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INITIATION DECISION REPORT (IDR): WASTE TO CLEAN ENERGY

By:

Dr. Eugene Tseng, J.D.
Principal Researcher
UCLA Engineering Extension
Environmental Management Program
Recycling/Municipal Solid Waste Management Program
Sevice-to-Government Research Program

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14. ABSTRACT

This IDR addresses WtCE technology as part of the solution to the growing compliance problem associated with closure of its landfills and disposal alternatives near its shore facilities. Discussion on feasibility of the following goals are discussed: 1. Alleviate the closure impacts of solid waste landfills near Navy installations, 2. Enhance the Navy's generation of clean renewable energy, 3. Prevent overburdening of landfills, and 4. Avoid ever-increasing landfill disposal costs.

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Waste to Clean Energy (WtCE), Non-incinerator, Thermal, Thermochemical, Conversion Technologies, Naval Base San Diego, Landfill Closing, CNO

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The University of California at Los Angeles Engineering Extension and the United States Navy Naval Facilities Engineering Command Engineering Service Center (NAVFAC ESC) do not endorse any specific company or technologies or facilities described in this document. The technology and/or facility descriptions are for the purpose of illustrating examples of various types of projects and technologies that are available for the conversion of municipal solid waste into clean renewable energy. Due to the limited time frame and scope of this project, not all technologies have been included; the listed technologies are only intended to a illustrate examples of the technologies that are available for the conversion of solid waste into clean energy.

The project concepts are generic in nature, and are not to be applied to any specific location without detailed analysis of the appropriate technical, social, cultural, legal, political, and other infrastructure issues and factors that need to be addressed for a project for a specific location.

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Tsuyum Richard Lee, PhD., Project Lead
Environmental Protection Technology Development Branch
Naval Facilities Engineering Service Center

Leslie Lyn McLaughlin
Sustainable Solid Waste Program Manager
Naval Facilities Engineering Command, Southwest

Nathan Eldon Butler
Renewable Energy Program Manager
Naval Facilities Engineering Command, Southwest

Lynn Torres
Specialty Center Acquisitions NAVFAC (SCAN)

Eduardo Llorente
Urbaser SA
Espana, Spain

Yasuhiko Hara, Manager, International Business Development
Ebara Environmental Plant Co. Ltd.
Tokyo, Japan

Kenji Asai, General Manageer
Ebara Environmental Plant Co. Ltd.
Tokyo, Japan

Shigeo Hishinuma, Supervisor for Super Eco-Town
Resource Recycling Promotion Section, Waste Management Division
Bureau of Environment
Tokyo Metropolitan Government, Tokyo, Japan

Takashi Sawada, Director,
Kawasaki EcoTown, Economic and Labor Affairs Bureau
Kawasaki, Japan

Kazumasa Wakimoto, Chief Engineer
JFE Engineering Corporation

Richard Adams
WSN Environmental Solutions
Spring Farm, Australia

Brian Elkins
Solid Waste Authority of Palm Beach County
West Palm Beach, Florida

Jocelyn Lin, Professor
UCLA Engineering Extension, Advisory Board Member
International Environmental Law, University of West Los Angeles School of Law

Greig Louis Smith, Los Angeles City Councilmember
Nicole Marie Bernson, Senior Policy Advisor
Twelfth Council District, City of Los Angeles

William Welch, Principal Development Engineer
Center for Environmental Research and Technology
University of California at Riverside

Coby Skye, Project Engineer
Los Angeles County, Department of Public Works

Kay Martin, Ph.D., Vice President
Bioenergy Producers Association

Yu Yue Yen, Executive Director
Ecotelesis International, Inc.

Karl Wong, Senior Waste Management Specialist
Ecotelesis International, Inc.

Denis Keyes, Senior Statistician / Environmental Justice Analyst
Ecotelesis International, Inc.

Dan Cummings
INEOS Bio
Isile, Illinois

Gary Petersen, Board Member
Governor Arnold Schwarzenegger Environmental Appointee
CalRecycle (formerly California Integrated Waste Management Board)

Wayne Tsuda, Director
Local Enforcement Agency, Environmental Affairs Department

City of Los Angeles
Stephen Shu-Hung Shen, PhD., Administrator
Environmental Protection Administration
Executive Yuan, Republic of China

Tsung Yung Liu, Executive Director
Office of Sustainable Development, Environmental Protection Administration
Executive Yuan, Republic of China

Chiang, Chun-Ching, Director
Environmental Protection Bureau, Bali Refuse Incineration Plant
Taipei County Government, Taipei, Taiwan

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Executive Summary

The technical objective of this project is to develop an Initiation Decision Report (IDR) that evaluates the feasibility of using Waste-to-Clean Energy (WtCE) conversion technologies as alternatives to landfill and incineration in order to: 1) alleviate the closure impacts of solid waste landfills near its installations, 2) enhance the Navy's use of waste as resources and generation of clean renewable energy, 3) to prevent overburdening of landfills, and 4) avoid ever-increasing landfill disposal costs. This waste management approach will drastically reduce the volume of the Navy's non-recyclable wastestream by utilizing it as feedstock material for conversion of WtCE.

