been commercially applied to biomass, such as rice hulls, wood waste, olive processing solids, and other agricultural wastes. They have the ability to tolerate very low quality feedstocks. Gasifiers are usually designed for a homogeneous feedstock, although they can utilize some variability. This can be an issue with gasifiers that use a slurry feed, since significant changes in the feedstock result in different slurry characteristics. This can lead to inefficient gasification, resulting in poor carbon conversion. When changes in the feedstock are anticipated, bench-scale or short-term testing can be used to optimize gasifier operation.

Due to the heterogeneous nature of MSW, significant pre-processing is often required. While some systems state that they can operate with little or no pre-processing, most include manual picking for large appliances, followed by primary and secondary rotary/stationary trommel screens, primary and secondary shredders, air classifiers, and magnetic and eddy-current separators to remove glass and metals and reduce the feedstock size. Sizing/shredding varies, with feedstocks ranging from 2 to 12 inches. Many systems incorporate an auger or ram feeder that compacts the processed MSW feed to as little as $1/10^{th}$ of the original volume. In order to increase efficiency, many systems incorporate drying to 10-20% moisture content, using steam or engine exhaust. Depending on the supplier, as much as 2/3 of the raw MSW may be removed prior to being fed into the gasifier.

#### 1.1.3.5 Byproducts

In low temperature gasification (below the melting point of most inorganic constituents), a powdery to clinker-type of bottom ash is formed. In high temperature gasification, the inorganic ash materials exit the bottom of the gasifier in a molten state, where the slag falls into a water bath, and is cooled and crystallized into a glassy, non-hazardous slag. The slag is crushed to form a grit that can be easily handled. Slag can be used in the manufacture of roofing tiles, sandblasting grit, and as asphalt filler. Bottom ash may require landfilling, although some suppliers have been able to manufacture ceramic-like bricks or paving stones. One system that utilizes oxygen injection creates extremely hot temperatures in the bottom of the gasifier, reaching the melting temperature of some metals. In that process, the metals can be recovered in “ingot” form.

#### 1.1.3.6 Environmental Issues

In gasification, like most pyrolysis systems, the process itself 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.

With regard to air emissions, the most important environmental issue for gasification, the discussion in Section 1.1.2.6 applies here as well.

Other environmental issues pertaining to gasification include:

- Solid residue management – As noted above, the inorganic constituents may be produced as bottom ash or slag, depending on the temperature in the reactor. Bottom ash will likely require disposal in a lined landfill. Slag, which is glassy and non-hazardous, is typically sold for the uses noted above. If markets are not available, it can be safely landfilled.
- Visual and Land Use – There may be impacts relating to the visual character of the facility or issues relating to compatibility of the facility with surrounding land uses.
- As with other facilities handling MSW, there will be concerns about odors, litter, noise, and dust.

### 1.1.4 Plasma Arc Gasification

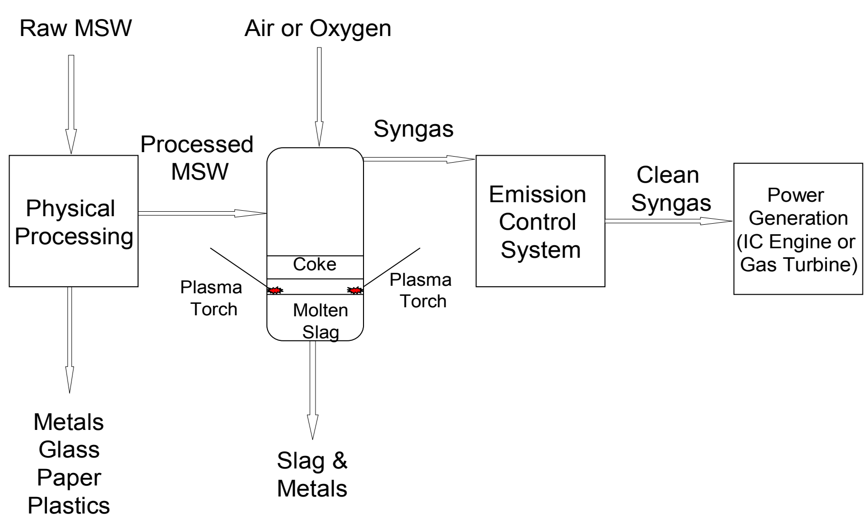
#### 1.1.4.1 Process Description

Plasma gasification has been used for years to treat waste products and incinerator ash, converting them to a non-hazardous, glassy slag. While application to MSW is in its infancy, it has great potential to convert MSW to electricity more efficiently than conventional pyrolysis and gasification systems, due to its high heat flux, high temperature, almost complete conversion of carbon-based materials to syngas, and conversion of inorganic materials to a glassy, non-hazardous slag.

Most of the recent development and use of plasma arc technology has been for melting incinerator ash or for destroying hazardous or medical wastes. Only very recently has R&D occurred on using plasma technology integrated with gasification technologies to process MSW.

Plasma is a hot ionized gas resulting from an electrical discharge. Plasma technology uses an electrical discharge (some use AC, some DC) to heat a gas, typically air, oxygen, nitrogen, hydrogen or argon, or combinations of these gases, to temperatures above 7,000°F. The heated gas, or plasma, can then be used for welding, cutting, or treating waste materials. Plasma gasification typically occurs in a closed, pressurized reactor. The feedstock enters the reactor, where it comes into contact with the hot plasma gas. In some designs, several torches arranged circumferentially in the lower portion of the reactor help to provide a more homogeneous heat flux pictured in Figure 1-5. When used for gasification, the amount of air or oxygen used in the torch is controlled to promote gasification reactions. The inorganic constituents are converted to molten form, then quench-cooled to form a glassy, non-hazardous slag.

**FIGURE 1-5**
**TYPICAL PLASMA GASIFICATION**
**SYSTEM FOR POWER GENERATION**




There are two types of plasma torches, the transferred torch and the non-transferred torch. The transferred torch creates an electric arc between the tip of the torch and a metal bath or the conductive lining of the reactor wall. In the non-transferred torch, the arc is produced within the torch itself. The plasma gas is fed into the torch, heated, and then exits through the tip of the torch.

There are several approaches to the design of the plasma gasification reactors. In one approach, developed by Westinghouse Plasma Corporation (plasma torch manufacturer) and Hitachi Metals (plasma gasification system developer and user), a medium pressure gas (usually air or oxygen) flows through a water-cooled, non-transferred torch, outside of the reactor. The hot plasma gas then flows into the reactor to gasify the MSW and melt the inorganic materials.

Another design is an in-situ torch, where the plasma torch is placed inside the reactor. This torch can either be a transferred or non-transferred torch. When using a transferred torch, the electrode extends into the gasification reactor and the arc is generated between the tip of the torch and the molten metal and slag in the reactor bottom or a conducting wall. The low-pressure gas is heated in the external arc. Alternatively, a non-transferred torch can be used in which the plasma gas is created within the torch and is injected into the reactor.

Several suppliers utilize a completely different approach. In their designs, the reactor is heated by electric induction coils or a graphite arc, forming a molten metal and slag bath. The MSW enters the reactor, where it is subjected to high temperatures, resulting in partial gasification of the feedstock. From there, the syngas exits the reactor. The plasma torch is situated either in a secondary reactor or in a recycle line, which goes back to the first reactor, assuring complete gasification of the feedstock.

Proponents of the in-situ torch claim its advantages include better heat transfer to the MSW and a hotter reactor temperature, resulting in more complete conversion to syngas. The main disadvantage is the potential corrosive effect of the hot MSW and gases on the torch in the reactor. Proponents of the external torch point out that this approach protects the torch from the corrosive effects of the MSW and hot gas, and prolongs the mechanical integrity of the torches. Electrodes in all designs experience some wear and must be replaced. The disadvantage of the external torch is the possibility of a somewhat lower reactor temperature resulting in less MSW being gasified.

The first two approaches have been applied to small-scale commercial waste and medical waste processing units. The throughput of the largest external system is approximately 4 tons per hour and the throughput of the largest internal system is approximately 10 tons per day. The Westinghouse/Hitachi design has been scaled up to 83 tons per day per reactor at Utashinai, Japan, which treats a combination of MSW and auto shredder residue.

In the reactor, coke is often added to assure a reducing atmosphere in a portion of the reaction zone, initiating the pyrolysis reactions. Lime may also be added to the bed as a flux to lower the melting point of the inorganic components, and to stabilize the slag. Air, oxygen, or steam may be added through ports to provide the water and oxygen necessary to initiate the gasification reactions. Some designs include mechanical stirrers to keep the bed material agitated and promote efficient carbon conversion to syngas.

The syngas can either be burned immediately in a close-coupled combustion chamber or boiler, or cleaned of contaminants and used in a reciprocating engine or gas turbine. In the first approach, the exhaust gases are cleaned after combustion, in an emission control system similar to what is used in WTE plants. The hot gases flow through the boiler, crating steam used for power generation in a conventional steam turbine. In the second approach, the syngas is cleaned before it enters the engine or gas turbine.

As noted above, the primary solid output from plasma facilities is a glassy slag, the result of melting the inorganic fraction of the waste. Any waste disposal facility generating an ash or slag is required by the USEPA to subject it to a Toxicity Characteristic Leaching Procedure ("TCLP") test. The TCLP test is designed to measure the amount of eight elements that leach from the material being tested. Data from existing facilities, even those processing highly hazardous materials or medical waste, show results that are well below regulatory limits.

While there are only a few plasma torch manufacturers, there are over a dozen companies that are taking the plasma technology and are developing it for use in MSW gasification. This has led to several suppliers claiming the same experience, i.e., several suppliers that use Westinghouse plasma torches all claim the experience in the Hitachi Metals plants as being their own.

#### 1.1.4.2 Throughput

Existing systems operate at throughputs of up to 83 tons/day on MSW/auto shredder residue combination, using two operating and one spare torch per reactor. Plasma torches can be added to the reactors, along with multiple reactors added to increase total capacity.

#### 1.1.4.3 Feedstock

Feedstock preparation is similar to what is described above under conventional gasification.

#### 1.1.4.4 Byproducts

Byproducts of plasma gasification are similar to those produced in high-temperature gasification, as noted above. Due to the very high temperatures produced in plasma gasification, carbon conversion nears 100%.

#### 1.1.4.5 Environmental Issues

With regard to air emissions and other environmental issues for plasma gasification, the discussion in Section 1.1.2.6 applies here as well.

### 1.1.5 Thermal Depolymerization (TDP)

In this process, organics are subjected to five steps of high pressure-high temperature treatment:

1) Pulping and slurrying the organic feed with water
2) Heating the slurry under pressure to the desired temperature
3) Flashing the slurry to a lower pressure to release the gaseous products
4) Reheating the slurry to drive off water and light oils from the solid
5) Separating the light oil from the water

Before the fourth step, flashed liquids are separated by density in a liquid separator similar to that used in the petroleum industry. The high-value oil that is removed and is further processed in a post-processing loop such as distillation or solvent extraction. The quality and marketability of the products will derive the development of the separation process. With this process, the large molecules in the feed (usually waste product of various sorts, often known as biomass) are broken down into smaller ones (cracking), and the waste stream is converted into various products including a liquid fuel. The process has been proven at pilot scale and a full-scale (250 tons/day) facility has been built in Carthage, MO. This facility is in operation since September 2004 processing turkey waste and agricultural waste. We will not be able to provide a more detailed description of this technology because this process is quite unique and offered only by one vendor and the specifics related to process are deemed to be confidential.

## 1.2 BIOLOGICAL AND CHEMICAL CONVERSION TECHNOLOGIES

### 1.2.1 Introduction

Biological and chemical conversion technologies are focused on the conversion of organics in MRF residues. The MRF residue consists of dry matter and moisture. The dry matter further consists of organics (i.e., whose molecules are carbon-based), and minerals (also referred to as the ash fraction). The organics can be further subdivided into biodegradable organics (for example food waste) and non-biodegradables (for example plastics).

Biological technologies can only convert biodegradables, while chemical processes can potentially convert any organics. Preliminary analyses indicate that the Southern California

MRFs residues are dominated by paper and other biodegradable organics. So, there is much potential for biological and chemical technologies to reduce the amount of MRF residue going to the landfill.

Biological and chemical conversion technologies are treated together in this section because they are often intimately intertwined. Note that thermal and physical processes can be involved in biological and chemical process trains as well.

We will also touch on some other processes, but in less detail because each of these processes is quite unique and offered by very few vendors. These additional processes include syngas to ethanol, catalytic cracking of plastics, and aerobic digestion.

### 1.2.2 Anaerobic Digestion

Anaerobic digestion (AD) can be considered both a biological conversion technology and a composting technology because the digestate is a compostable residue. As a composting technology processing a source-separated municipal solid waste, the AD facility would qualify for diversion credit. Anaerobic digestion and ethanol production are included in this study because technically they convert MSW to a useful fuel. Also, there are a number of vendors offering these technologies, and many commercial scale anaerobic digestion facilities are in operation outside the U.S.

#### 1.2.2.1 Process Description

In anaerobic digestion, biodegradable material is converted by a series of bacteria groups into methane and $CO_2$. A first group breaks down large organic molecules into small units like sugar; this step is referred to as hydrolysis. Another group of bacteria converts the resulting smaller molecules into volatile fatty acids, mainly acetate, but also hydrogen ($H_2$) and $CO_2$; this process is called acidification. The last group of bacteria, the methane producers or methanogens, produce biogas (methane and $CO_2$) from the acetate and hydrogen and $CO_2$. This biogas is a medium-Btu gas containing 50 to 70% methane. It can be used in boilers, and different types of generators with minimal pretreatment; it can also be upgraded to pipeline quality and used as a vehicular fuel.

Anaerobic digestion has been used for over a century to process sewage biosolids. If the MSW feed is processed in the solid phase, AD is often referred to as *anaerobic composting*. To distinguish AD from thermal gasification, as described earlier, it is also referred to as *biogasification*. In addition to biogas, AD generates a residue consisting of inorganics, non-degradable organics, non-degraded biodegradables, and bacterial biomass. If this material is sufficiently free of objectionable materials like colorful plastics, it can have market value as compost. Otherwise, it may be used as landfill cover.

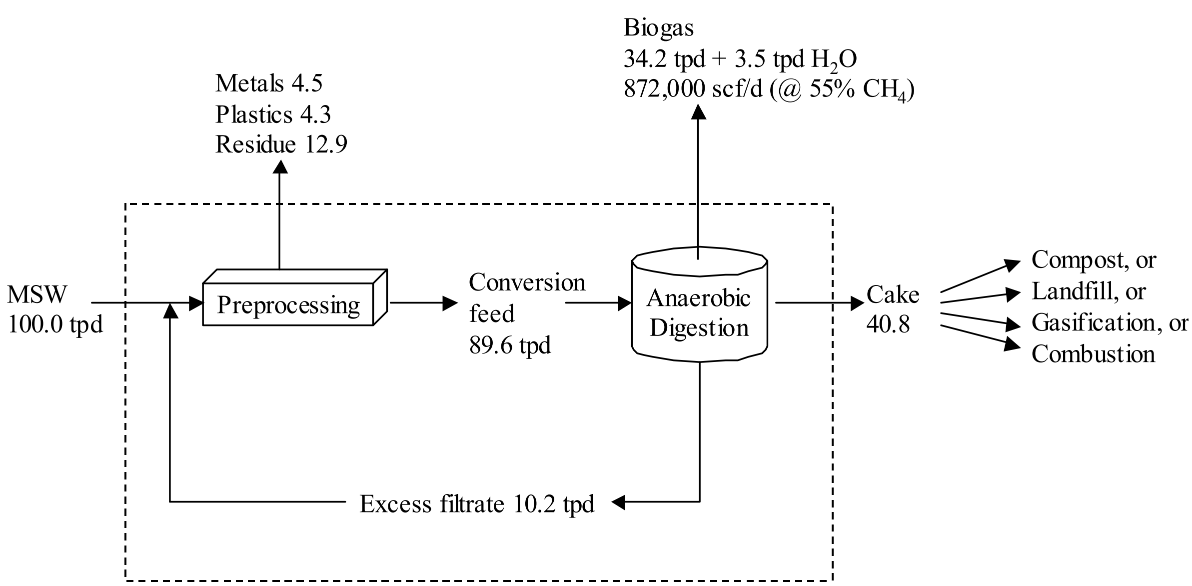
The contents of an anaerobic digester can be at different solids concentrations, ranging from a liquid slurry to a solid material. The material leaving the reactor can be dewatered in a press and the recovered filtrate liquid recirculated. In this manner, the moisture content of the feed material and that of the reactor contents are decoupled: a fairly dry feed can be digested as a liquid slurry without any significant net addition of water to the system. The dewatered material emerging from the press is referred to as filter cake or cake.

Some AD processes rely on a two-stage approach, in which the hydrolysis and acidification reactions are conducted in a first reactor and the methane fermentation itself in a second reactor. Most digesters are of the *continuous feed completely mixed* type (as opposed to batch or plug flow reactors). Mixing techniques include: large impellers; recirculation of effluent (e.g., Dranco process); or injection of pressurized biogas (e.g., Valorga process). The latter two approaches have the advantage that no moving parts are present inside the reactor.

The biogas produced can be used on site to generate electricity and heat using a generator (reciprocating engine, microturbine, conventional turbine, etc.). If a nearby industrial user exists, the biogas can be conveyed over short distances for such uses as boiler fuel. The biogas can also be purified extensively (dehydrating, $H_2S$ removal, $CO_2$ removal) to pipeline quality and pressurized, for example to be used as compressed natural gas (CNG), a safe and clean vehicular fuel. Biogas can also be converted into methanol and/or used in fuel cells.

Figure 1-6 illustrates the mass balance and process diagram for an anaerobic digestion facility with MSW-derived feedstock.

**FIGURE 1-6**
**SIMPLIFIED TYPICAL MSW ANAEROBIC DIGESTION PROCESS SCHEMATIC (after Legrand et al. 1989)**



#### 1.2.2.2 Throughput

AD facilities processing agricultural and solid industrial waste range up to 1300 tons per day (tpd) in capacity, while facilities processing MSW or MSW-derived streams range up to 800 tpd.

#### 1.2.2.3 Feedstock Characteristics

Microorganisms convert biodegradable matter. They do not convert minerals or non-biodegradables like plastic. From the standpoint of the microorganisms that perform the conversion, it does not matter if those non-degradable materials are present in the fermenting mix. It does matter from a materials handling perspective, as some extraneous materials like metal debris, plastic stringers, etc. can wreak havoc on the fermentation equipment. Additionally, if the resulting compost has to be marketable, it is important that as much as possible of these extraneous materials be removed before entering the process. So, the ideal feedstock is nearly pure biodegradable material, with as few inorganics or plastics as possible.

#### 1.2.2.4 Byproducts

The main byproduct is an effluent or filter cake consisting of undegraded organics and microbial biomass. If the material entering the AD process is sufficiently devoid of objectionable items like colorful plastics, the effluent can be formulated into a compost. The compost preparation may include a aeration and curing step, it also generally includes an additional screening step to remove undesirable elements in the filter cake. This compost is equally beneficial as a soil amendment as the compost produced in conventional aerobic facilities (windrow, static pile, etc.). Compared to these processes, AD has the advantage of requiring only a small footprint, and of being completely enclosed, which minimizes odor nuisances.

If the dewatered effluent is unmarketable as compost, it can still be burned or gasified in an appropriate facility; it can also be used as landfill daily cover, since it will not appreciably generate landfill gas or attract nuisance animals.

#### 1.2.2.5 Environmental Issues

As with other MSW processing facilities, AD will have environmental issues, such as noise, dust, odor and litter nuisances at the receiving end of the plant. It may also produce some wastewater, which would need treatment and disposal. Proper process design and moisture management can minimize this stream to negligible levels or eliminate it altogether.

There are no air emissions or odor nuisances from the AD process proper, since it is fully enclosed. Combustion and flaring of the biogas has the same impacts as any natural gas combustion process and must be controlled with appropriate emission controls.

Depending upon the size of the facility, traffic and visual impacts may be an issue as well.