The project team reviewed and analyzed solid waste generation data from a report funded by Commander Naval Installations Command (CNIC) and completed by Battelle in January 2011 together with the waste composition data provided by the State of California. Based on its findings and discussions, the team determined that the available solid waste feedstock tonnage at the majority of the naval facilities is not of sufficient volume for a stand-alone regional, or a community-based WtCE demonstration project that is economically feasible. Based on current energy and landfill disposal costs, the Navy should continue support of WtCE technologies as a provider of solid wastes to local commercial and/or municipal WtCE facilities..

The team reviewed over 40 technologies and classified them into three general categories utilized by the Navy: commercially proven technologies, emerging technologies, and developmental technologies. Currently, there are over a dozen commercially proven technologies and over 30 emerging and developmental technologies. Planning and operations information corresponding to these technologies was acquired by the team during facility site visits in over a dozen countries. Discussions with facility developers/operators and the regulatory agencies provided information supporting WtCE project planning, design and operations strategies.

The key findings and recommendations are:

1. ***Thermal Conversion Technologies***. WtCE thermal conversion technologies have been documented and proven for reliable operations. They are commercially available to meet the Navy's combined goals of renewable energy, distributed power generation, improved recycling recovery, maximizing landfill diversion, and reducing greenhouse gas emissions. WtCE thermal conversion technologies are capable of fully complying with the most stringent of air emissions standards and will beneficially impact climate change.

Table E-1 is a list of mature, commercially-proven, non-incineration thermal conversion technologies that are currently available.

Table E-1. Recommended Commercially Available Thermal Conversion Technologies

#	Type of Technology	Feedstock	Examples of Vendors
1	Fluidized Bed Gasification	Refuse Derived Fuel	Ebara, JFE Engineering, EPI
2	Gasification	Mixed Waste and/or Refuse Derived Fuel	Ntech Environmental, JFE Engineering, Thermoselect, IWT, Nippon Steel
3	Gasification / Plasma	Mixed Waste and/or Refuse Derived Fuel	Hitachi-Zosen, Westinghouse/Geoplasma

Note: The University of California at Los Angeles Engineering Extension and the United States Navy, Naval Facilities Engineering Service Center do not specifically endorse any company or technologies or facilities described in this document. The technology and/or facility descriptions are for the purpose of illustrating examples of various technologies that are available for the conversion of municipal solid waste into clean renewable energy.

Information on traditional combustion incinerator technologies is not included in these tables, since the Navy is already familiar with their fundamentals, including usage and acquisition.

2. ***Other Technologies and the "EcoPark Approach."*** Other types of commercially proven, non-combustion conversion technologies are operational around the world. These technologies, such as anaerobic digestion, are utilized to complete the "EcoPark" approach that is discussed in this IDR. Such an integrated approach is expected to maximize the amount of waste diverted from landfill while providing additional energy generation and production of other useful byproducts.

The two main types of non-combustion conversion technologies are thermochemical and biochemical, also differentiated in the terms "thermal" and "biological," respectively. A summary of these classifications is provided in Table E-2.

3. ***Funding, Acquisition, and Benefits***. Naval installations are a small stakeholder in solid wastes management. In many cases, the total lifecycle costs of a WtCE facility suggest that the state and/or local governments should be responsible for the costs supporting the development and operation of a WtCE facility, since they are mandated to ensure compliant, cost-effective solid waste disposal within their respective jurisdictions. It should also be noted that conversion technology projects can be privately funded, designed, procured, constructed, and operated as turnkey projects.

4. ***Supplemental to the Current, On-Going Navy Effort***. The Navy should have an ongoing effort to track and evaluate emerging/developmental technologies in addition to developing an ongoing effort to monitor and evaluate the various projects that are being

developed by the local governments and the private industry. The "lessons learned" from the development and implementation projects of appropriate and financially sustainable WtCE technologies will be invaluable to the Navy.

5. ***Recommendations Based on a Model Site Case Study***. Naval Base San Diego (NBSD) was used as the model for a case study to formulate the recommendations in this IDR. Currently, NBSD accumulates approximately 100 to 150 tons of waste per day, which is not sufficient for the "economy of scale benefits" from Material Recovery Facilities (MRF) with WtCE technologies. The Navy should determine the feasibility of being a principal player/investor and also be an advocate of cost effective, "green" options (of which one is WtCE) for solid waste management via Component Regional Environmental Coordinators (CREC) responsible for interfacing with State and local government.