### 1.2.3 Hydrolysis – Ethanol Production

#### 1.2.3.1 Process Description

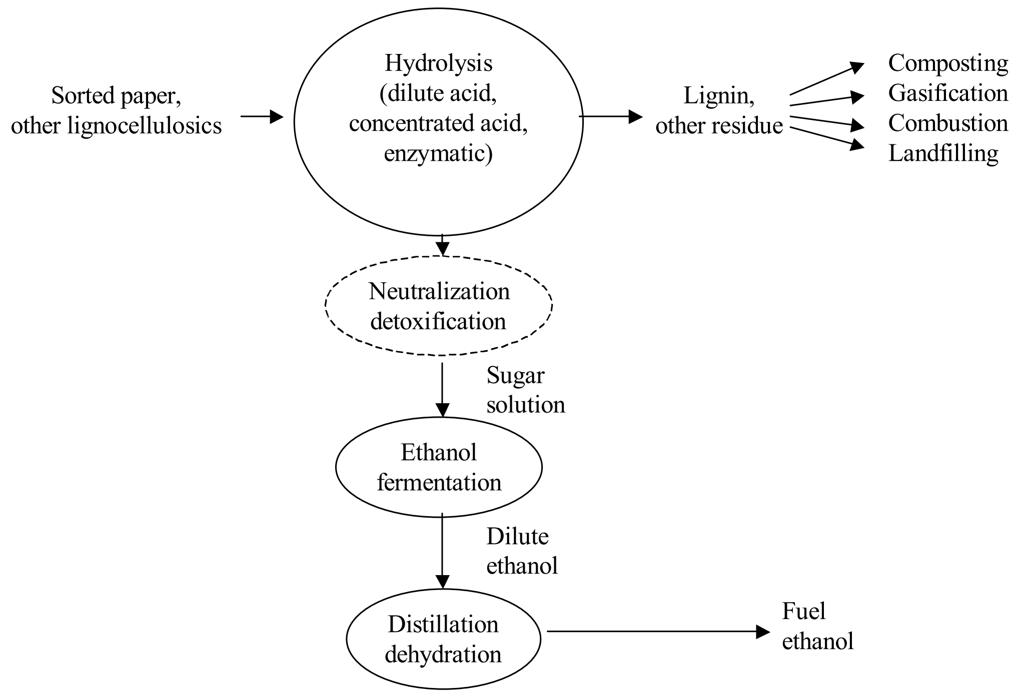
Sugar and starch can be fermented to ethanol. This process lies at the basis of the production of alcoholic beverages, but also of corn ethanol production. The latter process is used on a large scale in the US to produce fuel ethanol. Cellulose, the main constituent of most plants, is actually a polymer of glucose molecules. If the cellulose can be broken down into glucose, it can also be fermented to ethanol. However, the bonds between glucose molecules in cellulose are difficult to break; the process of breaking those bonds is known as hydrolysis. Additionally, cellulose can be encased in hard-to-degrade lignin, as in wood, making it less accessible for hydrolysis. Considerable effort has been devoted to cost-effectively hydrolyzing fibrous vegetable matter, referred to as “lignocellulosics.”

Various hydrolysis processes have been developed (concentrated acid, dilute acid, enzymatic) and demonstrated at pilot scale, some of them at demonstration scale. They could be applied to paper and vegetable matter, including wood, in the MSW stream. A simplified process diagram is provided in Figure 1-7. A purified lignocellulosic material is chopped up and introduced into a hydrolysis reactor. The effluent of this reactor is mostly a sugar solution. It is prepared for fermentation, for example by neutralizing the pH if strong acid hydrolysis was used. This detoxified solution is introduced into the fermenter where microorganisms convert the sugar to ethanol and $CO_2$. The ethanol concentration in the fermenter must remain below 5% otherwise the microorganisms would be inhibited. This dilute fermenting liquid is referred to as a “beer.” It is next introduced into a combined distillation and dehydration process to bring the ethanol concentration up to fuel grade (99% ethanol). The distillation process is particularly energy intensive. A solid residue of unfermented solids and microbial biomass is recovered (distiller’s grain) and can be used as animal feed.

#### 1.2.3.2 Throughput

Currently, corn ethanol facilities process thousands of tons of corn per day. However, there is at present no full-scale facility producing ethanol from lignocellulosics, although one such facility is in the startup phase in Canada. It processes exclusively agricultural crop residues.

**FIGURE 1-7**
**SIMPLIFIED ETHANOL PRODUCTION PROCESS SCHEMATIC**




### 1.2.3.3 Feedstock Characteristics

The ideal feedstock for ethanol production from MSW would be a stream containing only paper, wood, yard waste, and other purely vegetal biomass. Impurities like inert materials are a concern for two reasons. First, they could complicate materials handling by jamming pumps, clogging pipes, wrapping around mixers, etc. The second concern is that they could essentially render the solid residue worthless due to contamination.

### 1.2.3.4 Byproducts

Corn ethanol production yields $CO_2$ and a variety of other products such as distiller's grains, gluten, etc. If MSW is the source of the ethanol, the byproducts will not be acceptable for incorporation into human foodstuffs, including using $CO_2$ for beverage carbonation. Their marketability as animal feed is low. The marketability of the solid residue as compost depends on the purity of the feed stream and the resulting appearance of the compost. Of course, the solid residue could be burned or gasified. The $CO_2$ stream produced is relatively pure, and could have non-food industrial applications.

#### 1.2.3.5 Environmental Issues

An ethanol plant is a chemical processing plant. By chemical processing standards, it is fairly benign from an environmental perspective. However, there will be air emissions, for example in the production of heat for the distillation step. Ethanol production can emit significant quantities of VOCs, $NO_x$, $SO_2$, CO, and particulate matter (PM, $PM_{10}$). The primary sources of these emissions are the dryers, carbon furnaces, fermentation units, boilers, and ethanol load-out systems. There will be some handling of hazardous chemicals in the hydrolysis process. The potential nuisances associated with the delivery of MSW streams (litter, odor, vermin, etc,) will have to be minimized via proper design and operation, as for all MSW processing facilities.

### 1.2.4 Other Processes

#### 1.2.4.1 Syngas-ethanol

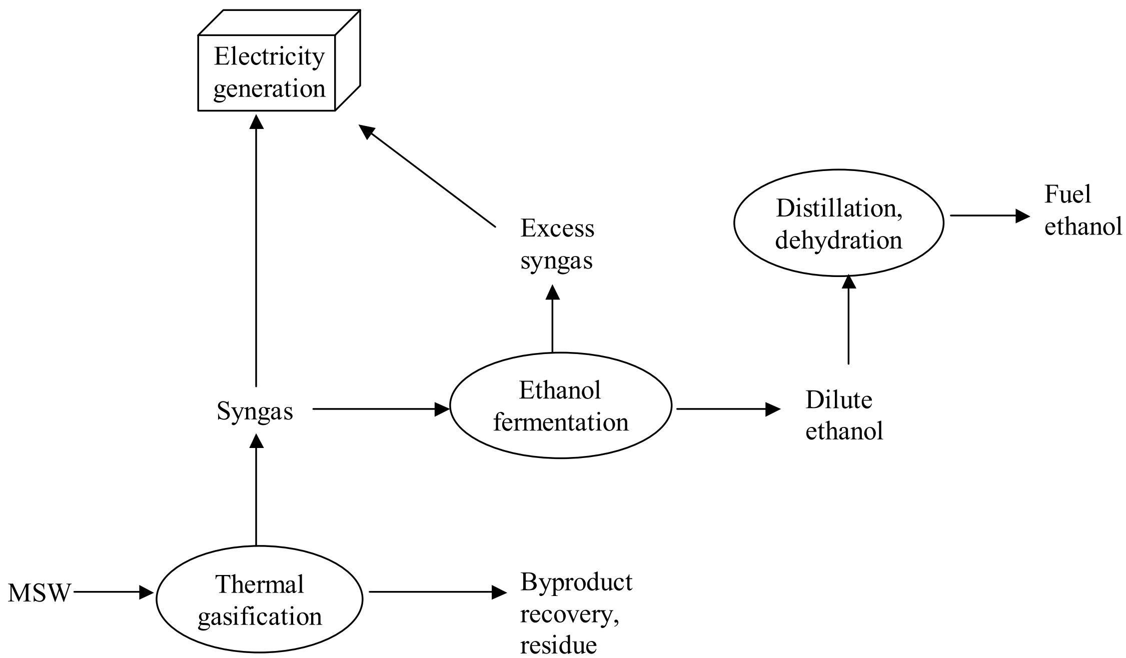
The syngas-ethanol process is illustrated in Figure 1-8. The organics in MSW are converted to syngas via thermal gasification (See Section 1.3, Gasification). The hot syngas is cooled, in the process generating steam, and it is introduced into a fermenter containing a specialized microbial population that converts the syngas into ethanol and $CO_2$. The resulting dilute ethanol is distilled and dehydrated to fuel grade ethanol, as described in the previous section. Unconverted syngas from the fermenter is used to generate electricity via a steam turbine. If desired, some of the syngas can bypass the fermenter and go directly to generation.

The main advantage of this process is that it makes all of the organics in MSW accessible to ethanol production, including plastics and hard-to-degrade woody materials. Therefore, the ethanol yield per ton of MSW feed should be significantly greater than it would be using the chemical or biochemical hydrolysis route to ethanol.

There would be little need for MSW sorting into hydrolyzable feed. Finally, this technology would minimize the landfilled residue to the same extent as gasification. Note also that there would be some flexibility in the quantity of electricity generated versus ethanol produced, so the facility could adapt to changing market conditions.

There is one vendor of syngas-ethanol technology; it has been developed to the pilot stage as of this writing.

**FIGURE 1-8**
**SIMPLIFIED SYNGAS-ETHANOL PROCESS SCHEMATIC**




#### 1.2.4.2 Catalytic Cracking of Plastics

In this process, plastics are cracked into smaller molecules, and eventually converted to a diesel fuel. This is a purely chemical process. A facility using this process has been operating in Poland at commercial scale (260 tpd) for a number of years. There is one vendor in the U.S. This process can complement conventional plastics recycling, especially for low quality commingled plastics streams that often end up in the landfill. It would only make sense if applied to a plastics stream separated from the solid waste or separately collected.

#### 1.2.4.3 Aerobic Digestion

This process applies mainly to food waste, agricultural waste, and sewage biosolids. The waste material is homogenized into a slurry, which is mixed with air in a bioreactor. Aerobic microorganisms in this reactor oxidize the easily biodegradable material, just like in an aerobic compost pile, producing substantial heat. The heat and retention time are enough to pasteurize the material, which is processed into several liquid and solid fertilizers. If MRF residues are the process feed, the marketability of the aerobic digestion products may be very low, considering the commingled nature of the MRF waste. Note that this process differs from anaerobic digestion in that no fuel is produced.

# SECTION 2.0 EVALUATION, SCREENING, AND RANKING OF TECHNOLOGIES

## 2.1 INTRODUCTION

The main objective of this portion of the project was to evaluate conversion technologies that are capable of processing MRF/TS residue. This residue is being landfilled at the present time. The following steps were followed in order to evaluate conversion technologies and identify the most suitable technologies:

- Prepare a list of available conversion technologies
- Prepare a list of conversion technology suppliers
- Prepare a questionnaire and distribute it to conversion technology suppliers
- Summarize and evaluate responses from the technology suppliers
- Develop screening criteria to screen conversion technology suppliers
- Establish ranking criteria
- Rank technology suppliers
- Use this ranking process to identify the most suitable conversion technologies

The following sections explain each of the above steps.

## 2.2 LIST OF CONVERSION TECHNOLOGIES AND SUPPLIERS

### 2.2.1 List of Conversion Technologies

The Los Angeles County Alternative Technology Subcommittee goal is to develop a conversion demonstration facility to process MRF/TS residue in Southern California. The evaluation of conversion technologies began by creating a list of potential technologies. This list includes both thermal and bio-chemical conversion technologies.

Thermal conversion technologies include:

- Pyrolysis
- Pyrolysis/gasification
- Pyrolysis/steam reforming
- Conventional gasification (fixed bed and fluid bed)
- Plasma gasification
- Thermal depolymerization

Biological/Chemical conversion technologies include:

- Anaerobic Digestion
- Hydrolysis-Ethanol production
- Syngas Ethanol
- Catalytic cracking of plastics
- Aerobic Digestion

Descriptions of the conversion technologies are provided in Section 1.0 of this report.

### 2.2.2 List of Conversion Technology Suppliers

The conversion technology evaluation was conducted in part by issuing a questionnaire to technology suppliers. The list of conversion technology suppliers was prepared using lists from the the following existing sources:

- California Integrated Waste Management Board
- Santa Barbara County, CA
- Riverside County, CA
- City of Alameda, CA
- City of Honolulu, HI
- Collier County, FL
- City of Toronto, Canada
- City of York, Canada
- Juniper Consultants
- URS database (from recent conversion technology studies and evaluations)
- Southern California Association of Governments
- Other technologies/vendors known to Subcommittee members

The complete conversion technology suppliers list is shown in Table A-1 in Appendix A.

## 2.3 QUESTIONNAIRE FOR TECHNOLOGY SUPPLIERS

### 2.3.1 Supplier Requirements

A list of questions for conversion technology suppliers was prepared. The answers to these questions provided preliminary information to select suitable technologies. Some basic requirements were established for the technology suppliers to qualify them to receive the questionnaire. The following requirements were established for evaluating suppliers and their technologies. The supplier and their technology had to comply with all of these requirements to be considered further in this process.

1. **Waste Diversion Rate.** The supplier's technology must be able to reduce the amount of MRF/TS residuals going to the landfill by at least 50%.
2. **Demonstrated Processing Experience.** The supplier must have developed at least a demonstration scale facility, designed to process MSW or similar feedstock at a rate of approximately 5 short tons/day (1 short = 2,000 lbs), and that has operated for at least one year. Note: sewage sludge, black liquor solids, chemicals, plastics, or tires are not considered a "similar feedstock".
3. **Conversion to Useful Products and By-products.** The supplier's technology must demonstrate the capability to produce marketable products and by-products.
4. **Environmental Compliance.** The supplier's technology must comply with all regulatory requirements in the State of California.
5. **Responsiveness.** The supplier must reply to URS' requests for data within a timely manner (i.e., within the timeframe noted in the questionnaire).
6. **Ability to Partner with a MRF/TS.** The supplier must be willing and able to create a partnership with a MRF/TS in Southern California.
7. **Facility Size.** The supplier must exhibit the capability to develop a demonstration facility that will process approximately 100 short tons/day of MRF residuals.

### 2.3.2 Preparation of Questionnaire

The purpose of the questionnaire was to obtain information about the technology and to address specific technical and financial issues regarding the technologies. A copy of the questionnaire is included as Table A-2 in Appendix A.

### 2.3.3 Distribution of Questionnaire

The questionnaire was distributed to the technology suppliers on January 13, 2005. The Alternative Technology Advisory Subcommittee at its January 21, 2005 meeting decided to amend the questionnaire in order to encourage more technology suppliers to respond. The amendment to the questionnaire was sent to the technology suppliers on January 26, 2005. A copy of the amendment to the questionnaire is also provided as Table A-3 in Appendix A. Follow-up telephone calls were made to each of the technology suppliers to ensure that they received the questionnaire and the three amendments, which included:

- Item No. 2-Los Angeles County prefers a technology supplier that developed at least a pilot scale facility designed to process MSW or similar feedstock at a rate of 5 short tons/day, and operated for 1 year
- Item No. 4-the supplier must demonstrate a technology capable of meeting all regulatory requirements (e.g., air emissions)
- Schedule-responses must be received by 5:00 PM on February 28, 2005

### 2.3.4 Summary of Conversion Technology Suppliers Responses

Twenty-eight responses to the questionnaire were received. A list of the technology suppliers that responded to the questionnaire is shown in Table 2-1. The responses from the technology suppliers were reviewed, and a summary of the thermal technologies provided by technology suppliers is included in Table 2-2. A brief description of the biological/chemical technologies is included in Table 2-3. More detailed information regarding the technology suppliers for thermal conversion and biological/chemical conversion technologies is provided in Tables A-4, and A-5, in Appendix A.

Evaluating the conversion technologies and suppliers of the various technologies is a complex task, with multiple dimensions. There are significant differences in the technology groups being considered (i.e., thermal conversion and bioconversion), and the specific technologies offered by suppliers within the technology groups vary widely. Even suppliers of similar technologies, i.e., gasification, have very different designs for their gasifiers, such as fixed bed or fluid bed reactors, as well as differences in how they address pre-processing, cleaning of syngas, and power generation.

Data provided by the suppliers at this stage of the study is preliminary and subject to change. A formal RFQ and/or RFP process, utilizing a detailed engineering specification, would provide more certain and detailed technical, design, and costs information, including more accurate revenues from byproduct sales. A number of technical and economic assumptions were made to “normalize” the data submitted by the suppliers and to facilitate analysis. The preliminary nature of the data provided focused the evaluation on the data outliers, in order to identify fatal flaws or major technical or economic issues.

## TABLE 2-1
## CONVERSION TECHNOLOGY SUPPLIERS WHO RESPONDED TO THE QUESTIONNAIRE

| Technology | Sub-Technology | Supplier Name | Process | Primary Feedstock Experience | Response Date |
|---|---|---|---|---|---|
| Gasification | Fixed bed | Omnifuel Technologies, Inc. | RDF Gasification | Organic wastes, tires, sewage sludge, biomass | 03/01/05 |
| Gasification | Fixed Bed | Primenergy, LLC | PRM Energy gasification | Biomass, RDF, rice hulls, olive waste | 02/24/05 |
| Gasification | Fixed Bed | Whitten Group International | Entech Renewable Energy System | MSW, medical, animal food wastes, dried sewage, hazardous wastes | 03/01/05 |
| Gasification | Fluid bed | Ebara Corporation/ Environmental Plants Division | Ebara Twin Rec TIFG (**T**win **I**nternally Circulating **F**luidized Bed **G**asification) and Ash Melting | MSW, RDF, ASR, sewage sludge, plastics | 02/21/05 |
| Other Thermal | Microwave | Molecular Waste Technologies, Inc. | | | 02/28/05 |
| Plasma Gasification | | Geoplasma LLC (part of Jacoby Development, Inc.) | Plasma Direct Melting Reactor. Westinghouse Plasma torches. | MSW | 03/01/05 |
| Plasma Gasification | | Plasma Environmental Technologies, Inc. | Plasma Assisted Gasifier | MSW | 2/28/2005 |
| Gasification | Fluid bed | Taylor Recycling Facility, LLC | FERCO SilvaGas | MSW, wood waste, agricultural waste and energy crops | 02/28/05 |
| Pyrolysis | | Conrad Industries | 121 Melhart Road Chehalis, WA, 98532 | Plastics | 03/01/05 |
| Pyrolysis | | Graveson Energy Management | GEM High-Speed Conversion Technology | MSW | 02/28/05 |
| Pyrolysis | | Pan American Resources, Inc. | Lantz Converter | MSW | 02/28/05 |
| Pyrolysis | | International Environmental Solution | Thermal Convertor | Mixed Waste | 02/28/05 |
| Pyrolysis/Gasification | Fixed bed | Interstate Waste Technologies | Thermoselect | MSW | 02/28/05 |

**TABLE 2-1 (CONTINUED)**
**CONVERSION TECHNOLOGY SUPPLIERS WHO RESPONDED**

| Technology | Sub-Technology | Supplier Name | Process | Primary Feedstock Experience | Response Date |
|---|---|---|---|---|---|
| Thermal Depolymerization | | Changing World Technologies | Heating under pressure, flash vaporization | Offall | 02/28/05 |
| Aerobic Composting | | American Bio-Tech | Air Lance (in-vessel) | | 02/25/05 |
| Aerobic Composting | | HotRot Exports Ltd, or Outspoken Industries | HotRot | | 02/28/05 |
| Aerobic Composting | | Wright Environmental Management Inc. | In-Vessel | | 02/24/05 |
| Aerobic Digestion | | International Bio Recovery Corporation (IBR) | IBR | | 02/28/05 |
| Anaerobic Digestion | | Arrow Ecology Ltd | ArrowBio | MSW | 02/28/05 |
| Anaerobic Digestion | | Canada Composting Inc. (CCI) | BTA | | 02/25/05 |
| Anaerobic Digestion | | Global Renewables | UR-3R, ISKA | MSW | 02/28/05 |
| Anaerobic Digestion | | Organic Waste Systems nv | DRANCO | | 03/01/05 |
| Anaerobic Digestion | | Waste Recovery Systems, Inc. | Valorga | | 02/28/05 |
| Syngas-Ethanol | BRI Energy, Inc. | Syngas - ethanol | BRI | | 02/28/05 |
| Plasma Gasification | | Rigel Resource Recovery and Conversion Company | | | 02/28/05 |
| Pyrolysis/Gasification | Fixed bed | Global Energy Solutions, Inc. | Thermal Converter | MSW | 3/3/2005 |
| Pyrolysis/Gasification | | WasteGen (UK) | Pyrolysis/Gasification | MSW | 2/28/05 |
| Gasification | | Green Energy Corp | Carbonaceous Waste to Electricity, Liquid Fuels, Synthetic Natural Gas and Liquid Natural Gas | Carbonaceous Waste | 4/10/2005 |

## TABLE 2-2
## SUMMARY OF INFORMATION PROVIDED BY THERMAL CONVERSION TECHNOLOGY SUPPLIERS

| Supplier Name | Technology | Brief Description |
|---|---|---|
| Conrad Industries | Pyrolysis | Feed enters the pyrolysis unit, which includes the retort, process auger, outlet end bell, and furnace chamber. The retort is a horizontal cylindrical vessel and serves as a combined reactor, heat exchanger, and mixing device. The retort extends into the furnace. The auger mixes the feedstock and moves it through the reaction vessel. Surrounding the retort is the furnace chamber. Four propane burners provide pre-heat needed for start-up, then syngas is utilized. Hot pyrolyzed vapors that exit the retort are first condensed in the high temperature condensing unit. Pyrolysis occurs at ~1,400°F. |
| Ebara Corporation | Pyrolysis/ Gasification | A Circulating Fluidized-bed Gasifier (ICFG), using pyrolysis is coupled with char combustion.<br>The conversion unit combines pyrolysis reactor and char oxidation chambers. Fluidizing sand provides heat source, with steam addition for fluidization and production of syngas at 1,560°F. Sand moves to char oxidation chamber, where air is added and combustion occurs.<br>Energy production occurs when the syngas is cleaned and combusted in reciprocating engines. |
| Global Energy Solution, LC | Pyrolysis/ Gasification | A Pyrothermic Thermal Converter incorporates pyrolysis, along with medium and high-temperature gasification to convert MSW to syngas. The converter includes a pre-heat zone, degasification zone, pyrothermic zone, pre-molten zone, and molten layer. |
| Molecular Waste Technologies, Inc. | Microwave Technology | The technology uses magnetrons to induce microwaves into the feedstock, resulting in "molecular reduction of organics", breaking it down into oil and carbon char. |
| Omnifuel Technologies, Inc. | Gasification | An RDF is fed into the gasifier. Inside the gasifier, a bubbling bed of olivine sand is used to provide mixing and contact of the RDF with the gasifying air. The RDF is converted to syngas at 1,500°F, with some ash and tar remaining. The stream exits the top of the gasifier into a primary cyclone, where most of the particulate matter is removed and recycle to the gasifier. The syngas stream enters an air preheater, where heat from the syngas is used to preheat the fluidizing air. The cooled syngas stream enters a secondary cyclone for removal of remaining ash, then to a carbon adsorption bed for mercury removal and a wet scrubber for removal of ammonia. The clean syngas then is piped to a boiler for combustion, producing steam for power generation. |
| Pan American Resources | Pyrolysis | PAR's technology is the Lantz Converter using "Destructive Distillation", which is essentially a pyrolysis process. Metals are removed by electromagnets and eddy current separators, followed by a shredder. The shredded material is then dried to 5% moisture, using the off-gases produced from combustion of the syngas used to provide the indirect heat for pyrolysis. The prepared MSW is subjected to pyrolysis at 1,200°F, forming syngas and a carbon char. The syngas is cleaned of particulate matter, acid gases, and mercury, and is then combusted in a boiler to make steam for power generation. The indirect heat for pyrolysis is supplied by a portion of the syngas. |