6. ***Recommendations for installation consideration of WtCE technologies***

- Optimize solid wastes recovery and recycling practices
- Remove objectionable wastes (e.g., food wastes, consumer batteries) that may reduce the energy value of the remaining solid wastes
- Assess and characterize remaining solid wastes to estimate energy value and requirements for pre-processing technologies (e.g., shredding, grinding)
- Conduct a feasibility study of suitable and sustainable WtCE alternatives
- Initiate action supporting alternatives recommended in the feasibility study

Table E-2. Summary of Non-Combustion Conversion Technologies

Conversion Technology Classification	Type of Technology	Preferred Feedstock Materials	Primary Product(s)	Secondary Product(s)	Solid Residues	Notes
Thermochemical (High heat process to convert the organic fraction to synthesis gas or fuel gas)	Gasification	Low Moisture Organics (paper, and other carbon based materials including not readily decomposable organics, e.g. plastics, rubber, etc.)	Fuel Gases (CO, CH_4, H_2) or Synthesis Gas	Fuels, chemicals, and electricity	Inorganic ash, metals, ceramics, glass, stones, etc. (other non-processables from preprocessing)	Synthetic gases can be used to produce methanol, ethanol, and other fuel liquids and chemicals
	Pyrolysis	Low Moisture (dry) Organics (carbon based materials, sludge, including plastics)	Fuel Gases (CO_2, CO, CH_4, H_2) or Synthesis Gas, and Pyrolitic Liquids & Tars	Electricity, some fuels	Carbonaceous char, ash, metals, glass, ceramics, stones, etc. (other non-processables from preprocessing)	Synthetic gases can be used to produce methanol, ethanol, and other fuel liquids and chemicals
	Pyrolysis /Gasifier	Low Moisture Organics (carbon based materials, sludge, including plastics)	Fuel Gases (CO_2, CO, CH_4, H_2) or Synthesis Gas	Electricity, some fuels	Carbonaceous char, ash, metals, glass, ceramics, stones, etc. (other non-processables from preprocessing)	Carbonaceous char often used as a substitute for low grade non-structural carbon black filler applications
Biochemical (Biological and chemical breakdown of organic materials to produce gas, alcohols, or other chemical products)	Anaerobic Digestion	Readily biodegradable Components, food waste, green waste, paper, etc. (plastics and rubber cannot be converted, woody and ligneous materials are difficult to process)	Biogas (CO_2 and CH_4), Ethanol,	Heat, power, solvents, acids, and other bio-based chemicals for refining, and soil amendment	Residue can include inorganics, metals, glass, undegraded/ unprocessed biomass	Bacterial breakdown of biodegradable organic materials. In absence of oxygen. Operates at lower temperatures.
	Fermentation		Ethanol	Heat, and other bio-based chemicals for refining, and soil amendment	Inorganics, metals, glass, undegraded/ unprocessed biomass	Plastic and rubber cannot be converted

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1.0 INTRODUCTION

Historically, the vast majority of municipal solid waste generated by the U.S. Navy has been disposed in local landfills, with a limited number of installations disposing of waste in traditional waste to energy facilities utilizing mass-burn incineration technology. The purpose of this Initial Decision Report (IDR) is to evaluate the feasibility of conversion technology as an alternative to landfill disposal and incineration facilities.

Navy interest in conversion technology is being driven by many factors, including renewable energy, energy security, waste diversion, and climate change. Conversion technologies have been identified as potential solutions that will contribute to the Navy's progress in these important areas.

In the United States, and particularly California, the development of even a basic waste-to-clean energy facility is extremely complex. The use of municipal solid waste (MSW) as a feedstock to produce energy gives rise to a number of regulatory, political, community, and social policy issues in addition to technical and environmental issues. For conversion technology project developers, there is a saying, "You are not in the energy business, you are really in the environmental business!" (Gary Petersen, Board member, California Integrated Waste Management Board (now CalRecycle)).

This Initial Decision Report Waste-to-Clean Energy (WtCE) study examines the technical feasibility and potential project scenarios on how the Navy can utilize the MSW stream as a feedstock in thermal (thermochemcial) conversion technologies for generating renewable energy for its onshore facilities and operations. This report provides an overview of potentially applicable conversion technologies and project scenarios to generate renewable energy from solid waste. The report also includes Navy installations in the San Diego area as a case study, but the conclusions are potentially applicable across the Navy.

The IDR examines how the implementation of WtCE project may help meet the combined and interlinked Navy goals for renewable energy, recycling and solid waste management, and greenhouse gas reduction / climate change, and demonstrate Navy and Federal leadership in environmental sustainability.

1.1 Definition of Municipal Solid Waste (MSW)

For the purposes of this report, MSW refers to the non-hazardous portion of the solid waste stream generated by the residential, commercial, and industrial sectors of a jurisdiction. More specifically, solid waste shall be defined using the California Resources Code, Section 40191 definition:

California Resources Code, Section 40191:

(a) Except as provided in subdivision (b), "solid waste" means all putrescible and nonputrescible solid, semisolid, and liquid wastes, including garbage, trash, refuse, paper, rubbish, ashes, industrial wastes, demolition and construction wastes, abandoned vehicles and parts thereof, discarded home and industrial appliances, dewatered, treated, or chemically fixed sewage sludge which is not hazardous waste, manure, vegetable or animal solid and semisolid wastes, and other discarded solid and semisolid wastes.

(b) "Solid waste" does not include any of the following wastes:

(1) Hazardous waste, as defined in Section 40141.

(2) Radioactive waste regulated pursuant to the Radiation Control Law (Chapter 8 (commencing with Section 114960) of Part 9 of Division 104 of the Health and Safety Code).

(3) Medical waste regulated pursuant to the Medical Waste Management Act (Part 14 (commencing with Section 117600) of Division 104 of the Health and Safety Code). Untreated medical waste shall not be disposed of in a solid waste landfill, as defined in Section 40195.1. Medical waste that has been treated and deemed to be solid waste shall be regulated pursuant to this division.

The California definition of MSW will be used for this report because San Diego was chosen for the case study. Since the specific definition of MSW varies by state, projects in other areas will need to consider the effects of local definitions. The definitions of the material categories and material types used in the waste composition data presented in this report are based upon the CalRecycle's (formerly the California Integrated Waste Management Board) Uniform Material Definitions. These definitions are contained in Appendix A and can also be found on the internet[1]

1.2 Definition of Conversion Technology

Conversion technologies can be classified into three broad categories: 1) Thermochemical conversion (or "thermal") technologies, 2) Biochemical conversion (or "biological") technologies, and 3) Secondary Manufacturing.

This report focuses specifically on thermochemical conversion technologies, with limited discussion on biochemical conversion technologies. Secondary manufacturing is the use of specific components of the mixed MSW stream as raw materials to manufacture new value-added product, involving significant manufacturing/processing steps. For example, in glass "recycling," glass is beneficiated into glass cullet and then used as raw materials in the manufacture of new glass containers or used as a filler (e.g., glassphalt). In

[1] CalRecycle: Solid Waste Characterization Database – solid Waste Material Type Definitions, Alphabetical. http://www.ciwmb.ca.gov/WasteChar/MatDefs.htm.

secondary manufacturing, glass is made into a completely new product, such as construction building materials such as foamed glass and/or glass/ash bricks and tiles. Secondary manufacturing is *no further discussed* in this report.

The following description of thermochemical and biochemical conversion technologies is from the CalRecycle (former California Integrated Waste Management Board) website[2] (see Figure 1):

Thermochemical Conversion Technology

Thermochemical conversion processes include combustion, gasification, and pyrolysis. Potential energy types include heat, steam, electricity, and liquid fuels (biofuels if the feedstock is biomass). Liquid fuel products from thermochemical conversion routes include, ethanol, methanol, mixed alcohols, Fischer-Tropsch (FT) liquids, other renewable gasolines and diesels, pyrolysis oils, and others. There currently are no commercial facilities producing liquid fuels from municipal solid waste (MSW)-derived feedstocks. (There are facilities producing electricity, heat, and steam).

Waste and Biomass to Energy

Waste to energy, also known as combustion, is oxidation of the fuel for the production of heat at elevated temperatures without generating useful intermediate fuel gases, liquids, or solids. Combustion normally employs excess oxidizer (air) to ensure maximum fuel conversion. Products of combustion processes include heat, oxidized species (e.g. carbon dioxide, water), products of incomplete combustion (e.g. carbon monoxide and hydrocarbons), other reaction products (most as pollutants), and ash. Electricity can be produced using boilers and steam-driven engines or turbines.

In the United States, there are currently some 89 facilities that combust MSW for energy recovery (three are in California), consuming about 30 million tons of waste per year. In Europe, about 400 combustion-based MSW energy plants are operating, consuming some 55 million tons of material annually. Sixty to one hundred new MSW combustion plants are expected to be built in Europe in the next ten years to meet landfill and greenhouse gases reduction requirements.
In California, about three dozen biomass to energy plants are in operation. These plants are fueled primarily by wood waste and agricultural residues. For additional information check the California Biomass Energy Alliance website.

Gasification

Gasification typically refers to conversion in an oxygen- or air-deficient environment to produce fuel gases (e.g. synthesis gas, producer gas). The fuel gases are principally carbon monoxide, hydrogen, methane, and lighter hydrocarbons, but depending on the process used, can contain significant amounts of carbon dioxide and nitrogen, the latter mostly from air. Gasification processes also produce liquids (tars, oils, and other condensates) and solids (char, ash) from solid feedstocks. The combustion of gasification-derived fuel gases generates the same categories of products as direct combustion of solids, but pollution control and conversion efficiencies may be improved.
Electricity and heat can be produced by burning the synthesis gas in a steam boiler and turbine plant, a gas turbine, or an internal combustion or Stirling engine generator. Synthesis gases can produce fuel products and other chemicals by chemical reactions such as Fischer-Tropsch synthesis.