**TABLE 2-2 (CONTINUED)
SUMMARY OF INFORMATION PROVIDED BY
THERMAL CONVERSION TECHNOLOGY SUPPLIERS**

| Supplier Name | Technology | Brief Description |
|---|---|---|
| Plasma Environmental Technologies | Plasma Gasification | No information addressing the questionnaire was provided. PET only provided a 2-page letter discussing a test program they are working on, and a 4 ton/day demo plant they are building. |
| Rigel Resource Recovery and Conversion Company | Autoclave/ Plasma Gasification | Rigel proposes to integrate autoclaving, MRF, plasma gasification, and power generation technologies. The MRF would utilize a Tempico Rotoclave, an autoclave that uses steam to physically reduce the volume of the MSW, and sterilize it. The output of the Rotoclave is then sent to a MRF for removal of metals and plastics. (Not known why Rigel has decided to put a MRF to treat MRF residuals). The MRF output, along with unsorted MSW, is sent to the plasma gasification system, supplied by Recovered Energy Inc., and using Westinghouse Plasma Corporation's plasma gasification technology. The syngas would be combusted in a gas turbine. |
| Taylor Biomass Energy LLC | Pyrolysis | Taylor proposes to use the FERC SilvaGas process, a unique fluid-bed pyrolysis technology that incorporates combustion of the syngas and the char remaining from pyrolysis. |
| WasteGen (UK) Ltd. | Pyrolysis/ Gasification | The shredded, dried MSW is fed to the 2 pyrolysis kilns, where it is thermally decomposed to syngas at 935ºF, leaving behind the inorganic components as ash, in a mixture with the unconverted carbon char. The char/ash mixture enters the carbon recovery unit, a rotary gasification kiln, where the carbon char is gasified, producing more syngas |
| Interstate Waste Technologies | Pyrolysis/ Gasification | Thermoselect high temperature gasification. This technology incorporates an initial degassing (pyrolysis) chamber, decomposing the MSW into volatile syngas and a carbon char mixed with inorganic components of the MSW. The carbon char enters the gasification chamber, where oxygen is added to complete the gasification of the carbon into more syngas. The syngas is then quench-cooled and cleaned; it can then be combusted in a boiler, reciprocating engine, or gas turbine for power generation. |
| Primenergy LLC | Gasification | Primenergy uses gasification technology developed by PRM Energy Systems, Inc. The fixed-bed gasifier operates at about 1,500°F, converting the MSW to syngas. The syngas enters a hot gas cyclone, where fly ash is removed. Bottom ash is removed from the bottom of the gasifier. The syngas is then combusted in a large combustion tube, and the hot gases flow through a waste heat boiler for steam production. The steam is piped to a steam turbine generator for production of electricity. |
| Ntech Environmental | Gasification | Ntech uses the ENTECH Renewable Energy System. The process utilizes low temperature, fixed-bed gasification with very low amounts of air, nearing pyrolysis, to convert MSW to syngas. The system has the following stages 1) a stepped-hearth designed pyrolytic gasification stage for conversion of MSW to syngas at 1,100°F, 2) a thermal reactor stage for immediate combustion of syngas at 2,200°F, 3) an energy utilization stage, including a heat recovery boiler for steam production and power generation. |

## TABLE 2-2 (CONTINUED)
## SUMMARY OF INFORMATION PROVIDED BY THERMAL CONVERSION TECHNOLOGY SUPPLIERS

| Supplier Name | Technology | Brief Description |
|---|---|---|
| Geoplasma LLC | Plasma Gasification | Geoplasma uses Hitachi Metals' Plasma Direct Melting Reactor using Westinghouse plasma torches. Plasma torches (consuming about 20 kWh/ton MSW) heat air to 4,500°F. This gasifies organic portion of MSW and melts inorganics to form slag layer above molten metal layer. Hot flue gas flows through boiler to make steam; steam flows to steam turbine generator to produce electricity. |
| Changing World Technologies | Thermal Depolymerization | The Thermal Conversion Process consists of five main steps. 1) pulping and slurrying the organic feed with water; 2) heating the slurry under pressure to the desired temperature; 3) flashing the slurry to a lower pressure to release the biogas, 4) reheating the slurry (coking) to drive off water and light oils from the solids; and 5) separating the light oils from the water. The oil is further processed using distillation or solvent extraction. The biogas goes to electric and/or steam generation based upon the economics of on-site use. |
| GEM America | Flash Pyrolysis | The conversion unit uses flash pyrolysis at 1,500°F to produce syngas and char/ash mixture. Syngas is quenched in ½ second to 75°F. Chlorine compounds removed. Sulfur compounds are removed in wet scrubber. The syngas is combusted in reciprocating engines to produce electricity. |
| International Environmental Solution | Pyrolysis | The process utilizes a horizontal retort, with a proprietary rotating auger to move the feed through the system. The MSW is heated to 1,200-1,800°F, where thermal degradation of the organic portion of the MSW occurs. Syngas is produced, and a carbon char mixed with metals and glass is discharged by gravity onto a conveyor. The syngas is immediately combusted in a thermal oxidizer, creating flue gas at 2,250°F. The flue gases are routed through a heat recovery steam generator to produce steam. The steam is used to generate electricity. |
| Green Energy Corporation | Steam Reforming Pyrolysis | Green Energy Corp. acquired a Technology License Agreement from Bio-Conversion Technology, LLC. of Denver, Colorado to market the patented BCT Gasifier Technology and reactors based on this technology. The syngas is cleaned before combustion to generate electricity. It can also catalytically produce Ethanol from the syngas. |

## TABLE 2-3
## SUMMARY OF INFORMATION PROVIDED BY BIOLOGICAL/CHEMICAL CONVERSION TECHNOLOGY SUPPLIERS

| Supplier Name | Technology | Brief Description |
|---|---|---|
| HotRot Composting System | Aerobic Composting | The HotRot system is an in-vessel aerobic composting process. Waste is slowly moved along a tunnel via tines on a longitudinal shaft; the tines double as air injectors. |
| Wright Tech System Inc. | Drying Biomass by biological Technology | Wright Environmental developed the Biodryer™ in-vessel biological drying technology based on its tunnel composting process. In the Biodryer, the processed material is dried to less than 15% moisture by using metabolic heat; the resulting dry material can be used as biomass fuel. Biological drying is an order of magnitude cheaper than conventional thermal drying, it does not require air pollution control equipment, and the air permitting is much simpler. The Biodryer can easily be retrofitted into a composter, should the client decide to produce compost rather than biomass fuel. |
| International Bio-Recovery Corp (IBR) | Aerobic Digestion | Food waste is slurried and aerobically digested with air injection inside a closed vessel using the EATAD process (Enhanced AutoThermal Aerobic Digestion); BRI has exclusive patent rights to its key components, the Shearator and the digester. |
| ABT-Haskell, LLC | Aerobic Composting | ABT has patented the AirLance™ in-vessel aerobic composting process. Air is injected and extracted via what is essentially a dense array of giant injection needles into a deep mass of composting sewage biosolids (sludge) and woodchips. The process occurs inside large 26-ft cubical composting cells with built-in screw conveyors. This system optimizes composting conditions, maximizing conversion rates and minimizing footprint. It is completely enclosed. |
| Organic Waste System (OWS) | Anaerobic Digestion | OWS has patented the DRANCO (Dry Anaerobic Composting) anaerobic digestion process. In this process, the digester feed is mixed with a large amount of recirculating digester effluent. The resulting mix is pumped to the top of the cylindrical digester where it is introduced into the digester. The contents have approximately 40 percent dry matter; they make their way down through the digester in a few days. Subsequently, most of the contents are recirculated to the top, so that the average residence time of the feed is 3 to 4 weeks. The fraction of the effluent removed from the digester (digestate) is aerobically matured using a static pile process and sold as compost. The products are biogas that can be used to generate electricity and compost. |
| Waste Recovery System (Valorga) | Anaerobic Digestion | Valorga international has patented the Valorga anaerobic digestion process. In this process, a solid or semi-solid waste feed is injected near the bottom of a cylindrical digester. The Valorga digesters have a vertical partition running from one wall across the center over approximately 2/3 of the diameter. The waste feed is introduced on one side of the partition and is removed from a port on the other side, to ensure a minimum residence time in the digester. During their transit, the contents are mixed via pulsed injections of pressurized biogas from the bottom of the digester. Typically, the waste resides in the digester for 3 to 4 weeks, at a dry solids content of 30 to 40%. The digester effluent is dewatered, aerobically matured, and marketed as compost. The products are biogas to generate electricity and compost. |

## TABLE 2-3 (CONTINUED)
## SUMMARY OF INFORMATION PROVIDED BY BIOLOGICAL/CHEMICAL CONVERSION TECHNOLOGY SUPPLIERS

| Supplier Name | Technology | Brief Description |
|---|---|---|
| Global Renewable | Anaerobic Digestion | The conversion feed goes to an ISKA percolator where it is sprayed with hot process water. This generates a percolate solution, which is biogasified in a hybrid packed-bed low solids digester. Solid residue from the percolator is dewatered in a press; the filtrate liquid goes to the digester, while the cake is screened and the undersize fraction goes to aerobic composting. The products are biogas and compost. |
| Arrow Ecology | Anaerobic Digestion | Arrow Ecology has patented the ArrowBio process for anaerobic digestion of solid waste. The first preprocessing step consists of submerging the waste. The conversion feed resulting from this process goes into an acidogenic reactor for a brief time. The dissolved and suspended effluent from that reactor is led to a wastewater digester, of the UASB type (Upflow Anaerobic Sludge Blanket). Liquid effluent can be cleaned up to high quality irrigation water. The products are biogas and compost. |
| Canada Composting Inc. (BTA) | Anaerobic Digestion | CCI holds the exclusive license for the BTA process in Canada and the U.S. The BTA process is a solid waste AD process that was developed in Germany in the 1980's. Its particularities include the use of wet pulping to prepare the facility feed for anaerobic digestion. This converts the feed into slurry, which is pumped to the anaerobic digester. The latter is operated in the liquid phase; various digester designs are used. Generally, the digester effluent is dewatered, aerobically matured, and marketed as compost. |
| BRI | Gasification/ Fermentation | BRI gasifies MSW to produce synthesis gas, followed by fermentation of the synthesis gas to ethanol. Waste heat from the process is converted to steam and electricity. BRI has selected a two-stage gasifier that raises the syngas temperature to over 2000°F in the second stage to enable cracking of any heavy hydrocarbons to CO and $H_2$, maximizing ethanol yield. The hot gases are then cooled to 100°F and introduce into fermenter where ethanol is produced. Nutrients are added to provide for cell growth and automatic regeneration of the biocatalyst. A dilute, aqueous stream of ethanol is continuously removed through a membrane retain cells for recycle to maximize reaction rate. |

## 2.4 SCREENING OF TECHNOLOGY SUPPLIERS

### 2.4.1 Screening Criteria

The following criteria were developed for the fatal flaw screening process:

1. **Incomplete Response** – Respondent did not respond directly to the questions in the questionnaire, or provided only sparse or general information on their basic technology, with no specific information related to the proposed system for Los Angeles County; Respondent provided no details or insufficient information on how they would develop an integrated conversion facility that incorporates the pre-processing, conversion unit, and products generation subsystems; respondent has experience on feedstocks other than MSW, and did not provide sufficient response to how the proposed facility would handle/treat MSW; Respondent's submittal had many technical and/or data errors.
2. **Only Generates RDF.** Respondent's technology provides only a physical change in the MSW, such as removal of recyclables, shredding and/or drying to produce a refuse-derived fuel (RDF) that would have to be utilized elsewhere, such as in an off-site boiler, as an alternative fuel or blended with coal or other fossil fuels.
3. **Only Generates Compost.** Respondent's technology only produces compost, with no utilization of biogas for power generation or other uses.
4. **No Pilot or Demonstration Units.** Respondent does not have any existing pilot or demonstration unit.
5. **Cost/Throughput is an Outlier.** Based on the economic information that the Respondent submitted (which may have been adjusted as part of the evaluation due to errors or incorrect assumptions), the capital cost of the proposed facility is >$100 million or the cost to treat/convert the MSW feed is >$300/ton of MSW. Due to the fact that the proposed facility would have a relatively small throughput, it will not likely be economical on a "per-ton" basis at these cost levels.
6. **Insufficient Cost Information.** Respondent did not provide capital and/or O&M cost information.

### 2.4.2 Screening Evaluation

The 28 respondents were evaluated on the basis of the fatal flaw screening criteria mentioned above. The respondents' submitted information was used for this screening process. Suppliers that failed one or more screening criteria were dropped from further evaluation. The suppliers that passed the screening criteria moved to the next step of the evaluation. Screening of conversion technology suppliers is shown in Table 2-4.

## TABLE 2-4
## SCREENING OF SUPPLIERS BY FATAL FLAW CRITERIA

| Supplier | Incomplete Response | Only Generate RDF or Compost | No Pilot or Demonstration Units | Cost is an Outlier Capital cost is >$100 million or net cost is >$300/ton | Insufficient Cost Information |
|---|---|---|---|---|---|
| Changing World Technologies | | | | | |
| Conrad Industries | F | | | | F |
| Ebara Corporation | | | | | |
| Geoplasma | | | | | |
| Global Energy Solutions | F | | | | F |
| GEM America | | | | | |
| International Environmental Solutions | | | | | |
| Interstate Waste Technologies | | | | | |
| Molecular Waste Technologies | F | | | | |
| Ntech Environmental | | | | | |
| Omnifuel Technologies | F | | F | | |
| Pan American Resources | F | | F | | |
| Plasma Environmental Technologies | F | | F | | F |
| Primenergy | | | | | |
| Rigel Resource Recovery and Conversion | | | F | F | |
| Taylor Recycling | | | F | F | |
| Green Energy Corporation | | | | | |
| WasteGen | F | | | | |
| Arrow Ecology | | | | | |
| Wright Tech | | F | | | |
| BRI Energy | | | | | |
| International Bio Recovery Corp. (IBR) | F | F | | | |
| Canada Composting Inc (CCI) BTA | | | | | |
| ABT-Haskell | | F | | | F |
| HotRot | | F | | | |
| Waste Recovery System (Valorga) | | | | | |
| Global Renewable (GR) | | | | | F |
| Organic Waste System (OWS) | | | | | |

Note:
Blank cell = Technology Supplier Passed Fatal Flaw Criteria
F = Technology Supplier Failed Fatal Flaw Criteria

The explanation for the screening of conversion technology suppliers is shown in Table 2-5.

## TABLE 2-5
## EXPLANATION FOR SCREENING OF SUPPLIERS BASED ON FATAL FLAW CRITERIA

| Supplier | Incomplete Response | Only Generate RDF or Compost | No Pilot or Demonstration Units | Cost is an Outlier >$100 million Capital or net cost >$300/ton | Insufficient Cost Information |
|---|---|---|---|---|---|
| Conrad Industries | Submittal provided general data on the technology treating tires, with little project-specific information No data on products and byproducts. Conrad states that equipment is provided by KleenAir Products; KleenAir brochure included did not show any pyrolysis equipment. | | | | No cost data provided. Conrad stated, “we cannot calculate detailed and verifiable information asked for on Attachments 2 and 3.” |
| Global Energy Solutions | Submittal did not address questionnaire. Information related to general process and technology, and listed basic information on existing systems; nothing specific provided for the proposed project. Emission data (much of it illegible) provided for existing systems (some levels shown as above limits). | | | | No cost data provided. |
| Molecular Waste Technologies | MWT provided a brief letter proposal and a brochure. Answers to questionnaire were vague and related to general technology discussion. Little to no information on the proposed facility. Throughput level was not specified. Very little pilot plant data on MSW. Process flow diagram was hand-drawn. | | | | |
| Pan American Resources | Submittal contained general information with no specific responses to the questionnaire | | No pilot or demonstration facilities. | | |

**TABLE 2-5 (CONTINUED)**
**EXPLANATION FOR SCREENING OF SUPPLIERS BASED ON FATAL FLAW CRITERIA**

| Supplier | Incomplete Response | Only Generate RDF or Compost | No Pilot or Demonstration Units | Cost is an Outlier >$100 million Capital or net cost >$300/ton | Insufficient Cost Information |
|---|---|---|---|---|---|
| Omnifuel Technologies | Submittal was sparse, with many errors. Throughput data in one portion of the submittal did not match values shown in another portion, as much as a factor of 3. Submittal describes an extensive pre-processing system, treating MRF residuals; Omnifuel may not fully understand the feedstock, since much of their experience has been on industrial and wood wastes. Little understanding of overall facility integration. | | No pilot or demonstration facilities. All operating have been shut down (mostly industrial wastes and wood waste). | | |
| Plasma Environmental Technologies | Submittal was a 2-page letter with no technical or financial information. | | No pilot or demonstration facilities. | | No cost information was provided. |
| Rigel Resource Recovery and Conversion | | | No pilot or demonstration facilities using the proposed technology. | Capital cost of $800,000,000 | |
| Taylor Recycling | | | Pilot and demonstration unit were shut down several years ago. | $348/ton | |
| WasteGen | Submittal was sparse. Much of data provided related to existing systems and a proposal for another project. Although WasteGen has significant, applicable experience, they were not particularly interested in developing a facility of this small size, since they have larger facilities already in operation. | | | | |

## TABLE 2-5 (CONTINUED)
## EXPLANATION FOR SCREENING OF SUPPLIERS BASED ON FATAL FLAW CRITERIA

| Supplier | Incomplete Response | Only Generate RDF or Compost | No Pilot or Demonstration Units | Cost is an Outlier >$100 million Capital or net cost >$300/ton | Insufficient Cost Information |
|---|---|---|---|---|---|
| Wright Tech | | Presents an aerobic in-vessel composting process, which is operated to minimize conversion but maximize drying (the Biodryer™ process, a drying process that does not rely on fossil fuels). The only product is refuse-derived fuel (RDF). | | | |
| ABT-Haskell | | Presents an aerobic in-vessel composting process; its only product is compost. | | | Has selected to provide no cost or revenue information whatsoever "because of the proprietary nature of this information". |
| HotRot | | Presents an aerobic in-vessel composting process; its only product is compost. | | | |
| Global Renewable | | | | | Has selected to provide no O& M cost and no revenue information |
| International Bio Recovery Corp. (IBR) | IBR presented an incomplete response based on an assumed feedstock composition that is fundamentally at odds with what is found at the MRFs in the county (e.g., IBR assumes 81% food waste and 5% bone and shell; total plastics is 2%, glass is 0.05%, metals 0.25%, etc.) | Presents an aerobic digestion process. This is not in-vessel composting, it occurs in slurry reactors. The output is a pelletized organic fertilizer and a liquid organic fertilizer marketed under the name Genica through an established network. These products are chemically similar to compost but not physically, so they occupy a different market niche. | | | |

### 2.4.3 Screening Results

Results of the screening process showed that the following conversion technology suppliers failed one or more fatal flaw screening criteria and were excluded from further evaluation.

- Conrad Industries
- Global Energy Solution
- Molecular Waste Technologies
- Omnifuel Technologies
- Pan American Resources
- Plasma Environmental Technologies
- Rigel Resource Recovery and Conversion
- Wright Tech
- IBR Corporation
- ABT-Haskel
- Global Renewable (GR)
- HotRot
- Waste Gen
- Taylor Recycling

The following conversion technology suppliers passed the screening process and moved to the next step for further evaluation:

| | |
|---|---|
| • Changing World Technologies | Thermal Depolymerization |
| • Ebara Corporation | Pyrolysis-Gasification |
| • Geoplasma | Plasma Gasification |
| • GEM America | Flash Pyrolysis |
| • International Environmental Solution | Pyrolysis |
| • Interstate Waste Technologies | Pyrolysis-Gasification |
| • Ntech Environmental | Gasification |
| • Primenergy | Gasification |
| • Green Energy Corporation | Steam Reforming Pyrolysis |

| | |
|---|---|
| • Arrow Ecology | Anaerobic Digestion |
| • BRI | Gasification/Fermentation |
| • Canada Composting Inc. (BTA) | Anaerobic Digestion |
| • Waste Recovery System (Valorga) | Anaerobic Digestion |
| • Organic Waste System (OWS) | Anaerobic Digestion |

## 2.5 FURTHER EVALUATION AND RANKING OF TECHNOLOGY SUPPLIERS

A comparative evaluation was conducted for the technology suppliers that passed the screening process. Essential differences among technology suppliers and the main objective of this project were used to develop a set of ranking criteria. Conversion technology suppliers were ranked based upon technical and economic parameters. The results were used to identify a list of suitable technologies for consideration to develop a conversion facility demonstration project in Southern California.