Figure 1. CalRecycle Description of Conversion Technologies

[2] CalRecycle: Conversion Technologies – Thermochemical Conversion Processes. http://www.calrecycle.ca.gov/organics/conversion/Pathways/ThermoChem.htm

Pyrolysis

Pyrolysis is the thermal degradation of a material usually without the addition of any air or oxygen. The process is similar to gasification but generally optimized for the production of fuel liquids or pyrolysis oils (sometimes called bio-oils if biomass feedstock is used). Pyrolysis also produces gases and a solid char product.

Pyrolysis liquids can be used directly (e.g. as boiler fuel and in some stationary engines) or refined for higher quality uses such as motor fuels, chemicals, adhesives, and other products. Direct pyrolysis liquids may be toxic or corrosive.

There are several gasification or pyrolysis systems that consume MSW components (usually in combination with other feedstocks such as industrial waste, petcoke, coal, auto-shredder residue, etc.) operating in the world, primarily in Japan and Europe. These include seven Thermoselect gasification facilities and some fifteen Ebara gasifiers operating in Japan and at least two rotary kiln pyrolyzers in Germany. No such facilities that consume MSW components are known to be in commercial operation in the U.S.

Plasma Arc

Plasma arc refers to a specific device used to provide heat for gasification, pyrolysis, or combustion, depending on the amount of oxygen fed to the reactor. Plasma arc processes use electricity passing through electrodes to produce a discharge converting the surrounding gas to an ionized gas or plasma. Gases heated in plasmas typically reach temperatures of 7000° F or higher.

There are two or three plasma arc gasification systems that have used some combination of MSW components and high energy industrial wastes for feedstocks operating in Japan. It has been reported that MSW is no longer consumed in the Japanese plasma arc gasifiers. A gasifier with plasma arc assist is being demonstrated in Ottawa, Canada. The company, Plasco Energy, claims two commercial facilities are being planned for Canada pending successful demonstration of the technology. Though no plasma-based systems are operating in the U.S. (consuming MSW components), several are proposed.

Biochemical Conversion Technology

Biochemical conversion processes include aerobic conversion (i.e., composting), anaerobic decomposition or digestion (which occurs in landfills and controlled reactors or digesters), and anaerobic fermentation (for example, the conversion of cellulose derived sugars to ethanol). Biochemical conversion proceeds at lower temperatures and lower reaction rates (compared to thermochemical processes). Higher-moisture feedstocks, such as food waste, are generally good candidates for biochemical processes.

For biomass feedstocks, the lignin fraction currently can not be converted biochemically,[1] although research is currently investigating lignin fermentation processes.

Energy products from biochemical routes include biogas (also landfill gas) and ethanol (sometimes referred to as bioethanol). Biobutanol and other fermented alcohols are being investigated and could become important biofuels. Biogas can be burned directly for heat or steam or converted to electricity in reciprocating or gas turbine engines, steam turbines, or fuel cells. Biogas can be upgraded to biomethane (by stripping carbon dioxide and minor contaminants) and used as a vehicle fuel, injected to the natural gas transmission system, or reformed into hydrogen fuel.

Figure 1. CalRecycle Description of Conversion Technologies (cont)

The lignin and other stabilized residue from biochemical conversion may be suitable as a compost product or could be used for energy by burning or gasifying, perhaps to supply the energy needs for the biochemical conversion plant. If the residue is of poor quality (i.e., the feedstock came from mixed waste rather than clean source separated material), it may not have a market value and would likely end up in the landfill.

Anaerobic Digestion

Anaerobic digestion (AD) is a fermentation technique that operates without free oxygen and results in a biogas containing mostly methane and carbon dioxide but frequently carrying impurities such as moisture, hydrogen sulfide (H2S), ammonia, siloxane, and particulate matter. Anaerobic digestion occurs in manure lagoons (covered or not), controlled reactors, or digesters and is the principal process occurring in landfills.

Biogas, primarily methane and carbon dioxide, is the principal energy product from AD processes. Biogas can be burned directly for heat or steam or converted to electricity in reciprocating or gas turbine engines, steam turbines, or fuel cells. Biogas can be upgraded to biomethane and used as a vehicle fuel, injected to the natural gas transmission system, or reformed into hydrogen fuel. The digestate from AD (lignin and other stabilized residue) may be suitable as a compost product.

AD systems are employed in many wastewater treatment facilities for sludge degradation and stabilization, and used in engineered anaerobic digesters to treat high-strength industrial and food processing wastewaters prior to disposal.

AD systems are used, primarily in Europe, to treat the biodegradable fraction of solid waste prior to landfilling in order to reduce future methane and leachate emissions and recover some energy.[2,3] As a consequence of the European Commission Landfill Directive, installed AD capacity in Europe has increased sharply and now stands at more than 4 million tons annual capacity.[4]

There are no commercial-scale AD systems operating on municipal solid waste (MSW) in the United States. A few have been operating in Canada. There are a few pilot-scale systems in operation in California. AD technologies are among those appearing on technology review “short lists” for several California jurisdictions exploring alternatives to landfills.

Anaerobic Fermentation

Anaerobic fermentation (i.e., hydrolysis followed by fermentation to alcohols) is generally used industrially to convert substrates such as glucose to ethanol for use in beverage, fuel, and chemical applications and to other chemicals (e.g., lactic acid used to produce renewable plastics) and products (e.g., enzymes for detergents).[6]

Fermentation of starch- and sugar-based feedstocks (i.e., corn and sugar cane) into ethanol is fully commercial but not yet for cellulosic biomass because of the expense and difficulty in breaking down (hydrolyzing) the materials into fermentable sugars.

Cellulosic feedstocks, including the majority of the organic fraction of MSW, need hydrolysis pretreatment (acid, enzymatic, or hydrothermal hydrolysis) to break down cellulose and hemicellulose to simple sugars needed by the yeast and bacteria for the fermentation process. With the possible exception of acid recycling and recovery, acid processes are technologically mature, but enzymatic processes are projected to have a significant cost advantage once improved.[7]

Figure 1. CalRecycle Description of Conversion Technologies (cont)

Lignin in biomass is a byproduct of fermentation processes and is typically considered for use as boiler fuel or as a feedstock for thermochemical conversion to other fuels and products. Hydrolysis of lignocellulosic feedstocks is the subject of intense research.

Alcohols, such as ethanol and butanol, are the primary energy product from hydrolysis and fermentation processes.

There are no known hydrolysis and fermentation systems operating on MSW feedstocks in the world. A facility that would use acid hydrolysis on MSW residuals is undergoing permitting in Southern California.

Figure 1. CalRecycle Description of Conversion Technologies (cont)

While the definitions above have been established, even within a region, terminology has not been standardized. The City of Los Angeles Bureau of Sanitation utilizes the term "Alternative Technology," which includes the traditional mass burn / incineration technology. The City of Los Angeles Bureau of Sanitation describes the newer generation of mass burn incineration facilities as "Advanced Thermal Recycling" facilities to differentiate them from older incineration facilities developed in the 1980's.

Los Angeles County Department of Public Work's Alternative Technology Subcommittee defines "conversion technologies" as the array of emerging technologies capable of converting post-recycling residual solid waste into useful products and chemicals, green fuels like ethanol and biodiesel, and clean, renewable energy. This definition does not specifically exclude mass burn type combustion technologies, but the focus has been on "non-incineration" type technologies (e.g., thermal gasification, etc.)

For the purposes of this report, the Navy will utilize the more narrow definition of conversion technology:

> "Conversion Technology" (CT) is a <u>non-incineration</u> thermal, chemical, biological, or mechanical conversion process, or a combination of those processes, which produces a clean burning fuel for the purpose of generating electricity and/or a renewable fuel from either a solid waste feedstock or from carbonaceous materials not derived from fossil fuels. Note that the traditional mass burn / incineration technology is not included in this definition.

The generation of electrical energy from solid waste utilizing traditional incineration or mass burn technology has been well established and is a commercially proven approach. Therefore, this IDR will not address incineration technologies in detail.

Table 1 summarizes the differences between thermal conversion processes (a.k.a. thermochemical conversion) and biological conversion processes (a.k.a. biochemical conversion):

Table 1. Summary of Non-Combustion Conversion Technologies

Conversion Technology Classification	Type of Technology	Preferred Feedstock Materials	Primary Product(s)	Secondary Product(s)	Solid Residues	Notes
Thermochemical (High heat process to convert the organic fraction to synthesis gas or fuel gas)	Gasification	Low Moisture Organics (paper, and other carbon based materials including not readily decomposable organics, e.g. plastics, rubber, etc.)	Fuel Gases (CO, CH_4, H_2) or Synthesis Gas	Fuels, chemicals, and electricity	Inorganic ash, metals, ceramics, glass, stones, etc. (other non-processables from preprocessing)	Synthetic gases can be used to produce methanol, ethanol, and other fuel liquids and chemicals
	Pyrolysis	Low Moisture (dry) Organics (carbon based materials, sludge, including plastics)	Fuel Gases (CO_2, CO, CH_4, H_2) or Synthesis Gas, and Pyrolitic Liquids & Tars	Electricity, some fuels	Carbonaceous char, ash, metals, glass, ceramics, stones, etc. (other non-processables from preprocessing)	Synthetic gases can be used to produce methanol, ethanol, and other fuel liquids and chemicals
	Pyrolysis /Gasifier	Low Moisture Organics (carbon based materials, sludge, including plastics)	Fuel Gases (CO_2, CO, CH_4, H_2) or Synthesis Gas	Electricity, some fuels	Carbonaceous char, ash, metals, glass, ceramics, stones, etc. (other non-processables from preprocessing)	Carbonaceous char often used as a substitute for low grade non-structural carbon black filler applications
Biochemical (Biological and chemical breakdown of organic materials to produce gas, alcohols, or other chemical products)	Anaerobic Digestion	Readily biodegradable Components, food waste, green waste, paper, etc. (plastics and rubber cannot be converted, woody and ligneous materials are difficult to process)	Biogas (CO_2 and CH_4), Ethanol,	Heat, power, solvents, acids, and other bio-based chemicals for refining, and soil amendment	Residue can include inorganics, metals, glass, undegraded/ unprocessed biomass	Bacterial breakdown of biodegradable organic materials. In absence of oxygen. Operates at lower temperatures.
	Fermentation		Ethanol	Heat, and other bio-based chemicals for refining, and soil amendment	Inorganics, metals, glass, undegraded/ unprocessed biomass	Plastic and rubber cannot be converted