### 2.5.1 Ranking Process

Ranking criteria were needed to evaluate the many conversion technologies represented by the suppliers. The process of developing these criteria consisted of the following steps:

1. Establish Ranking Criteria
2. Develop Performance Levels for each Criterion
3. Assign Ratings to each Performance Level
4. Assign Weights to the Criteria

Each of these steps is briefly discussed below.

#### 2.5.1.1 Ranking Criteria

Ranking criteria were identified by considering the project objectives and subdividing them until specific, measurable criteria are found. By satisfying these criteria, the overall project objective is satisfied.

#### 2.5.1.2 Performance Levels

Performance levels, or scales, must be developed for the criteria. These performance levels are shown on the criteria table, and derive from experience and the data supplied. However, the process to assign these levels involves looking at the criterion, comparing it with the overall objectives of the project, and determining the best and worst level based upon actual information about the technologies. Then intermediate levels are added as appropriate.

#### 2.5.1.3 Ratings

Ratings are assigned to the performance levels to enable numeric scoring of the criteria. Certain rules are followed to make this process mathematically sound. For example, 100 points are assigned to the best performance level, and zero points to the worst level as a rule. Then the intermediate levels are assigned appropriate points based upon the relative position of the level with respect to the other levels.

#### 2.5.1.4 Weights

Weights are assigned to the criteria based upon two issues: the intrinsic importance of the criterion (e.g., equipment scaling can introduce performance risk), and the range over which the criterion extends (i.e., if the range is wide, or there is a large difference between the lowest and highest level for the technologies, then the importance will be higher).

#### 2.5.1.5 Scores

Finally, scores were calculated by multiplying the weights by the ratings and summing. The technology with the highest score is ranked number one and so forth. The group of technologies with the best scores will be advanced to the next step in the study.

### 2.5.2 Ranking of Technology Suppliers

The conversion technology suppliers that passed the screening process, moved to the next step for further evaluation. These technology suppliers were ranked according to the ranking criteria established for this project. This ranking is strictly based on information provided by the technology suppliers in the responses to questionnaire, and there was no independent verification of this information.

#### 2.5.2.1 Ranking Criteria

The process for establishing ranking criteria included starting with the project objective and identifying criteria that would satisfy this objective.

We subdivided the overall objective of identifying a technology that can successfully process the residues from a MRF/TS facility into the following sub-objectives:

- Maximize Environmental Suitability
- Maximize Technical Performance
- Minimize Cost and Maximize Revenues

Environmental suitability is an important issue. However, at this early stage, there is insufficient environmental data regarding the technology designs to differentiate these designs among the alternatives. The only environmental criterion added at this point was Landfill Diversion, an indicator of the amount of residual that will still be landfilled. All of the technologies will be designed to meet the prevailing environmental regulations.

Technical performance, as an objective to maximize, was represented by several criteria:

- Equipment Scaling: if a design must be scaled up significantly in size, performance risks will be higher.
- Waste Suitability: if the technology supplier has limited experience with regard to processing MRF residuals, performance risk will be higher.
- Operational Experience: technology suppliers with a greater amount of experience operating their facilities will have lower performance risk.
- Engineering Design Experience: technology suppliers with more experience integrating the pre-processing system, conversion unit, and product generation systems will have less performance risk.

The objective of minimizing cost and maximizing the value of products generated was recognized as an important issue by including a criterion that addresses cost and revenues, as well as a criterion that addresses the capacity of the supplier to provide the necessary technical and financial resources to carry out a project for the Los Angeles County.

A brief description of the technology ranking criteria is listed in Table 2-6.

## TABLE 2-6
## BRIEF DESCRIPTIONS OF TECHNOLOGY SUPPLIER RANKING CRITERIA

| | |
|---|---|
| Waste Suitability | Suppliers who have operating experience with MRF residuals or MSW will be ranked higher than suppliers who have processed other types of feedstocks similar to MRF residuals, such as biomass (e.g., green waste), plastics and tires. Lack of MSW processing experience introduces potential operational risks. |
| Need for Equipment Scaling to 100 TPD | When evaluating suppliers for a demonstration facility, many suppliers will have operating experience with systems far smaller than 100 TPD. Increasing throughput can be accomplished by designing larger modules or adding more modules. Designing larger modules introduces scaling risk. |
| Marketability of Conversion Products | We have defined a conversion facility to have the ability to convert MRF residuals to marketable products. Suppliers with products (e.g., electricity, ethanol, metals, compost, etc) that have existing strong market will score higher than those without market. |
| Engineering the Complete System | Some suppliers have expertise in only one technical area (e.g., preprocessing, conversion, or power production), while others have designed and built complete systems. Lack of expertise in one or more areas introduces design risks. |
| Existing Operational Experience | Suppliers with more operating experience will be ranked higher than those with less experience. More experience should result in smaller development risk. |
| Economics | The supplier must provide costs that are within reasonable ranges, and provide sufficient backup to understand the costs. Similarly, suppliers must demonstrate an understanding of product marketing. Suppliers that provide clear and reasonable costs and revenue projections will be rated higher. |
| Landfill Diversion | Suppliers who produce more marketable products, and thus less residuals, will be ranked higher. Larger amounts of residuals may lead to higher costs, and requires more landfill capacity. |
| Supplier Credibility | Suppliers must have organizations with the technical and financial resources to carry out design, construction and commissioning of a conversion facility. Suppliers with more resources will be rated higher. |

## TABLE 2-7
## RANKING CRITERIA FOR TECHNOLOGY AND TECHNOLOGY SUPPLIER EVALUATION

| Criterion | Attributes | Performance Levels | Ratings |
|---|---|---|---|
| Waste Suitability | Suitability is a function of the type of waste feedstock processing experience | 1. Commercial experience with MRF Residuals or MSW | 100 |
| | | 2. Commercial experience with Refuse Derived Fuel (RDF) | 75 |
| | | 3. Pilot or demo scale experience with MRF residuals, MSW, or RDF | 50 |
| | | 4. Commercial experience with biomass (i.e., green waste) | 25 |
| | | 5. Experience with other wastes | 0 |
| Need to Scale Conversion Unit to 100 TPD Size | Scaling introduces potentially significant engineering hurdles | 1. Scaling factor <=1 | 100 |
| | | 2. Scaling factor >1, <=5 | 66 |
| | | 3. Scaling factor >5, <=20 | 33 |
| | | 4. Scaling >20X | 0 |
| Engineering the Complete System | Supplier/partner has experience/understanding, designing, and integrating entire system | 1. Supplier/partner has designed/developed entire facilities/submitted designs complete | 100 |
| | | 2. Supplier/partner has developed only one facility, or has limited experience with one or more system components | 75 |
| | | 3. Technology has limited operational experience | 50 |
| | | 4. Lead firm has no development experience, but partners do | 25 |
| | | 5. Supplier/partner has not developed a complete system | 0 |
| Marketability of Conversion Products | Marketability of conversion products is desired | 1. Electricity | 100 |
| | | 2. Electricity Plus Green Fuel (Ethanol, Others) | 66 |
| | | 3. Electricity Plus Compost | 33 |
| | | 4. No Products | 0 |
| Existing Operational Experience | What level of operating experience does the supplier have? | 1. Multiple operating commercial units, >5 yrs | 100 |
| | | 2. One large operating facility, <1 year | 75 |
| | | 3. Small operating commercial unit, >1 yr | 50 |
| | | 4. Operating demonstration unit(s) or small commercial unit shut down | 25 |
| | | 5. Small pilot unit operating, or was operating | 0 |

**TABLE 2-7 (CONTINUED)**
**RANKING CRITERIA FOR TECHNOLOGY AND TECHNOLOGY SUPPLIER EVALUATION**

| Criterion | Attributes | Performance Levels | Ratings |
|---|---|---|---|
| Economics | Are the estimated costs and revenues within expected ranges? Are they substantiated? | 1. Net costs are supported and are reasonable (between $20 - $100/ton)<br>2. Net costs lack supporting and reasonable or supported and not reasonable<br>3. Net cost are not supported and are not reasonable | 100<br>50<br>0 |
| Landfill Diversion | Percent by weight of feedstock sent to landfill | 1. =< 10%<br>2. 11-20%<br>3. 21-40%<br>4. >40% | 100<br>66<br>33<br>0 |
| Supplier Credibility | Suppliers must have organizations with sufficient technical and financial resources | 1. Supplier organization has significant technical and financial resources<br>2. Lead firm has few resources, but backed by other partners with significant resources<br>3. Lead firm has limited resources, but backed by other firms with adequate resources<br>4. Supplier has limited technical and financial resources, but has developed a small commercial unit or demo facility<br>5. Supplier resources are limited, with no development record | 100<br>75<br>50<br>25<br>0 |

#### 2.5.2.2 Assignment of Performance Levels and Ratings

Using the data supplied, performance levels were developed, and appropriate ratings assigned to each performance level. The performance levels and ratings are shown in Table 2-7. Supporting data for this table can be found in Table A-6 in Appendix A.

#### 2.5.2.3 Assignment of Weights

Weights were assigned to criteria by spreading a total of 100 points among the eight criteria. These weights were assigned by the members of the Los Angeles County Alternative Technology Subcommittee and averaged for each criterion.

The weight distribution is as follows:

| | |
|---|---|
| 1. Waste Suitability | 13 |
| 2. Need to Scale Conversion Unit to 100 TPD Size | 15 |
| 3. Engineering the Complete System | 12 |
| 4. Marketability of Conversion products | 13 |
| 5. Existing Operation Experience | 7 |
| 6. Economics | 12 |
| 7. Landfill Diversion | 17 |
| 8. Supplier Credibility | 11 |

The most critical criteria were judged to be Landfill Diversion, Need to Scale Conversion Unit to 100 TPD, Waste Suitability, and Marketability of Conversion Products. Economics, Engineering the Complete System, and Supplier Credibility also received relatively high weighting. These criteria related to the ability of the supplier to provide the resources necessary (both technical and financial) to implement this project in Southern California. Existing operational experience received the lowest weight because the Los Angeles County Alternative Technology Subcommittee did not want to exclude emerging conversion technologies from evaluation at this stage.

## 2.6 RESULTS

The results of the ranking process are presented in this section.

### 2.6.1 Scores

A performance level was assigned to the conversion technology suppliers for each criterion based on information received from suppliers in response to the questionnaire. A weight was assigned to each ranking criteria according to Section 2.5.2.3.

Ranking, assigned performance levels and their justification for each technology supplier are provided in Table A-6 of Appendix A.

The final scores for the conversion technology suppliers are shown in Table 2-8. The graphical results of the final scores are shown in Figure 2-1.

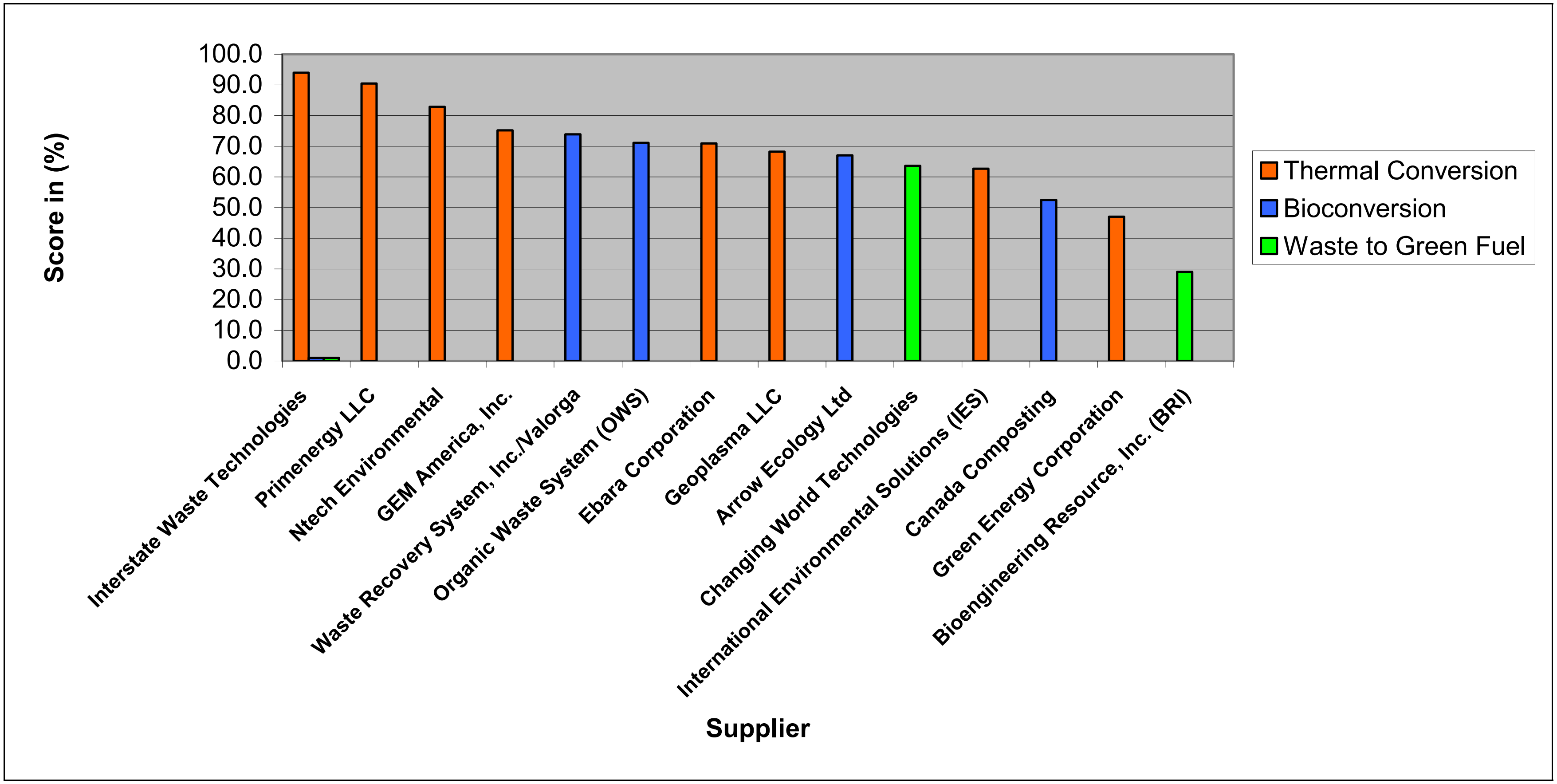
The following list shows conversion technology suppliers in order of their final scores received.

1. Interstate Waste Technologies
2. Primenergy LLC
3. Ntech Environmental
4. GEM America
5. Waste Recovery System (Valorga)
6. Organic Waste System (OWS)
7. Ebara Corporation
8. Geoplasma LLC
9. Arrow Ecology
10. Changing World Technologies
11. International Environmental Solutions
12. Canada Composting Inc. (BTA)
13. Green Energy Corporation
14. BRI

## TABLE 2-8
## SCORING OF THE CONVERSION TECHNOLOGY SUPPLIERS BY RANKING CRITERION

| | Waste Suitability | Need to Scale to 100 TPD | Engineering the Complete System | Marketability of Conversion Products | Existing Operational Experience | Economics | Landfill Diversion | Supplier Credibility | Total Score |
|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **13** | **15** | **12** | **13** | **7** | **12** | **17** | **11** | **100** |
| Interstate Waste Technologies | 100 | 100 | 100 | 100 | 100 | 50 | 100 | 100 | **94.0** |
| Primenergy LLC | 50 | 100 | 75 | 100 | 100 | 100 | 100 | 100 | **90.5** |
| Ntech Environmental | 100 | 66 | 50 | 100 | 100 | 50 | 100 | 100 | **82.9** |
| GEM America, Inc. | 100 | 66 | 75 | 100 | 25 | 50 | 100 | 50 | **75.2** |
| Waste Recovery System, Inc./Valorga | 100 | 100 | 100 | 33 | 100 | 50 | 33 | 100 | **73.9** |
| Organic Waste System (OWS) | 100 | 100 | 100 | 33 | 100 | 50 | 33 | 75 | **71.2** |
| Ebara Corporation | 50 | 33 | 75 | 100 | 50 | 50 | 100 | 100 | **71.0** |
| Geoplasma LLC | 100 | 100 | 25 | 100 | 25 | 0 | 100 | 50 | **68.3** |
| Arrow Ecology Ltd | 100 | 66 | 100 | 33 | 75 | 50 | 33 | 100 | **67.1** |
| Changing World Technologies | 25 | 100 | 75 | 66 | 75 | 0 | 100 | 50 | **63.6** |
| International Environmental Solutions (IES) | 50 | 66 | 25 | 100 | 25 | 50 | 100 | 50 | **62.7** |
| Canada Composting | 25 | 100 | 100 | 33 | 100 | 0 | 0 | 100 | **52.5** |
| Green Energy Corporation | 50 | 0 | 0 | 100 | 25 | 50 | 100 | 25 | **47.0** |
| Bioengineering Resource, Inc. (BRI) | 50 | 0 | 0 | 66 | 0 | 0 | 66 | 25 | **29.1** |

**FIGURE 2-1**
**SCORES OF CONVERSION TECHNOLOGY BY SUPPLIERS**



### 2.6.2 Technical Comparison of Technologies

This section addresses a few important technical differences among the various technologies including:

- Gasification
- Pyrolysis
- Anaerobic Digestion
- Plasma Gasification
- Thermal Depolymerization

The fourteen suppliers on the "short-list" include thermal, and/or biological conversion technologies. These technologies produce different products, including:

- Syngas-to-electricity
- Biogas-to-electricity + compost or soil amendment
- Biodiesel + solid and liquid fertilizers
- Syngas-to-Ethanol or Biogas-to-Ethanol

The technologies represented on the short-list of suppliers have different levels of maturity in the marketplace. According to the final ranking scores established by this study, the technology suppliers were divided into the following three categories:

1. Technologies with ranking scores of 75% or higher
2. Technologies with ranking scores between 60% to 75%
3. Technologies with ranking scores of less than 60%

These categories are compared as follows:

1. The following conversion technology suppliers received final ranking scores of 75% or more:
    - Interstate Waste Technologies (Pyrolysis -Gasification)
    - Primenergy LLC (Gasification)
    - Ntech Environmental (Gasification)
    - GEM America (Flash Pyrolysis)

The technologies proposed by these suppliers are gasification and pyrolysis, which are the most mature technologies; there are many operating commercialized facilities using these technologies that process MSW in Europe and Japan.

A comparison of technical and operational characteristics of these technology suppliers is shown in Table 2-9.

2. Suppliers that received final ranking scores between 60% and 75% are:

- Geoplasma LLC (Plasma Gasification)
- Waste Recovery System (Valorga) (Anaerobic Digestion)
- Organic Waste System (OWS) (Anaerobic Digestion)
- Ebara Corporation (Pyrolysis-Gasification)
- Arrow Ecology (Anaerobic Digestion)
- Changing World Technologies (Thermal Depolymerization)
- International Environmental Solutions (Pyrolysis)

These supplier proposed technologies are: plasma gasification, anaerobic digestion, thermal depolymerization, and pyrolysis. Other than anaerobic digestion, these technologies are not as mature or commercialized at the same level as the first category.

**TABLE 2-9**
**COMPARISON OF THE PREFERRED**
**CONVERSION TECHNOLOGY SUPPLIERS**

| Supplier | Advantages | Disadvantages |
|---|---|---|
| | **Thermal Conversion** | |
| The thermal conversion technologies that ranked higher are pyrolysis gasification, gasification, and flash pyrolysis. These conversion technologies are producing syngas as conversion products. Depending on the supplier design, the syngas can go through a quenching, cooling and cleaning process before combustion, or the syngas can be directly combusted to generate electricity. The following is a brief comparison of the thermal conversion technology suppliers. This comparison summarizes their advantages and disadvantages. | | |

## TABLE 2-9 (CONTINUED)
## COMPARISON OF THE PREFERRED CONVERSION TECHNOLOGY SUPPLIERS

| Supplier | Advantages | Disadvantages |
|---|---|---|
| Interstate Waste Technology (IWT)<br><br>(Pyrolysis/ Gasification, Thermoselect) | 1. The syngas produced by IWT gasification process is quenched-cooled and cleaned; it can then be combusted to generate electricity. The inorganic components are heated to >3,000 F, where they are converted to molten form. They flow into water bath and recovered as metals or slag aggregates, both of which are salable.<br>2. IWT has many years of experience processing MSW in Europe and Japan. IWT and its partners are large financially sound companies, which have implemented large projects worldwide. | 1. IWT system capital cost, net cost and tipping fee are high. They suggest a 300-ton/day unit with a tipping fee of $186/ton.<br>2. IWT does not have operational experience in the USA. |
| Prime Energy LLC<br><br>(Gasification) | 1. Primenergy is part of Renewable Resource Alliances (RRA). Affiliates of RRA are CR&R, Community Recycling, Nexant Corporation (gasification technical support), Nixon Peabody (engineering contracting legal), CH2M Hill (engineering). RRA affiliates hold more than 30 municipal franchises for MSW; Community Recycling and CR&R are two large recycling facilities in California. Both are well capitalized and capable of obtaining financing for the project.<br>2. The RRA is USA based alliance and their experience is in the USA. | 1. The syngas produced by Primenergy gasification process enters a hot gas cyclone, where solids and fly ash are removed. Bottom ash is removed from the bottom of the gasifier. The sygas is then combusted in a large combustion tube and the hot gases flow through a waste heat boiler for steam and power generation. The syngas is only partially cleaned before combustion.<br>2. Their primary experience is processing biomass. They have only tested MSW and RDF.<br>3. Primenergy has not designed, nor built a complete gasification and energy generation system processing MSW or MRF residue. |
| Ntech Environmental<br><br>(Gasification) | 1. Ntech Environmental has operational systems that process MSW.<br>2. Ntech Environmental and its partners have the credibility to successfully implement the project. | 1. The syngas produced by Ntech system is immediately combusted to generate steam and electricity.<br>2. Ntech has operating units processing 67 tons/day. A 2X scale up is required to process 100 tons/day<br>3. Ntech has not designed a complete system to include power generation<br>4. Lack of backup for cost analysis.<br>5. No operational experience in the USA. |

## TABLE 2-9 (CONTINUED)
## COMPARISON OF THE PREFERRED CONVERSION TECHNOLOGY SUPPLIERS

| Supplier | Advantages | Disadvantages |
|---|---|---|
| GEM America<br><br>(Flash Pyrolysis) | 1. The syngas produced by GEM America system is going through a cleaning process and removal of chlorine and sulfur and then the clean syngas is used to generate electricity. | 1. The GEM America system requires a specific feedstock. Shredding and drying may required.<br>2. It requires 1/16th in size and 8% moisture content.<br>3. The existing pilot plant has been shutdown for commercial reasons (not technical). It is waiting to restart.<br>4. No operational experience in the USA. |
| Ebara Corporation<br><br>(Pyrolysis-Gasification) | 1. The syngas produced by Ebara proposed system is cleaned and combusted in reciprocating engines<br>2. Ebara is a large engineering, environmental, construction and operation company with $1.8 billion per year in revenues | 1. The hot flue gas from the char combustion section flows through a heat recovery boiler, where the steam is produced for the fluidizing process in the pyrolysis chamber. The cooled flue gas leaving the boiler passes through an air emission control system and then to a stack.<br>2. The Ebara Corporation proposed system is in pilot stage with one facility (4,950 tons/year capacity).<br>3. No operational experience in the USA. |
| **Bioconversion** | | |
| Anaerobic digestion is ranked higher on the list of bioconversion technologies. It has essentially no air emissions. The conversion product is biogas that it can be processed and sold as industrial, commercial, or vehicular fuel. Also, anaerobic digestion generates a lot of solid matter, some of which can be processed into marketable compost. In the California market, it is unclear what amount of these solids can go to compost versus to the landfill (note that the landfilled material would be organically stabilized and usable as alternative daily cover). The following are advantages and disadvantages of anaerobic digestion suppliers. | | |
| Waste Recovery Systems, Inc. Valorga (WRSI)<br><br>(Anaerobic Digestion) | 1. WRSI/Valorga has a proven technology and has built many commercial facilities since the 1980's. They have excellent operational records.<br>2. WRSI/Valorga has the financial and technical credibility to successfully implement the project.<br>3. WRSI/Valorga has Shaw-Emcon Group as a partner in the USA. | 1. At this point, WRSI/Valorga indicates that 24% of the feed tonnage will go to the landfill, so the landfill diversion is only 76% (best case).<br>2. WRSI generates biogas plus compost. Marketing of the compost in California is questionable. |
| Organic Waste System (OWS)<br><br>(Anaerobic Digestion) | 1. OWS has technically sound process and operates large facilities processing MSW and MRF residue in Europe.<br>2. OWS has financial and technical credibility to successfully implement the project. | 1. Landfill diversion is only 60%. 40% of the waste has to be disposed in a landfill.<br>2. OWS generates biogas plus compost. Marketing of the compost in California is questionable.<br>3. No operational experience in the USA. |

3. Suppliers that received ranking scores of less than 60% are:

    - Green Energy Corporation (Steam Reforming Pyrolysis)
    - Canada Composting Inc. (BTA) (Anaerobic Digestion)

    BRI (Gasification-Fermentation)

    These suppliers are proposing technologies such as steam reforming pyrolysis and waste to green fuel, using MSW as feedstocks. These technologies are in the emerging category for processing MSW. The experience with these technologies is primarily at the pilot or demonstration stage.

To finalize the evaluation of technology suppliers, scoring was compiled by technology categories. The following pyrolysis and gasification technologies received ranking scores (more than 75%) greater than anaerobic digestion and other thermal technologies:

- Interstate Waste Technologies (Pyrolysis-Gasification)
- Primenergy LLC (Gasification)
- Ntech Environmental (Gasification)
- GEM America (Flash Pyrolysis)

These technologies are commercialized and have operating facilities. Other pyrolysis and gasification processes are in the pilot or testing stage and they ranked lower. They are:

- Ebara Corporation (Pyrolysis-Gasification)
- Geoplasma LLC (Plasma Gasification)
- International Environmental Solutions (Pyrolysis)

Ranking scores for pyrolysis-gasification, gasification, and pyrolysis are shown in Table 2-10.

**TABLE 2-10**
**SCORING OF THE PYROLYSIS, GASIFICATION TECHNOLOGY SUPPLIERS BY RANKING CRITERIA**

| | Waste Suitability | Need to Scale to 100 TPD | Engineering the Complete System | Marketability of Conversion Products | Existing Operational Experience | Economics | Landfill Diversion | Supplier Credibility | Total Score |
|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **13** | **15** | **12** | **13** | **7** | **12** | **17** | **11** | |
| Interstate Waste Technologies | 100 | 100 | 100 | 100 | 100 | 50 | 100 | 100 | **94.0** |
| Primenergy LLC | 50 | 100 | 75 | 100 | 100 | 100 | 100 | 100 | **90.5** |
| Ntech Environmental | 100 | 66 | 50 | 100 | 100 | 50 | 100 | 100 | **82.9** |
| GEM America, Inc. | 100 | 66 | 75 | 100 | 25 | 50 | 100 | 50 | **75.2** |
| Ebara Corporation | 50 | 33 | 75 | 100 | 50 | 50 | 100 | 100 | **71.0** |
| Geoplasma LLC | 100 | 100 | 25 | 100 | 25 | 0 | 100 | 50 | **68.3** |
| International Environmental Solutions (IES) | 50 | 66 | 25 | 100 | 25 | 50 | 100 | 50 | **62.7** |
| Green Energy Corporation | 50 | 0 | 0 | 100 | 25 | 50 | 100 | 25 | **47.0** |

Ranking scores for anaerobic digestion technologies fall between 50 and 75%. These technology suppliers also have operating facilities processing MSW or biomass. They are:

- Waste Recovery System (Valorga)
- Organic Waste System (OWS)
- Arrow Ecology
- Canada Composting Inc. (BTA)

The ranking scores for anaerobic digestion suppliers are shown in Table 2-11.

**TABLE 2-11**
**SCORING OF THE ANAEROBIC DIGESTION TECHNOLOGY SUPPLIERS BY RANKING CRITERIA**

| | Waste Suitability | Need to Scale to 100 TPD | Engineering the Complete System | Marketability of Conversion Products | Existing Operational Experience | Economics | Landfill Diversion | Supplier Credibility | Total Score |
|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **13** | **15** | **12** | **13** | **7** | **12** | **17** | **11** | |
| Waste Recovery System, Inc./ Valorga | 100 | 100 | 100 | 33 | 100 | 50 | 33 | 100 | **73.9** |
| Organic Waste System (OWS) | 100 | 100 | 100 | 33 | 100 | 50 | 33 | 75 | **71.2** |
| Arrow Ecology Ltd | 100 | 66 | 100 | 33 | 75 | 50 | 33 | 100 | **67.1** |
| Canada Composting | 25 | 100 | 100 | 33 | 100 | 0 | 0 | 100 | **52.5** |

Other emerging conversion technologies with green fuel production are ranked lower because they do not have substantiated data and/or long track records utilizing MSW as feedstock. They are:

- Changing World Technologies (Thermal Depolymerization)
- BRI (Gasification-Fermentation)

Ranking scores for the waste to green fuel conversion technologies are shown in Table 2-12.

**TABLE 2-12**
**SCORING OF THE WASTE TO GREEN FUEL OR OTHER CONVERSION TECHNOLOGY SUPPLIERS BY RANKING CRITERION**

| | Waste Suitability | Need to Scale to 100 TPD | Engineering the Complete System | Marketability of Conversion Products | Existing Operational Experience | Economics | Landfill Diversion | Supplier Credibility | Total Score |
|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **13** | **15** | **12** | **13** | **7** | **12** | **17** | **11** | |
| Changing World Technologies | 25 | 100 | 75 | 66 | 75 | 0 | 100 | 50 | **63.6** |
| Bioengineering Resource, Inc. (BRI) | 50 | 0 | 0 | 66 | 0 | 0 | 66 | 25 | **29.1** |

### 2.6.3 Cost Summary of Conversion Technology Suppliers

The cost comparison of conversion technologies was made based on information provided by the suppliers. This information included the following items:

- Total capital cost
- Annualized capital cost
- Annual operation and maintenance (O&M) cost

In order to compare the economics for different technologies and suppliers, the following assumptions were made:

- Hauling and disposal of the final solid residue is $50 per ton.
- Power will be provided to the facility at $60 per Megawatt-hour.
- Operating and maintenance costs should be escalated at 3% per year.
- Buildings and site improvements are amortized at an annual interest rate of 6% over 20 years.
- All equipment are amortized at 6% over 7 years.
- Electricity generated by suppliers will be sold at $0.045 per kW-hour.

Table 2-13 shows the cost comparison of the conversion technology suppliers.

The graphical results for capital costs are shown in Figure 2-2.

The annual net costs (annual capital + annual O&M – annual revenue) are shown in Figure 2-3.

Annual revenue generated by conversion technology suppliers is shown in Figure 2-4.

It must be noted that the cost and revenue provided by the suppliers varied greatly. This large variation in the cost between suppliers resulted for the following reasons:

- Some suppliers did not follow the procedures provided by the questionnaire and did not submit clear and substantiated cost and revenue data.
- By requesting a demonstration-level facility size, cost for facilities that are commercial overseas became excessive because of lack of economies of scale. These costs will be much lower with higher throughput systems.
- Most of the “emerging technology” firms (those without commercial facilities) do not have strong cost and revenue data.

## TABLE 2-13
## COST COMPARISON OF CONVERSION TECHNOLOGY SUPPLIERS

| | Throughput (TPD) | Capital Cost ($) | Annual Net Cost ($) | Annual Revenue ($) | Tipping Fee or Break Even Tipping Fee ($/Ton) |
|---|---|---|---|---|---|
| Interstate Waste Technologies | 300 | 75,511,000 | 18,615,132 | 4,430,873 | 186.00 |
| Primenergy LLC | 100 | 15,500,000 | 3,072,100 | 1,067,900 | 87.00 |
| Ntech Environmental | 100 | 19,356,500 | 4,271,040 | 869,400 | 129.00 |
| GEM America, Inc. | 100 | 13,215,317 | 3,143,790 | 1,244,340 | 105.00 |
| Waste Recovery System, Inc./Valorga | 100 | 9,000,000 | 1,916,200 | 378,000 | 67.00 |
| Organic Waste System (OWS) | 100 | 23,600,000 | 4,925,000 | 660,000 | 197.00 |
| Ebara | 70 | 47,490,000 | 6,112,135 | 327,865 | 289.00 |
| Geoplasma LLC | 100 | 45,190,000 | 4,507,500 | 540,000 | 172.00 |
| Changing World Technologies | 100 | 15,000,000 | 136,192 | 5,136,848 | 4.00 |
| Arrow Ecology Ltd | 100 | 16,000,000 | 2,883,000 | 383,000 | 93.00 |
| International Environmental Solution (IES) | 147 | 23,225,500 | 3,297,594 | 3,004,282 | 61.00 |
| Canada Composting | 100 | 24,400,000 | 6,800,000 | 280,000 | 272.00 |
| Green Energy Corporation | 120 | 10,250,000 | 1,783,785 | 1,908,000 | 45.00 |
| Bioengineering Resource, Inc. (BRI) | 300 | 26,600,000 | 0 | 12,700,000 | -49.00 |

*Some technology suppliers provided a tipping fee, while others did not. For those who did not provide tipping fee for MRF residue delivered to the conversion facility, a break even tipping fee was calculated by simply deducting annual revenue from annual cost and dividing the results by annual tonnage of residue processed by the facility.

**FIGURE 2-2**
**CAPITAL COST BY SUPPLIER**

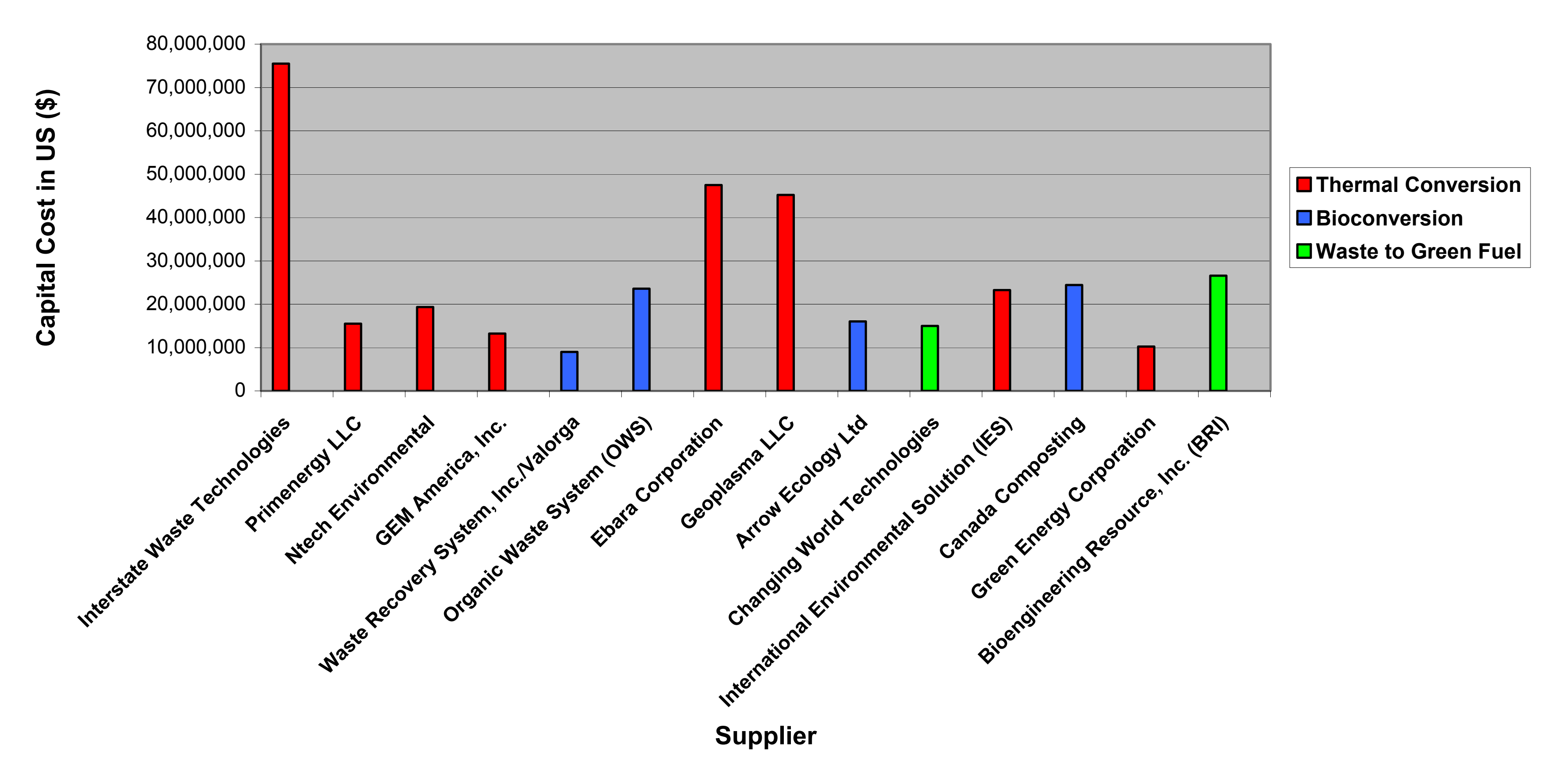


**FIGURE 2-3**
**ANNUAL NET COST BY SUPPLIER**

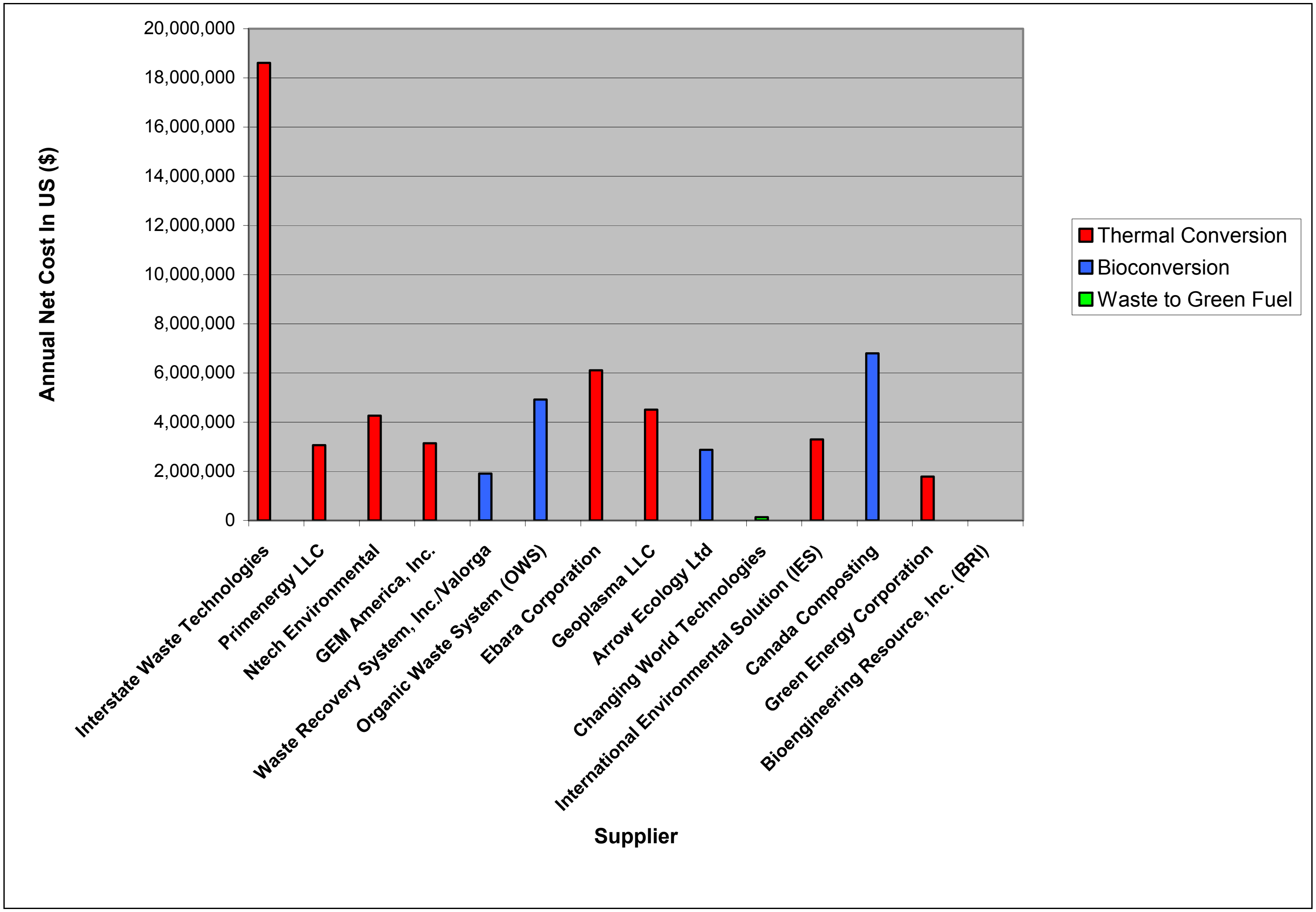
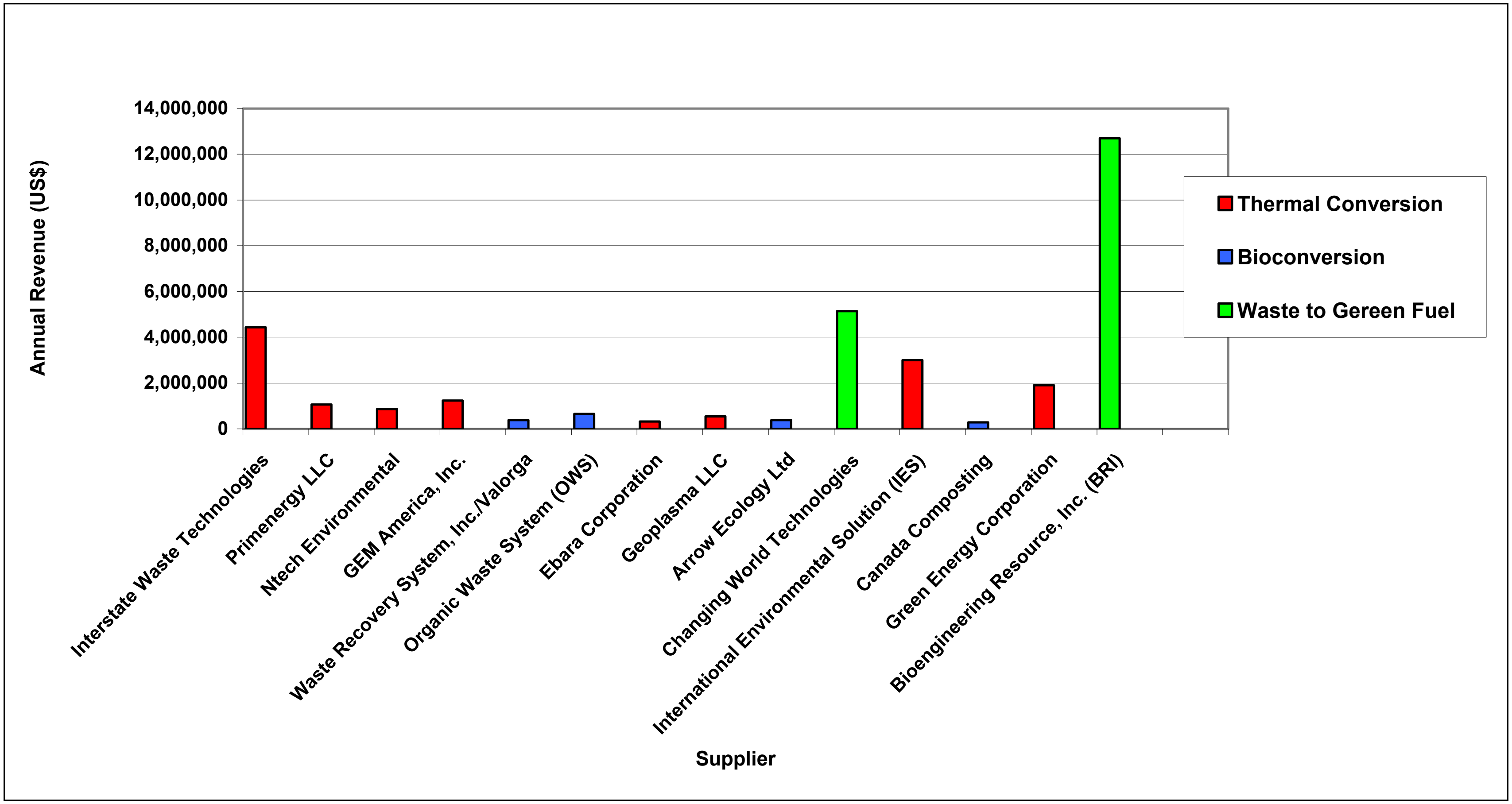


**FIGURE 2-4**
**ANNUAL REVENUE BY SUPPLIER**



Therefore, the costs for a demonstration facility should be evaluated in greater detail, along with a study of funding mechanisms and sources.