1.3 Definition of a Conversion Technology Facility

Each type of conversion technology has a preference for certain components in the mixed MSW stream for use as a feedstock. Materials that would be considered “non-processable” in a biochemical/biological conversion technology would be an ideal feedstock material in a thermochemical/thermal conversion technology, for example, plastic is not readily biodegradable in a biochemical conversion technology such as anaerobic digestion, but would be an ideal source of high fuel content feedstock in a thermochemical gasification conversion technology. Project developers must be familiar with the available waste stream and also be aware of the different type of feedstock preparation operations required to produce a preferred feedstock for their selected technologies.

Therefore, a conversion technology “project” can utilize both a thermochemical and a biochemical conversion technology in order to efficiently process the greatest portion of the wastestream. This can be considered a “hybrid” technology, but is really a combination of a discrete thermochemical process and a separate discrete biochemical conversion process. An example of this would be a project/facility that utilized a thermal gasification of MSW to produce synthesis gas in the first stage, followed by the utilization of the synthesis gas as a feedstock in a biochemical process to produce ethanol in the second phase. A conversion technology project could also utilize a thermochemical process on a high fuel value portion of the processed waste stream, along with a biochemical process on the high-moisture, readily decomposable and compostable portion of the processed waste stream. This integrated project approach is designed to minimize landfill diversion and also treat each fraction of the wastestream as efficiently as possible.

2.0 PROBLEM DEFINITION

2.1 Extent of the Problem

Metro San Diego Navy installations currently generate approximately 200 to 300 tons per day of MSW. Approximately 50 percent of this waste is recycled, and the balance is disposed at the City of San Diego Miramar landfill. The Miramar landfill is located on Department of the Navy (DON) property, and operated by the City of San Diego under a lease agreement with the DON. The terms of this lease agreement include free tipping for all Navy and Marine Corps generated waste. The Miramar landfill is scheduled to close in 2019; when it closes the Navy will be faced with approximately \$8 to \$12 million in additional disposal costs for transportation and tipping fees at private landfills. (Note: Similar scenarios in future will be able to benefit from the findings in this IDR.)

The Navy is also subject to various statutory, regulatory, and policy goals for the generation of renewable and alternative energy, as discussed in Section 2.2. Rather than incurring the additional costs for landfill disposal when the Miramar landfill closes, the Navy is interested in the potential financial and environmental benefits of converting its MSW into energy.

According to the Annual Energy Management Report, in Fiscal Year 2009, DON consumed renewable electricity equivalent to 0.6 percent of annual electricity consumption per EPAct 2005 goal. The renewable sources include wind and solar electric generation. DON is making progress toward the 10 USC 2911(e) goals, generating 18.9 percent of electricity from renewable sources.

In Fiscal Year 2010, Navy Region Southwest had a base electrical demand of 84 megawatts (MW) with a peak demand of 229 MW. Total consumption for the region was approximately 1.2 million megawatt-hours (MWh).

Naval Base San Diego consumed 413,000 (MWh) in 2010; approximately 1,130 MWh per day. In order to meet the electrical portion of the Secretary of the Navy 2020 goal for Naval Base San Diego to produce at least half of their shore-based energy requirements from renewable sources, 206,000 MWh per year (566 MWh per day) must be generated from renewable sources. Currently, Navy Region Southwest (NRSW) gets renewable energy from solar, wind, and geothermal resources; no renewable energy is being generated from the utilization or conversion of the 100 to 150 tons of MSW generated daily in the Metro San Diego area.

For Naval Base San Diego to use alternative energy sources for at least 50 percent of the facility's total energy needs, including ships, tanks, planes, vehicles, and shore installations, additional research on the potential of producing liquid fuels from solid waste and other renewable sources should also be conducted (not a part of this project).

The "problem definition" is described by the following questions:

1. What thermal / thermochemcial WtCE technologies (non mass burn technologies) are available and appropriate for implementation by Naval Base San Diego to convert MSW to renewable energy?
2. How much energy is potentially available within the waste stream generated by Naval Base San Diego and what impact can WtCE projects have on the Navy's shore facilities' renewable and alternative energy goals?
3. Is a private-public partnership with local jurisdictions and Naval Base San Diego feasible to increase the overall recovery of renewable energy from MSW? (If yes, how much feedstock and how much energy can be potentially generated?)
4. What would a potentially feasible WtCE project scenario look like for Naval Base San Diego?
5. What would be the estimated potential capital and operating costs for such a project?
6. What are the major tasks and what would a potential schedule look like for the development of conversion technology projects?
7. What are the potential issues, regulatory drivers, technology gaps, and other insights/considerations that a Navy project developer needs to be aware of in developing such a project?
8. What is a recommended course of action?