### 2.6.4 Conclusions

The top ranking technologies are pyrolysis-gasification, gasification, and pyrolysis. These technologies are well known, and have been widely used overseas for MSW processing. These technologies generate electricity as their primary product, and create only small quantities of residue. Four technology suppliers of this group ranked higher than any other technologies. These suppliers received total ranking scores of more than 75%. They are:

- Interstate Waste Technologies (IWT) – Pyrolysis/Gasification
- Primenergy LLC – Gasification
- Ntech Environmental – Gasification
- GEM America – Flash Pyrolysis

IWT, Ntech Environmental, and GEM America have operating facilities overseas. Primenergy has a facility in the United States processing rice hulls. Also, Primenergy has an alliance with CR&R MRF and Community Recycling and tested Refuse Derived Fuel (RDF).

The capital and operational costs for a demonstration facility using the Interstate Waste Technologies system are higher than other three pyrolysis and gasification technologies in this group ($186/ton processing 300 tons/day). However, IWT has many commercial operating facilities overseas processing MSW and submitted the most complete response to the questionnaire. Primenergy, Ntech Environmental, and GEM America costs are $87, $129, and $105 per ton respectively for processing 100 tons/day. These costs will be much lower with higher throughput in a commercial facility.

Other pyrolysis-gasification, plasma gasification, and pyrolysis suppliers ranked lower (47 to 75 %). These suppliers do not have commercial facilities processing MWS. They only have a pilot or test unit.

The second group of technologies includes anaerobic digestion. These technologies are also well known, and many facilities are operating overseas that process MSW or source separated organics. The primary product is compost, along with some electricity. A considerable quantity of residue is created that must be landfilled. In addition, the marketability of compost is uncertain and unpredictable. The following four suppliers from this group (all anaerobic digestion) are ranked between 50-75%:

- Waste Recovery System (Valorga)
- Organic Waste System (OWS)

- Arrow Ecology
- Canada Composting Inc. (BTA)

Despite second place in the ranking scores, anaerobic digestion was not recommended for the next phase of the process for the reasons provided in Section 4 of this Report.

The third group is waste to green fuel. This group of technologies includes thermal depolymerization and gasification with fermentation to ethanol. Although ethanol production from starch and sugar based material are commercialized processes, these technologies can be termed “emerging” since there are no commercial facilities processing MSW, and design data is limited. While these technologies demonstrate significant promise the development risk is substantial. The suppliers of these technologies are:

- Changing World Technologies (Thermal Depolymerization) – CWT has one operating demonstration/commercial facility using turkey waste as a feedstock.
- BRI (Gasification-Fermentation) – BRI has only a pilot facility.

If green fuel production becomes an objective of the proposed conversion facility, the syngas or biogas produced by the thermal or bioconversion technologies can be used to produce green fuel. In this case a combination of thermal, chemical and/or bioconversion technologies may be required, and such a combination can be evaluated in the next phase of this project.

The data presented in this report is preliminary, and subject to change when more detailed studies are conducted.

The main objective of this phase of the project is to evaluate Material Recovery Facilities and Transfer Stations (MRF/TSs) in Southern California and to find a MRF/TS that is willing to partner with conversion technology vendor, have adequate space, and can provide feedstock for a conversion facility. Partnership between a MRF/TS and conversion technology vendor will provide several advantages such as:

- Provide the processing capability of an existing MRF to produce the required composition of the feedstock for the conversion facility
- Reduce environmental impacts such as noise, odor, and traffic in comparison to a new facility
- Provide zoning and siting advantages for a conversion facility
- Provide financial incentive such as locating the facility in a Recycling Development Zone
- Make the permitting process easier compared to siting a new conversion facility
- Reduce overall project costs

URS evaluated Southern California MRF/TSs in order to identify MRF/TSs that are compatible for partnership with a conversion technology. The following procedure was followed to prepare a shortlist of MRF/TSs that exhibit the required features to facilitate a conversion system interface and be considered for further evaluation in this process:

- Prepare a long list of MRF/TSs
- Prepare and distribute a survey to identify interest in partnering with a conversion facility
- Identify a short list of MRF/TSs that are interested in partnering with a conversion facility
- Apply selection criteria to identify preferred MRF/TSs for continued evaluation

Each of these steps is described below.

## 3.1 EVALUATION OF MATERIAL RECOVERY FACILITIES AND TRANSFER STATIONS

### 3.1.1 Preparation of Long List of MRFs and Large TSs in Southern California

URS prepared a long list of MRFs and TSs in Southern California. The long list of MRF/TSs, which included 52 MRFs and TSs, was prepared using California Integrated Waste Management Board (CIWMB) database and Local Enforcement Agencies (LEA) data in Southern California. This list is presented in Table 3-1. Additional data about these facilities is shown in Table A-7 in Appendix A.

**TABLE 3-1**
**LONG LIST OF MATERIAL RECOVERY FACILITIES (MRF) AND LARGE TRANSFER STATIONS (TS) OF SOUTHERN CALIFORNIA**

| Name | Address | Location County | Permitted Daily Throughput (tons/day) | Category | Operational Status |
|---|---|---|---|---|---|
| South Coast Recycling & Transfer Station | 4430 Calle Real<br>Santa Barbara, CA 93110 | Santa Barbara | 550 | Transfer/ Processing | Active |
| Santa Ynez Valley Recycling & Transfer Station | 4004 N. Foxen Canyon Road at Landfill Los Olivos, CA 93441 | Santa Barbara | 212 | Transfer/ Processing | Active |
| MarBorg C and D Recycling/Transfer St. | 119 North Quarantina Street<br>Santa Barbara, CA 93101 | Santa Barbara | 750 | Transfer/ Processing | Active |
| Tehachapi Recycling, Inc | 416 North Dennison Road<br>Tehachapi, CA 93561<br>Phone (661) 822-6421 | Kern | 850 | Transfer/ Processing | Active |
| Mt. Vernon Metropolitan Recycling Center | 2601 South Mt. Vernon Avenue<br>Bakersfield, CA 93307 | Kern | 100 | Transfer/ Processing | Active |
| Gold Coast Recycling Facility | 5275 Colt Street<br>Ventura, CA 93003 | Ventura | 440 | Transfer/ Processing | Active |
| Del Norte Regional Recycling & Transfer | 111 South Del Norte Blvd.<br>Oxnard, CA 93030 | Ventura | 2779 | Transfer/ Processing | Active |
| Santa Clarita MRF and Transfer Station | Proposed Site<br>26000 Springbrook Ave<br>Santa Clarita, CA 91350 | Los Angeles | 1000 | Transfer/ Processing | Planned |
| Rail Cycle Commerce Materials Recovery Facility | 6300 E. 26th Street<br>Commerce, CA 99999 | Los Angeles | 4200 | Transfer/ Processing | Planned |
| Coastal Material Recovery Facility | 357 W. Compton Blvd.<br>Gardena, CA 90248 | Los Angeles | 500 | Transfer/ Processing | Active |
| Angelus Western Paper Fibers, Inc. | 2474 Porter Street<br>Los Angeles, CA 90021 | Los Angeles | 650 | Transfer/ Processing | Active |
| East Los Angeles Recycling and Transfer | 1512 N. Bonnie Beach Place,<br>City Terrace, CA 90063 | Los Angeles | 700 | Transfer/ Processing | Active |
| Waste Management South Gate Transfer | 4489 Ardine Street<br>South Gate, CA 90280 | Los Angeles | 2000 | Transfer/ Processing | Active |
| Athens Services | 14048 E. Valley Blvd.<br>Industry, CA 91746 | Los Angeles | 1920 | Transfer/ Processing | Active |
| City Terrace Recycling Transfer Station | 1525 Fishburn AvenueLos Angeles, CA 90063 | Los Angeles | 200 | Transfer/ Processing | Active |

## TABLE 3-1 (CONTINUED)
## LONG LIST OF MATERIAL RECOVERY FACILITIES (MRF) AND LARGE TRANSFER STATIONS (TS) OF SOUTHERN CALIFORNIA

| Name | Address | Location County | Permitted Daily Throughput (tons/day) | Category | Operational Status |
|---|---|---|---|---|---|
| Puente Hills Materials Recovery | 2800 Workman Mill Road, Whittier, CA 99999 | Los Angeles | 4400 | Transfer/ Processing | Planned- Commence at the end of the year |
| Innovated Waste Control | 4133 Bandini Blvd Vernon, CA 90023 Phone: (323) 264-0202 | Los Angeles | 1250 | Transfer/ MRF | Active |
| Carson Transfer Station & MRF | 321 West Francisco Street Carson, CA 90745 | Los Angeles | 5300 | Transfer/ Processing | Active |
| American Waste Transfer | 1449 W. Rosecrans Ave. Gardena, CA 90249 | Los Angeles | 2225 | Transfer/ Processing | Active |
| South Gate Transfer | 9530 Garfield Ave. South Gate, CA 90280 | Los Angeles | 1000 | Transfer/ Processing | Active |
| Browing-Ferris Ind. | 2509 W. Rosecrans Ave. Compton, CA 90220 | Los Angeles | 1500 | Transfer/ Processing | Active |
| Culver City Transfer & Recycling Station | 9255 W. Jefferson Blvd. Culver City, CA 90230 | Los Angeles | 500 | Transfer/ Processing | Active |
| Downy Area Recycling and Transfer | 9770 Washburn Road Downy, CA 90201 | Los Angeles | 5000 | Transfer/ Processing | Active |
| Paramount Resources | 7230 Patterson Lane Paramount, CA 90723 | Los Angeles | 1200 | Transfer/ Processing | Active |
| Southern Cal. Disposal | 1908 Frank Street Santa Monica, CA 90404 | Los Angeles | 1056 | Transfer/ Processing | Active |
| Grand Central Recycling/Transfer | 999 Hatcher Ave. Industry, CA 91744 | Los Angeles | 1500 | Transfer/ Processing | Active |
| Bel-Art Waste | 2501 East 68th Street Long Beach, CA 90805 | Los Angeles | 1500 | Transfer/ Processing | Active |
| Community Recycling/Resource Recovery, Inc. | 9147 De Garmo Ave. Sun Valley (In Los Angeles), CA 91352 | City of Los Angeles | 1700 | Transfer/ Processing | Active |
| Central Los Angeles Recycling Center and Transfer Station | 2201 Washington Blvd. Los Angeles (City), CA 90034 | City of Los Angeles | 1850 | Transfer/ Processing | Active |
| Mission Road Recycling and Transfer Station | 840 South Mission Road Los Angeles (City), CA 90023 | City of Los Angeles | 1500 | Transfer/ Processing | Active |

## TABLE 3-1 (CONTINUED)
## LONG LIST OF MATERIAL RECOVERY FACILITIES (MRF) AND LARGE TRANSFER STATIONS (TS) OF SOUTHERN CALIFORNIA

| Name | Address | Location County | Permitted Daily Throughput (tons/day) | Category | Operational Status |
|---|---|---|---|---|---|
| West Valley Materials Recovery Facility | 13373 Napa Street Fontana, CA 92335 | San Bernardino | 5000 | Transfer/ Processing | Active |
| Victor Valley MRF & Transfer Station | NW Corner of Abby Lane & 'b' Street Victorville, CA 92307 | San Bernardino | 600 | Transfer/ Processing | Active |
| Advance Disposal Transfer/ Processing Facility | 17105 Mesa Street Hesperia, CA 92345 | San Bernardino | 600 | Transfer/ Processing | Active |
| Inland Regional MRF & Transfer Station | 2059 East Steel Road Colton, CA 92324 | San Bernardino | 1950 | Transfer/ Processing | Active |
| Twentynine Palm Transfer Station | 7501 Pinto Mountain Road Twentynine Palms, CA 92277 | San Bernardino | 200 | Transfer/ Processing | Active |
| Big Bear Transfer Station | Holcomb Valley Road 1.5 Miles N of HWY 18 Big Bear City, CA 92314 | San Bernardino | 400 | Transfer/ Processing | Active |
| Heap Peak Transfer Station | N Side of HWY 18; 3 Miles West of Running Springs Lake Arrowhead, CA 92407 | San Bernardino | 300 | Transfer/ Processing | Active |
| Sheep Creek Transfer Station | 10130 Buckwheat Road Phelan, CA 92371 | San Bernardino | 198 | Transfer/ Processing | Active |
| Stanton Transfer and Recycling Center # 8 | 11232 Knott Ave. Stanton, CA 90680 | Orange | 1800 | Transfer/ Processing | Active |
| Rainbow Recycling/ Transfer Station | 17121 Nichols Ave. Huntington Beach, CA 92647 | Orange | 2800 | Transfer/ Processing | Active |
| Consolidated Volume Transporters | 1131 N. Blue Gum Street Anaheim, CA 92806 | Orange | 6000 | Transfer/ Processing | Active |
| Sunset Envir Inc. Transfer Station/Resource Recovery Facility | 16122 Construction Circle East Irvine, CA 92606 | Orange | 2050 | Transfer/ Processing | Active |
| Waste Management of Orange/Transfer Station | 2050 N. Glassell Street Orange, CA 92865 | Orange | 1500 | Transfer/ Processing | Active |
| Moreno Valley Solid Waste Recycle & Transfer Facility | 17700 Indian Street Moreno Valley, CA 92551 | Riverside | 2000 | Transfer/ Processing | Active |
| Idyllwild Collection Station | 28100 Saunders Meadow Road Idyllwild, CA 92549 | Riverside | 200 | Transfer/ Processing | Active |

## TABLE 3-1 (CONTINUED)
## LONG LIST OF MATERIAL RECOVERY FACILITIES (MRF) AND LARGE TRANSFER STATIONS (TS) OF SOUTHERN CALIFORNIA

| Name | Address | Location County | Permitted Daily Throughput (tons/day) | Category | Operational Status |
|---|---|---|---|---|---|
| Robert A. Nelson (RANT) Transfer Station & MRF | 1830 Agua Mansa Rd Rubidoux, CA 92509 | Riverside | 2700 | Transfer/ Processing | Active |
| Perris Transfer Station and MRF | 1706 Goetz Road Perris, CA 92570 | Riverside | 1800 | Transfer/ Processing | Active |
| Escondido Resource Recovery | 1044 W. Washington Avenue Escondido, CA 92033 | San Diego | 2500 | Transfer/ Processing | Active |
| Ramona MRF And Transfer Station | 324 Maple Street Ramona, CA 92065 | San Diego | 370 | Transfer/ Processing | Active |
| Fallbrook Recycling Facility | 550 W. Aviation Road Fallbrook, CA 92028 | San Diego | 500 | Transfer/ Processing | Active |
| Edco Station | 8152 Commercial Street La Mesa, CA 91942 | San Diego | 200 | Transfer/ Processing | Active |
| Valley Environmental Services Recycling | 702 East Heil Avenue El Centro, CA 92243 | Imperial | 200 | Transfer/ Processing | Active |

NA - Not Available

### 3.1.2 Prepare and Distribute a Survey

The County of Los Angeles Department of Public Works wrote a letter to each one of the facilities listed in Table 3-1 to introduce URS as County's contractor for the evaluation of the facility and to explain the purpose of this project. A copy of the County letter is included in this report Table A-8 in Appendix A. URS prepared a self-addressed stamped postcard with questions regarding the facility. The postcard included the following questions.

1. Are you interested in entering into partnership to develop a demonstration conversion facility to process residual feedstock that would otherwise be disposed?

   If yes, please specify the contact person (provide contact information).

2. Is space available at your facility to potentially develop a demonstration conversion technology operation?

   If yes, please specify facility name/address and maximum potential space available.

3. Additional Comments

The County introductory letter including URS' postcard with questions was sent to each of the 52 MRFs/TSs in Southern California. Follow up telephone calls were made to each facility to ensure that they received the letter and postcard.

### 3.1.3 Identify a Short List of MRF/TSs Interested in Conversion Facilities

URS received 13 positive responses from different MRF and large TSs in Southern California. These 13 MRF/TSs indicated that they are interested in conversion technology and may have space for a conversion demonstration facility. Table 3-2 shows the short list of MRF/TSs.

### 3.1.4 Select Preferred MRF/TSs

The process used to select the most appropriate of the remaining eleven MRF/TSs was the following:

- Develop selection criteria
- Collect data through letters and site visits
- Identify Preferred MRF/TSs

The selection criteria are shown in Table 3-3. These criteria represent the desired characteristics for MRF/TSs to be a satisfactory candidate for partnering with a conversion facility.

## TABLE 3-2
## SHORT LIST OF MRF/TS IN SOUTHERN CALIFORNIA INTERESTED IN CONVERSION FACILITY

| Name | Location County | Operator/ Business Owner | Permitted Daily Throughput (Tons/Day) | Operational Type/ Pretreatment | Waste Type | Utility Availability |
|---|---|---|---|---|---|---|
| Mt. Vernon Metropolitan Recycling Center | Kern | Kern Refuse Inc.<br>C/O 1501 Truxtun Avenue<br>Bakersfield, CA 93301<br>Phone: (661) 326-3114 | 100 | **MRF** | Construction/ demolition<br>Mixed municipal | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |
| Gold Coast Recycling Facility | Ventura | Gold Coast Recycling Inc.<br>5275 Colt Street, Suite 2<br>Ventura, CA 93003<br>Phone: (805) 642-9236<br>Fax: (805) 642-9340 | 440 | **MRF** | Mixed municipal | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |
| Del Norte Regional Recycling & Transfer | Ventura | BLT Enterprises of Oxnard, Inc.<br>511 Spectrum Circle<br>Oxnard, CA 93030<br>Phone: (805) 278-8220 | 2779 | **MRF** | Agricultural<br>Construction/ demolition<br>Industrial<br>Mixed municipal | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes |
| Santa Clarita MRF and Transfer Station | Los Angeles | Burrtec Waste Industries, Inc.<br>Eric Herbert<br>9890 Cherry Avenue<br>Fontana, CA 92335<br>Phone: (909) 429-4200<br>Fax: (909) 355-7158 | 1000 | **MRF** | Mixed municipal | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |
| Angelus Western Paper Fibers, Inc. | Los Angeles | Angelus Wester Paper Fibers, Inc.<br>2474 Porter Street<br>Los Angeles, CA 90021<br>Phone: (213) 623-9221 | 650 | | Mixed Municipal | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |

## TABLE 3-2 (CONTINUED)
## SHORT LIST OF MRF/TS IN SOUTHERN CALIFORNIA INTERESTED IN CONVERSION FACILITY

| Name | Location County | Operator/ Business Owner | Permitted Daily Throughput (Tons/Day) | Operational Type/ Pretreatment | Waste Type | Utility Availability |
|---|---|---|---|---|---|---|
| Community Recycling/ Resource Recovery, Inc. | City of Los Angeles | Community Recycling and Resource Recover<br>9189 De Garmo Ave.<br>Sun Valley, CA 91352<br>Phone: (818) 767-6000<br>Mr. John Richardson | 1700 | **MRF** | Commercial and Multifamily (Apartment/Condo)<br>Mixed Municipal Waste | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes |
| Central Los Angeles Recycling Center and Transfer Station | City of Los Angeles | BLT<br>Waste Systems of North America<br>2201 East Washington Blvd.<br>Los Angeles, CA 90021<br>Phone: (213) 746-9700 | 1850 | | Construction/ demolition<br>Industrial<br>Mixed municipal | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes |
| West Valley Materials Recovery Facility | San Bernardino | West Valley Recycling and Transfer<br>9890 Cherry Avenue<br>Fontana, CA 92335 Phone: NA | 5000 | **MRF** | Green Materials<br>Mixed Municipal<br>Wood Waste | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |
| Victor Valley MRF & Transfer Station | San Bernardino | Burrtec Waste Industries, Inc.<br>9890 Cherry Avenue<br>Fontana, CA 92335<br>Phone: (909) 822-2396<br>Fax: (909) 355-7158 | 600 | **MRF** | Mixed Municipal | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |
| Robert A. Nelson (RANT) Transfer Station & MRF | Riverside | Agua Mansa MRF, LLC<br>9890 Cherry Avenue<br>Fontana, CA 92335<br>Phone: (909) 822-2397 | 2700 | **MRF** | Mixed municipal | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes |

## TABLE 3-2 (CONTINUED)
## SHORT LIST OF MRF/TS IN SOUTHERN CALIFORNIA INTERESTED IN CONVERSION FACILITY

| Name | Location County | Operator/ Business Owner | Permitted Daily Throughput (Tons/Day) | Operational Type/ Pretreatment | Waste Type | Utility Availability |
|---|---|---|---|---|---|---|
| Perris Transfer Station and MRF | Riverside | CR&R Incorporated<br>11292 Western Avenue<br>Stanton, CA 90680<br>Phone: (714) 826-9049 | 1800 | **MRF** | Mixed municipal | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes |
| Edco Station | San Diego | Edco Disposal Corporation<br>6670 Federal Blvd<br>Lemon Grove, CA 91945<br>Phone: (619) 287-3532 | 200 | **MRF** | Construction/ demolition<br>Green materials<br>Industrial<br>Mixed municipal | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |
| Valley Environmental Services Recycling | Imperial | Valley Environmental Services<br>3354 Dogwood Road<br>Imperial, CA 92251<br>Phone: (760) 355-0004 | 200 | **MRF** | Mixed municipal from the curb recycling with high percentage of residue | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone |

M-3 - Heavy Industrial Zone

**TABLE 3-3**
**SELECTION CRITERIA FOR EVALUATION OF POTENTIAL FACILITY LOCATION**

| Criterion | Description |
|---|---|
| Ability and Willingness to Partner | Material Recovery Facility (MRF) or Transfer Station (TS) must have the ability (legal; financial etc.) and willingness to partner with conversion technology developer. |
| Availability of Adequate Space | MRF/TS must have adequate space adjacent to their facility to house a conversion technology facility. |
| Residual Quantity | MRF/TS must generate enough residue that is currently going to the landfill (TAD) to provide adequate feedstock for the conversion technology. |
| Residual Suitability | MRF/TS residue must have composition suitable to be used as feedstock for a conversion technology. |
| Pretreatment Capability | MRF/TS may have some pretreatment capabilities (sizing, sorting, etc.), which help the preparation of feedstock for conversion technology. |
| Flexibility in Residue Generation | MRF/TS may be designed/redesigned to generate a specific feedstock for a specific conversion technology. |
| Local Environmental Sensitivity | MRF/TS location (adjacent land use and zoning) must be suitable for development of conversion technology. |
| Utility Availability | MRF/TS must have adequate utility access including water, electricity, natural gas, and sewer. |
| Transportation Access | MRF/TS access to the rail or truck road, with consideration of traffic and land use along the road. |
| Site Specific Regulatory Issues | MRF/TS Site specific regulatory issues should not prevent the permitting of the conversion technology facility. |
| Financial Incentive | MRF/TS may have some financial incentive to develop conversion technology. For example recycling market development zone or partnership with other agencies or local governments. |
| Access to Local Market | MRF/TS may have access to local markets for products and byproducts of conversion technology. Steam, electricity, ethanol etc. |

The next step was to collect data regarding these criteria so that the short list of MRF/TSs could be evaluated and preferred facilities identified. URS sent a letter to each short listed MRF requesting information related to the criteria in Table 3-3. A sample of URS' letter and the County letter sent to the short list of MRF/TSs is included in Appendix A. In addition, URS visited several MRF/TS facilities in Southern California to collect additional data.

If there were many facilities in the selection process, a formal ranking methodology, similar to that implemented to rank the technology suppliers would be used. However, because the list of MRF/TSs was short, a more informal selection process was applied.

When the data obtained from the short-listed facilities was compiled and evaluated, the following facilities satisfied the criteria and were identified as Preferred Facilities:

- Del Norte Regional Recycling and Transfer in the City of Oxnard
- Community Recycling/Resource Recovery, Inc in Sun Valley
- Central Los Angeles Recycling Center and Transfer Station in the City of Los Angeles
- Robert A. Nelson Transfer Station & MRF in Rubidoux (Riverside)

In addition, the Santa Clarita MRF/TS is planned to open in 2006 and they also indicated that they are very interested in a conversion facility and should be included in the short-list for a conversion technology demonstration facility. The Perris Transfer Station and MRF operated by CR&R is also very interested in conversion technology. Imperial County and San Diego County MRF/TSs were too small (200 tons/day incoming MSW), and therefore were not included in the final preferred list of MRFs/TSs.

Republic Services, Inc. and Burrtec Waste Industries, Inc., which operate the Del Norte Regional Recycling/Transfer Station and Robert A. Nelson Transfer Station & MRF, respectively indicated that these two MRF/TSs are the best for siting a conversion facility. However, they are operating many MRF/TSs in Southern California and willing to provide back-ups if these facilities are not satisfactory.

Table 3-4 shows data compiled for these facilities.

The composition of the MRF residue for four different MRFs in Southern California that are going to the landfill is provided in Figure 3-1. This composition was used as example for conversion technology evaluation.

The following is a brief description of the preferred Southern California MRF/TSs for development of a conversion facility.

## 3.2 PREFERRED MATERIAL RECOVERY FACILITIES

### 3.2.1 Del Norte Regional Recycling and Transfer Station in the City of Oxnard

Del Norte Regional Recycling and Transfer Station is located in 111 South Del Norte Boulevard, City of Oxnard (County of Ventura), California. The Facility is operating as a MRF and Transfer Station. The permitted daily throughput of this MRF/TS is 2,700 tons. The facility is accepting approximately 1,350 tons/day. The MRF and Transfer Station combined generate an average of approximately 890 tons/day residue.

## TABLE 3-4
## LIST OF PREFERRED MRF/TS IN SOUTHERN CALIFORNIA FOR POTENTIAL DEVELOPMENT OF CONVERSION FACILITY

| Name/ Operational Status | Location County | Daily Throughput Permitted/ Actual (TPD) | Daily Residue Disposal (Tons/Day) | Availability of Residue Composition | Operational Waste/Type | Recycling Market Development Zone/Zoning | Utility Availability | Space Available | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Del Norte Regional Recycling & Transfer<br><br>Active | Ventura | 2700/1350 | 890 Average of 11 month. | Detail Waste and Residue Composition is Available | **MRF/**<br>Agricultural<br>Construction/ demolition<br>Industrial<br>Mixed municipal | **Yes/Industrial** | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes | **Yes.**<br>**10 to 15 acres adjacent City owned space available**<br>**Rail Access** | **Dr. Eugene Tseng is their consultant and very interested in conversion facility.**<br>**URS visited the facility on December 7, 2004** |
| Santa Clarita MRF and Transfer Station<br><br>Planned | Los Angeles | 1000/NA | Not Available | Not Available | **MRF/**<br>Mixed municipal | **Yes** | Water<br>Gas<br>Electricity<br>Sewer<br>Telephone | **Yes** | **This MRF is planned and will be built in 2005. They are very interested in conversion facility** |

## TABLE 3-4 (CONTINUED)
## LIST OF PREFERRED MRF/TS IN SOUTHERN CALIFORNIA FOR POTENTIAL DEVELOPMENT OF CONVERSION FACILITY

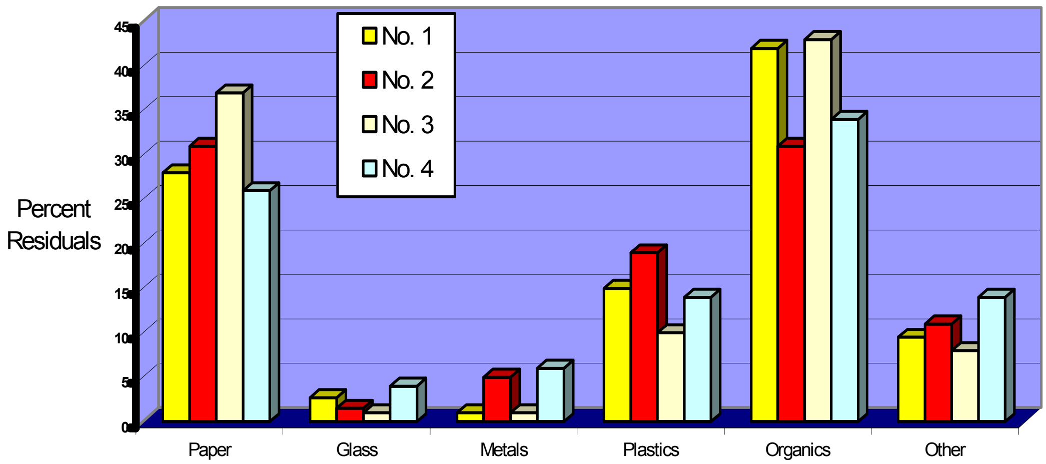
| Name/ Operational Status | Location County | Daily Throughput Permitted/ Actual (TPD) | Daily Residue Disposal (Tons/Day) | Availability of Residue Composition | Operational Waste/Type | Recycling Market Development Zone/Zoning | Utility Availability | Space Available | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Community Recycling/ Resource Recovery, Inc.<br><br>Active | City of Los Angeles | 1700 (will be increased to 2400)/1500 | 1350 | Not Available | **MRF/**<br>Commercial and Multifamily (Apartment/ Condo)<br>Mixed Municipal Waste | **Yes/M-3-G** | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes | **Yes- Approximately 3 acres of Land Available** | **URS visited the MRF on 11/16/04. They are very interested in conversion facility. Traffic congestion problem.** |
| Central Los Angeles Recycling Center and Transfer Station<br><br>Active | City of Los Angeles | 4025/3000 | Approximately 3000. Only large Bulk items are separated. | This is the City of Los Angeles Black Bin waste supposedly with no recyclables. URS Performed an estimated and rough waste characterization in 2004. | **Transfer Station/**<br>Construction/ demolition<br>Industrial<br>Mixed municipal | **Yes/M-3** | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes | **Yes.<br>Have 9 acres on Washington Blvd Between Alameda and Santa Fe.<br>Rail Access** | **URS visited the TS in October 2004. Los Angeles City owns the MRF. The City's Black Bin Waste (non recyclables) are transferred in this facility, which is going direct to the landfill.** |

## TABLE 3-4 (CONTINUED)
## LIST OF PREFERRED MRF/TS IN SOUTHERN CALIFORNIA
## FOR POTENTIAL DEVELOPMENT OF CONVERSION FACILITY

| Name/ Operational Status | Location County | Daily Throughput Permitted/ Actual (TPD) | Daily Residue Disposal (Tons/Day) | Availability of Residue Composition | Operational Waste/Type | Recycling Market Development Zone/Zoning | Utility Availability | Space Available | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Robert A. Nelson (RANT) Transfer Station & MRF<br><br>Active | Riverside | 2700/2300 | 2060 | Not Available | **MRF/**<br>Mixed municipal | **Yes** | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes | **Yes.<br>5 acres of land is available beside the facility.** | **URS visited the MRF on 11/16/04. This is a Transfer Station and MRF. Very interested in conversion facility.** |
| Perris Transfer Station & MRF<br><br>Active | Riverside | 1800 (It will be expanded to 3600)/NA | Not Available | Not Available | **MRF/**<br>Mixed municipal | **Yes** | Water Yes<br>Gas Yes<br>Electricity Yes<br>Sewer Yes<br>Telephone Yes | **Yes.<br>MRF/TS comprising approximately 28 acres of land and 2 acres is reserved for conversion facility in the master plan.** | **This MRF will be undergoing an approximately $15 million redevelopment within one year.** |

M-3 - Heavy Industrial Zone

**FIGURE 3-1**
**EXAMPLES OF MRF RESIDUAL COMPOSITION**




The MRF is located in an industrial zone in the City of Oxnard with a rail and truck road access to the facility. The MRF occupies approximately 27 acres, and the City of Oxnard owns approximately 10-15 acres of land adjacent to the property.

The MRF is owned by the City of Oxnard and operated by Republic Services, an example of Public-Private Partnership. They are very interested in conversion facility beside their MRF to process MRF residue.

### 3.2.2 Community Recycling/Resource Recovery, Inc. in Sun Valley

Community Recycling/Resource Recovery Inc. is located at 9147 De Garmo Ave, Sun Valley, California 91352. The permitted daily throughput of this MRF is 1,700 tons/day. At the present time it processes approximately 1,500 tons/day of MSW. Approximately 1,350 tons/day residue is going to the landfill from this facility. Community Recycling operates one of the largest composting facilities in California utilizing municipal green and food waste and it is also one of the largest C&D recyclers with a daily operating capacity of 2000 tons/day. A detailed waste characterization and composition of the MRF residue is not available. This MRF is very interested in developing a conversion system adjacent to their facility. They have approximately 3 acres of land adjacent to their facility, which at this time is used to process woodchip and green waste. This land would be made available for a conversion facility. Also, in addition to this, they have 3 acres of land across the street from the MRF facility. The traffic is very congested in the streets around the facility. The zoning of this facility is heavy industrial M-3-G according to their operators.

### 3.2.3 Central Los Angeles Recycling Center and Transfer Station

Central Los Angeles Recycling Center and Transfer Station located at 2201 Washington Boulevard in the City of Los Angeles, California 90034. This transfer station was operated by BLT until 2004. In 2004 the City of Los Angeles took over the operation of this facility. The City of Los Angeles black bin waste is coming to this facility (the City of Los Angeles provides its residents three bins. A blue bin is used for all recyclable items, green bins for all green waste and black bins for the remainder of MSW going to a transfer station. A very preliminary and rough waste characterization was performed by URS in 2004, which is included in Attachment 3. Daily permitted throughput for this facility is 4,025 ton/day. At the present time the facility receives approximately 3,000 ton/day. All 3,000 tons/day is going directly to the landfill because this facility is operating as a transfer station only. There is some equipment for material recovery but according to BLT operators this facility never operated as a MRF. The TS is located in a heavy industrial zone with approximately 9 acres of land available adjacent to this TS.

### 3.2.4 Robert A. Nelson Transfer Station and MRF (RANT)

The Robert A. Nelson Transfer Station and MRF is located at 1830 Aqua Mansa Road, Rubidoux, CA 92509 in the County of Riverside. Burrtec Waste Industries, Inc. operates the MRF. This MRF is permitted for 2,700 tons/day and receiving approximately 2,700 tons/day MSW. The amount of residue generated by this MRF and going to the landfill is approximately 2,060 tons/day. Part of the MRF is operating for material recovery and part is operating only as transfer station. This MRF is located in the Recycling Market Development Zone in a heavy industrial City zoning area. The land use surrounding this facility is suitable for a conversion facility and there are undeveloped land available adjacent to the MRF to locate a conversion facility.

### 3.2.5 Perris MRF/TS

The Perris Transfer Station and MRF is located in 1706 Goetz Road Perris, California 92570 in the County of Riverside and operated by CR&R. The daily permitted throughput of this facility is 1,800 tons/day, which will be expanded to 3,600 tons/day. This facility is going through $15 million renovation and CR&R Incorporated is in the process of designing a new state-of-the-art mixed MRF at Perris facility, which will be capable of producing an engineered fuel for gasification. CR&R already reserved 3 acres of land beside the MRF in the master plan for a conversion facility. CR&R is also very interested in conversion technology for processing its residue currently going to the landfill.

### 3.2.6 Santa Clarita MRF/TS

The Santa Clarita MRF/TS is planned to open in 2006. The proposed site for this MRF/TS is 26000 Springbrook Ave. Santa Clarita, California 91350. This location is in dispute at this time because of Rail Road crossing. The permitted throughput of this planned MRF/TS is 1,000 tons/day. Burrtec Waste Industries is designing this facility for the City of Santa Clarita. They also indicated that they are very interested in a conversion facility regardless of the location of this MRF because they are planning to have adequate space adjacent to it for a conversion facility and should be included in the short-list for a conversion technology demonstration facility. The Alternative Technology Advisory Subcommittee decided that the Del Norte, Robert A. Nelson and Perris MRF/TSs would be preferred for the first phase of the project.

## 4.1 INTRODUCTION

The Alternative Technology Advisory Subcommittee's goal is to develop a conversion technology demonstration facility in partnership with a Materials Recovery Facility and Transfer Station (MRF/TS) in Southern California. The main purpose of this phase of the project is to find the most suitable combinations of MRF/TSs and conversion technologies that can process the residue from the MRF/TS currently going to landfill. In order to evaluate the most suitable combinations, first MRF/TSs of Southern California were evaluated and a short list of MRF/TSs was established. Also, conversion technology suppliers were evaluated to identify suitable conversion technologies. The most suitable combinations of MRF/TSs and conversion technology are evaluated in this section.

## 4.2 PREFERRED MRF/TS

As discussed in previous sections, all MRF/TSs of Southern California were evaluated in order to find the most suitable MRF/TS that has the ability and willingness to partner with a conversion technology supplier. These MRF/TSs should be able to provide the following:

- Produce the required quantity and composition of the feedstock for a conversion facility
- Reduce environmental impacts such as noise, odor, and traffic in comparison to a new conversion facility
- Provide zoning and siting advantages for a conversion facility
- Provide synergies, such as the ability to provide the required feedstock quality so that preprocessing costs for the conversion facility can be avoided
- Provide financial incentive such as locating the facility in a Recycling Development Zone
- Willingness to create a partnership with a conversion technology supplier

A detailed evaluation of the Southern Californian MRF/TSs is provided in the MRF evaluation of Southern California section of this study. The MRF evaluation was based on a survey conducted by URS Corporation and site visits by the Los Angeles County Alternative Technology Subcommittee members to the selected MRF. The following MRFs made to the shortlist of preferred MRF/TSs to be considered for a conversion technology demonstration facility:

- Del Norte Regional Recycling and Transfer Station (Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) (Riverside County)
- Perris MRF/TS (Riverside County)
- Santa Clarita MRF/TS (Planned MRF)

- Community Recycling/Resource Recovery, Inc. in Sun Valley (City of Los Angeles)
- Central Los Angeles Recycling Center and Transfer Station (City of Los Angeles)

Preferred MRF/TS information summary is provided in Table 4-1.

## 4.3 PREFERRED TECHNOLOGIES

Conversion technologies and their capabilities are described in Section 1.0 of this report. Conversion technology suppliers were screened and ranked by issuing a questionnaire to the suppliers and evaluating their responses to the questionnaire. The detailed description of screening and ranking of the technology and technology suppliers are described in Section 2.0. Preferred technologies were identified using the following general criteria:

- The technology must have the capability to process MRF/TS residue.
- The technology must divert at least 50 percent of the waste stream.
- The technology must be capable of processing 100 tons/day in a demonstration project.
- Costs and revenues must be "reasonable" for a demonstration project.

Based on the information received from the technology suppliers, the following technologies were selected to be considered by the County for development of conversion technology demonstration facility:

- Thermal Conversion:
    - Pyrolysis/gasification
    - Gasification
    - Plasma gasification
    - Thermal depolymerization
    - Pyrolysis including flash pyrolysis and steam reforming pyrolysis
- Biological/Chemical Conversion:
    - Anaerobic digestion
    - Gasification with fermentation to ethanol

## TABLE 4-1
## PREFERRED MATERIAL RECOVERY FACILITIES INFORMATION SUMMARY

| MRF | Acres Available | Information |
|---|---|---|
| Del Norte Regional Recycling and Transfer Station | 10-15 acres | Del Norte is located in the City of Oxnard County of Ventura, California. The facility is operating as a MRF and Transfer Station. The permitted daily throughput of this MRF/TS is 2,700 tons. The facility is accepting approximately 1,350 tons/day. The MRF and Transfer Station combined generate an average of approximately 890 tons/day residue.<br>A detailed waste characterization for this facility is available.<br>This MRF is located in the Recycling Market Development Zone and in a heavy industrial zone in Ventura County with a rail and truck road access to the facility. This MRF is occupying approximately 27 acres.<br>The Subcommittee members visited this MRF as part of the evaluation. |
| The Robert A. Nelson (RANT) Transfer Station and MRF | 3 – 5 acres | RANT is located in the County of Riverside. Burrtec Waste Industries, Inc. operates the MRF. This MRF is permitted for 2,700 tons/day and receiving approximately 2,700 tons/day MSW. The amount of residue generated by this MRF and going to the landfill is approximately 2060 tons/day. Part of the MRF is operating as a MRF and part is operating only as a transfer station.<br>A detailed waste characterization and composition of the MRF residue for this facility is not available.<br>This MRF is located in the Recycling Market Development Zone in a heavy industrial City zoning area. The land use surrounding this facility is suitable for a conversion facility and there are undeveloped land available adjacent to the MRF to locate a conversion facility.<br>The Subcommittee members visited this MRF as part of the evaluation. |
| Perris Transfer Station and MRF | 3 acres | Perris TS and MRF is located in the County of Riverside and operated by CR&R. The daily permitted throughput of this facility is 1800 tons/day, which will be expanded to 3600 tons/day.<br>This facility is going through $15 million renovation and CR&R Incorporated is in the process of designing a new state-of-the-art mixed MRF at Perris facility, which will be capable of producing an engineered fuel for gasification. CR&R already reserved 3 acres of land beside the MRF in the master plan for a conversion facility.<br>A detailed waste characterization and composition of the MRF residue for this facility is not available.<br>This MRF is located in the Recycling Market Development Zone and heavy industrial City zoning area.<br>CR&R is also part of Renewable Resource Alliance (RRA), which is a partnership between Primenergy, CR&R, and Community Recycling. This partnership is trying to develop a conversion facility in Southern California Mr. Paul Relis a principal of CR&R made a presentation at the Subcommittee meeting discussing their efforts for conversion facility development processing MRF residue at the Perris facility. |

## TABLE 4-1 (CONTINUED) PREFERRED MATERIAL RECOVERY FACILITIES INFORMATION SUMMARY

| MRF | Acres Available | Information |
|---|---|---|
| Community Recycling/ Resource Recovery Inc. | 3 acres | Community Recycling is located in Sun Valley, California. Approximately 1,350 tons/day residue is going to the landfill from this facility.<br>Community Recycling operates one of the largest composting facilities in California utilizing municipal green and food waste.<br>This MRF is very interested in developing a conversion system adjacent to their facility. They have approximately 3 acres of land adjacent to their facility, which at this time is used to process woodchip and green waste. This land would be made available for a conversion facility. Also, in addition to this, the facility has 3 acres of land across the street from the MRF facility.<br>A detailed waste characterization and composition of the MRF residue for this facility is not available.<br>The traffic is congested in the streets around this facility.<br>This MRF is located in the Recycling Market Development Zone in a heavy industrial (M-3-G) zone according to the operators.<br>This facility is part of Renewable Resource Alliance, which is a partnership between Primenergy, CR&R, and Community Recycling. This facility indicated that they will help financially for a conversion facility development.<br>The Subcommittee members visited this MRF as part of the evaluation. |
| Central Los Angeles Recycling Center and Transfer Station | 9 acres<br>(Questionable) | Central LA Transfer Station is located in the center of Los Angeles. This transfer station was operated by BLT until 2004. In 2004 the City of Los Angeles took over the operation of this facility. This facility is a transfer station for the City of Los Angeles black bin waste. Daily permitted throughput for this facility is 4,025 ton/day and at the present time the facility receives approximately 3,000 ton/day. All 3,000 tons/day is going directly to the landfill.<br>A very preliminary and rough waste characterization was performed by URS in 2004.<br>The TS is located in a heavy industrial zone with approximately 9 acres of land available adjacent to this TS. The long-term availability of this land is questionable.<br>The City of Los Angeles (the operator of this facility) is also exploring options for alternative waste disposal facility. |
| The Santa Clarita MRF/TS | Planned | Santa Clarita MRF/TS is planned to open in 2006. The proposed site for this MRF/TS is 26000 Springbrook Ave. Santa Clarita, California 91350. This location is in dispute at this time because of Rail Road crossing. The permitted throughput of this planned MRF/TS is 1000 tons/day. Burrtec Waste Industries is designing this facility for the City of Santa Clarita.<br>The City of Santa Clarita also indicated that they are very interested in a conversion facility regardless of the location of this MRF because they are planning to have adequate space adjacent to it for a conversion facility. Therefore, the facility should be included in the short-list for a conversion technology demonstration facility. |

## 4.4 TECHNOLOGY/MRF COMBINATIONS

### 4.4.1 Thermal Conversion/MRF Combinations

Thermal conversion technologies were evaluated for the development of a conversion facility in Southern California with combination of a MRF. The following issues were considered for the thermal conversion and MRF combinations:

- Waste suitability
- Feedstock availability
- Preprocessing needs
- Space availability
- Environmental compatibility
- Infrastructure availability

#### 4.4.1.1 Waste Suitability

Although a detailed and comprehensive waste characterization for the MRF residue was not available at this time, the available waste characterization data were used to evaluate the application of thermal conversion technologies. All thermal technologies evaluated in this study that made the shortlist are capable to treat carbon-based portion of the MRF residue.

The Perris MRF, which is owned and operated by CR&R is going through an extensive renovation. The Santa Clarita MRF/TS is planned and will be designed by Burrtec Industries. These two MRFs can be designed to generate a specific feedstock suitable for a thermal conversion unit. Also, each of the other four Southern Californian MRFs in the shortlist indicated that they are flexible enough to generate feedstock for a thermal conversion facility; therefore a combination of thermal conversion technology and MRF does not have a limitation on the basis of feedstock suitability.

#### 4.4.1.2 Feedstock Availability

The Los Angeles County Alternative Technology Subcommittee is planning to develop a conversion technology demonstration facility adjacent to a MRF/TS in Southern California. This demonstration facility will process at a minimum of 100 tons/day MRF residue. All six MRF/TSs in the shortlist can generate at least 100 tons/day of residue.

#### 4.4.1.3 Preprocessing

Thermal conversion technologies require specific preprocessing of MSW waste before processing in a conversion unit, such as size reduction, moisture content etc. MRF residue is going through resource recovery, but not necessarily preprocessing. The MRF residue may require additional equipment and processing to be prepared for treatment in a conversion unit. The Perris MRF operated by CR&R is undergoing an extensive renovation and Santa Clarita MRF/TS is planned by Burrtec Industries. Both MRFs can be designed to produce feedstock for a specific thermal conversion unit. The other four existing MRF facilities on the shortlist are willing to make changes to generate the specific feedstock for a thermal facility.

#### 4.4.1.4 Space Availability

Thermal technologies evaluated in this study require 1-3 acres of land adjacent to the MRF facilities. The Perris MRF is going through a renovation and they indicated that they reserved 3 acres in the master plan for a conversion facility. The planned Santa Clarita MRF also will have enough space for a conversion facility. The four existing MRFs have space available for the development of a conversion facility.

#### 4.4.1.5 Infrastructure Availability

Developing a conversion facility at a MRF/TS location will require additional infrastructure, such as electricity interconnect, water supply, sewer, and transportation access. The short-listed MRF/TS facilities are located in industrial areas that should have sufficient infrastructure to support a conversion facility.

#### 4.4.1.6 Environmental Compatibility

Environmental and regulatory issues relating to developing a conversion facility at one of the short-listed MRF/TSs are discussed in the Siting Plan.

### 4.4.2 Biological/Chemical Conversion/MRF Combinations

Biological conversion technologies were also evaluated using the technology supplier's response to the questionnaire and MRF/TS evaluation. The same issues that were evaluated for thermal technologies were used to analyze the biological technology/MRF combinations.

#### 4.4.2.1 Waste Suitability

**4.4.2.1.1 Anaerobic Digestion (AD).** AD is using only the biodegradable portion of the MRF residue to generate biogas and compost or soil amendment material. Very extensive material preprocessing is required to generate the consistent composition of feedstock for AD units. The MRF residue may have to undergo another round of processing before it can be utilized by AD facility.

**4.4.2.1.2 Gasification with Ethanol Fermentation.** In this technology the carbon-based portion of MRF residue (including plastic) is treated in a gasifier to generate syngas. The syngas is fermented to produce ethanol.

Most MRF facilities prefer gasification with ethanol production over the biological conversion technologies. This preference is based on assumption that ethanol is a better product to market than compost.

#### 4.4.2.2 Feedstock Availability

As mentioned above, AD can process only the biodegradable portion of MRF residue. The 100 tons/day only biodegradable residue may not be available after extensive resource recovery from some of the MRFs in Southern California. A very comprehensive waste characterization will be required for the development of an AD facility adjacent to a MRF.

With regard to gasification with ethanol production, all six MRFs can provide the required feedstock.

#### 4.4.2.3 Preprocessing

AD technologies require extensive preprocessing of MSW waste, including separation of virtually all non-biodegradable material such as plastic, metals etc. MRF residue is not necessarily homogenous enough for AD processing. The MRF residue will require additional equipment and processing to be prepared for treatment in an AD conversion unit.

Gasification with ethanol production can process all carbon-based portion of MRF residue including plastic and may require little or no changes in MRF operation; therefore, all six MRF in the shortlist can accept this technology.

#### 4.4.2.4 Space Availability

Some of the AD systems require large areas for processing MRF residue. For example Waste Recovery/Valorga, and Canada Compost require 7 and 6 acres of land, respectively. Most of the MRF in Southern California do not have large enough area available adjacent to their facilities.

Other bioconversion systems require smaller area and can be located adjacent to any one of the six MRF/TSs in the shortlist.

#### 4.4.2.5 Infrastructure Availability

Developing a conversion facility at a MRF/TS location will require additional infrastructure, such as electricity interconnect, water supply, sewer, and transportation access. The short-listed MRF/TS facilities are located in industrial areas that should have sufficient infrastructure to support a conversion facility.

#### 4.4.2.6 Environmental Compatibility

Environmental and regulatory issues relating to developing a conversion facility at one of the preferred MRF/TSs are discussed in the Siting Plan.

## 4.5 CONCLUSIONS

### 4.5.1 Most Suitable MRF

Preliminary analysis indicates that any of the six MRF/TSs are suitable for development of a conversion demonstration facility in Southern California. The Perris MRF will be renovated and can be designed for a specific conversion facility. The Santa Clarita MRF/TS is planned and also can be designed to facilitate a conversion unit. Del Norte, Community Recycling, Central Los Angeles, and Robert A. Nelson are also suitable for conversion technologies. Members of the Alternative Technology Advisory Subcommittee at the June 16, 2005 meeting unanimously agreed that the short list of preferred MRFs for the first phase of development of a conversion facility should include:

- Del Norte Regional Recycling and Transfer Station (Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) (Riverside County)
- Perris MRF/TS (Riverside County)

The Community Recycling, Central Los Angeles and Santa Clarita MRF/TSs should also be considered in the next phase of the project.

### 4.5.2 Most Suitable Technology

Preliminary evaluation of conversion technology and conversion technology suppliers showed that the most suitable technologies for MRF/technology combinations are thermal conversion or waste to green fuel technologies. Anaerobic digestion (composting by CIWMB definition) was dropped from the list of most suitable technology processing MRF residue for the following reasons:

- Anaerobic digestion requires very extensive preprocessing of the feedstock. MRF residue may not be a suitable feedstock for anaerobic digestion.
- Anaerobic digestion requires larger area because of a larger footprint.
- Anaerobic digestion (WRSI/Valorga) is in the process of building a commercial facility in Southern California and, therefore, there is no need for a demonstration facility.
- Anaerobic digestion generates a larger percentage of residue, and therefore has a lower diversion rate.
- Anaerobic digestion generates mostly compost and soil amendment with small amount of biogas to generate electricity. The marketing of the compost is questionable.

### 4.5.3 Most Suitable MRF/Technology Combinations

Results of this study conclude that the most suitable MRF/technology combinations are the six MRF/TSs in list of preferred facilities and thermal conversion or waste to green fuel technologies. The Alternative Technology Advisory Subcommittee decided that the Del Norte, Robert A. Nelson and Perris MRF/TS would be included in the short list for the first phase of this project.

In order to select the final most suitable MRF/technology combinations, a more detailed evaluation of the MRF and technology supplier is required. This detailed evaluation can be accomplished by issuing an official RFQ or RFP to selected technology suppliers, and negotiating a partnership between MRF owners and technology suppliers. This can be included in the scope of work for the next phase of the study.

Several supporting documents were included in the scope of work for this project. A brief summary of these documents is presented below and the complete documents are included in appendices attached with this Report.

## 5.1 STRATEGIC ACTION PLAN

The Strategic Action Plan prepared as part of this study considers the prospective steps the County, the Integrated Waste Management Task Force, and its Alternative Technology Advisory Subcommittee may take over short (6-12 month), mid (1-5 years), and long-term to satisfy the objective of this study.

The Strategic Action Plan recommends a number of specific actions for development of a conversion facility in Southern California. The following issues are discussed in this Plan:

- Environmental Issues
- Technical Challenges
- Public Outreach Issues
- Legislative Issues
- Cost and Financing Issues

A preliminary implementation schedule is presented in the Strategic Action Plan, which indicates a possible commissioning date of mid 2008. The Strategic Action Plan is included in Appendix B.

## 5.2 PUBLIC OUTREACH PLAN

A Public Outreach Plan was prepared. This Public Outreach Plan recommends specific actions the County and its Alternative Technology Advisory Subcommittee can take for conducting a public outreach program in connection with development of a conversion demonstration facility in Southern California. This Plan recognizes the unique nature of this project, including the need for public involvement and communication at the community level. This Plan emphasizes the following:

- Why Public Outreach Is Needed
- What Is Public Outreach With Regards to Conversion Facilities
- The Public Interest In A Conversion Facility
- A Strategic Approach to Public Outreach
- Communication Strategy

- Suggested Public Involvement Techniques
- Specific Recommendations

Public acceptability is a major factor for implementation of a conversion demonstration facility. An early and aggressive public outreach program will contribute to the success of this project. The Public Outreach Plan is included in Appendix C.

## 5.3 MARKETING ANALYSIS

Conversion technologies produce marketable products and byproducts. The quality and quantity of these products depend on type and design of conversion systems, and feedstock composition. A preliminary marketing analysis for conversion products was performed as part of this study. The following issues are discussed:

- End Products of Conversion Technologies
  - Electricity
  - Green Fuel
  - Compost and Soil Amendment

Other by-products such as carbon char, chemicals, inert material, and recyclable material may also be produced in small quantities. The type, quantity and quality of these by products depend on the type and design of the conversion systems, type and quality of preprocessing, MRF residual composition, and many other factors. Market analysis for these by products will be addressed in the second phase of this project.

- Market Assessment for Conversion Products
- Expected Market Prices and Volatility

Preliminary market analysis shows that electricity has the most reliable and stable local market. Green fuels are in a developing marketplace and compost market is uncertain and unpredictable. The Market Analysis of conversion products is included in Appendix D.

## 5.4 SITING ANALYSIS

A preliminary siting analysis for the development of a conversion demonstration facility was performed. The following issues are discussed in this analysis:

- Preferred Conversion Technologies
- Preferred MRF Locations
- Regulatory and Permitting Issues

  - CIWMB
  - Air Emissions for Thermal and Bioconversion Technologies
  - Air Permit Requirements
  - Water Discharges
  - Solid Waste

- Environmental Issues and Mitigation
  - CEQA
  - Air Quality
  - Nuisance (Traffic, Odor, Dust, and Noise)
  - Visual Impacts
  - Surrounding Land Use

- Public Acceptability

There are no currently commercial operating conversion facilities processing MSW or MRF residue in the United States. Preliminary data from Japan and Europe indicates that conversion facilities can operate within regulatory framework in the U.S. Facilities with the most advanced environmental control systems would be able to meet regulatory requirements in California.

The actual environmental impacts of a specific conversion technology in a specific location will be evaluated as part of permitting process for the facility.

The Siting Analysis for the development of a conversion demonstration facility is included in Appendix E.

## 6.1 CONCLUSIONS

The following conclusions are based on finding of this study:

I – The results of the technology evaluation indicated that the top ranking technologies are pyrolysis-gasification, gasification, and pyrolysis. The top four suppliers according to their ranking scores for these technologies are:

- Interstate Waste Technologies (Pyrolysis-Gasification)
- Primenergy LLC (Gasification)
- Ntech Environmental (Gasification)
- GEM America (Flash Pyrolysis)

The second group of technologies is anaerobic digestion. Anaerobic digestion was dropped from the list of technologies for reasons provided in Section 4 of this Report.

The third group is waste to green fuel technologies. These emerging technologies do not have commercial facilities processing MRF residue or MSW, therefore they ranked lower. However, the significantly increased development risk may be offset by the potential benefits offered by these technologies. The suppliers for these technologies are:

- Changing World Technologies (Thermal Depolymerization)
- BRI (Gasification-Fermentation)

II – Analysis of the Southern California MRF facilities concluded that six MRF/TSs are preferred for a conversion technology demonstration facility development. They are:

- Del Norte Regional Recycling and Transfer Station operated by Republic Services (City of Oxnard, Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) operated by Burrtec Industries (City of Aqua Mansa, Riverside County)
- Perris MRF/TS operated by CR&R (City of Perris, Riverside County)
- Central Los Angeles Recycling Center and Transfer Station operated by the City of Los Angeles Bureau of Sanitation (City of Los Angeles, Los Angeles County)
- Community Recycling/Resource Recovery, Inc. MRF in Sun Valley operated by Community Recycling (City of Los Angeles, Los Angeles County)

Santa Clarita MRF/TS (Planned MRF to be built by Burrtec Industries, likely in or near the City of Santa Clarita, Los Angeles County)

III – Results of most suitable technology/MRF combinations analysis concluded that the suitable technologies are thermal conversion or waste to green fuel technologies. Anaerobic digestion (composting by CIWMB definition) was dropped from the list of suitable technology/MRF combinations for the reasons provided in Section 4 of this report. The most suitable MRF are six MRF/TSs on the list of preferred facilities. Members of the Alternative Technology Advisory Subcommittee at the June 16, 2005 meeting unanimously agreed that the short list of preferred MRF for the first phase of development a conversion facility should include:

- Del Norte Regional Recycling and Transfer Station (Ventura County)
- Robert A. Nelson Transfer Station and MRF (RANT) (Riverside County)
- Perris MRF/TS (Riverside County)

The Community Recycling, Central Los Angeles and Santa Clarita MRF/TS should be considered in the next phase of the project.

IV – The Strategic Action Plan provides a “road map” for project implementation. The schedule indicates a possible commissioning date of mid 2008.

V – A Public Outreach Plan, which was prepared by this study, emphasized the steps that have to be taken for public outreach and education on conversion facilities. This Public Outreach Plan concludes that public acceptability is a major factor for developing a conversion demonstration facility in Southern California. An early and comprehensive public outreach program will contribute to the success of this project.

VI – The preliminary market analysis shows that electricity has the most reliable and stable local market. Green fuels are in a developing marketplace where current demand outstrips supply in California. The compost market is uncertain and unpredictable.

VII – The siting analysis conducted as part of this study indicates that co-location of a conversion demonstration facility at an existing MRF in Southern California has several advantages over current practices of residue disposal. The actual environmental impacts of a specific conversion technology in a specific location will be evaluated as part of permitting process for the facility.

**Alternative Technology Advisory Subcommittee – Findings and Conclusions**

Based on existing published studies of conversion technologies, including but not limited to those by the University of California at Davis, University of California at Riverside, and the California Integrated Waste Management Board, as well as the findings of this conversion technology evaluation process, and the professional expertise of URS Corporation and Subcommittee Members, the Alternative Technology Advisory Subcommittee of the

Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force also adopted the following preliminary conclusions. These conclusions were adopted in support of the Subcommittee's decision to recommend the development of a demonstration conversion technology facility in Southern California, and it is the intent of the Subcommittee to confirm the validity of these conclusions through the next process:

1. Utilizing conversion technologies to process MRF residues and recover energy or green fuel with marketable byproducts will increase diversion from landfills and enhance Southern California's solid waste management and recycling programs.
2. Each of the technology groups evaluated (pyrolysis-gasification, gasification and waste to green fuel) appeared to be environmentally and technically feasible for processing MRF residue or MSW.
3. Available data from Japan and Europe indicates that conversion facilities can operate within regulatory framework in the U.S. and that facilities with the most advanced environmental control systems would be able to meet regulatory requirements in California.
4. Conversion technologies have been in successful, long-term use around the world, although they typically use more homogeneous feedstocks such as coal and biomass. While technical challenges are expected with most of these technologies, because of their relatively short operating history using MSW as a feedstock and complexity of the process, these challenges are judged to be manageable.
5. Economically, these technologies appear to have the ability to compete favorably with other solid waste disposal methods in a commercial facility.

## 6.2 RECOMMENDATIONS

It is recommended to proceed with the following tasks for development of a conversion demonstration facility to process MRF residue in Southern California:

1. Acquire and confirm and complete data provided by the top four thermal technology suppliers through an official Request for Qualification (RFQ) or Request for Proposal (RFP). These suppliers are:
   - Interstate Waste Technologies (IWT) – Pyrolysis/Gasification
   - Primenergy LLC – Gasification
   - Ntech Environmental – Gasification
   - GEM America – Flash Pyrolysis
2. Acquire and confirm and complete data provided by the two emerging technology suppliers through an official RFQ or RFP. The suppliers for these technologies are:

- Changing World Technologies (CWT) – Thermal Depolymerization
- BRI – Gasification/Fermentation to Ethanol

These technologies do not have a commercial facility processing MSW or MRF residue. Changing World Technologies has a demonstration facility processing turkey waste, and BRI has a pilot facility. While these technologies demonstrate significant promise, the development risk is substantial.

3. Evaluate RFQ/RFP responses and select preferred supplier(s).
4. Clarify permitting pathways and requirements for each technology.
5. Visit preferred suppliers operating facilities.
6. Conduct a detailed evaluation of preferred MRF/TSs in the shortlist.
7. Pursue and negotiate a partnership between MRFs and technology suppliers.
8. Determine the most cost effective and technically feasible throughput for the proposed conversion facility.
9. Pursue funding mechanisms.
10. Start public outreach as early as possible for the implementation of this project.

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