Figure 2 is a pictorial diagram of the current solid waste management practices of Naval Base San Diego.

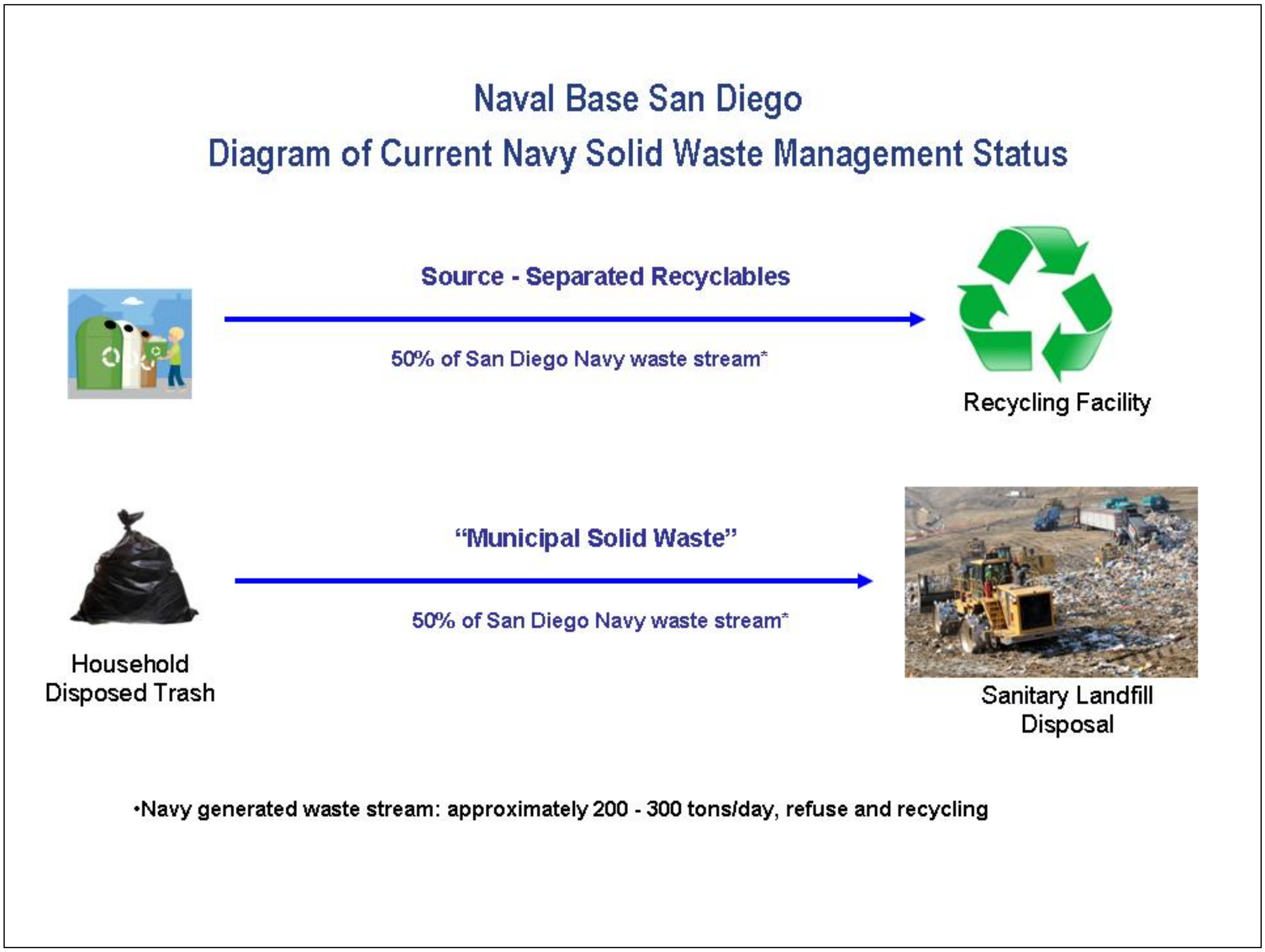

Figure 2. Current Solid Waste Practices at Naval Base San Diego

Figure 3 is a pictorial diagram developed by N. Butler / L. McLaughlin (October 2010) representing the waste flow of a potential WtCE project scenario for Naval Base San Diego (or other naval facilities). The pictorial diagram shows a project in which the materials flow of the waste stream includes recovering energy and additional recyclables from the current post-recycled landfill disposed portion of the waste stream.

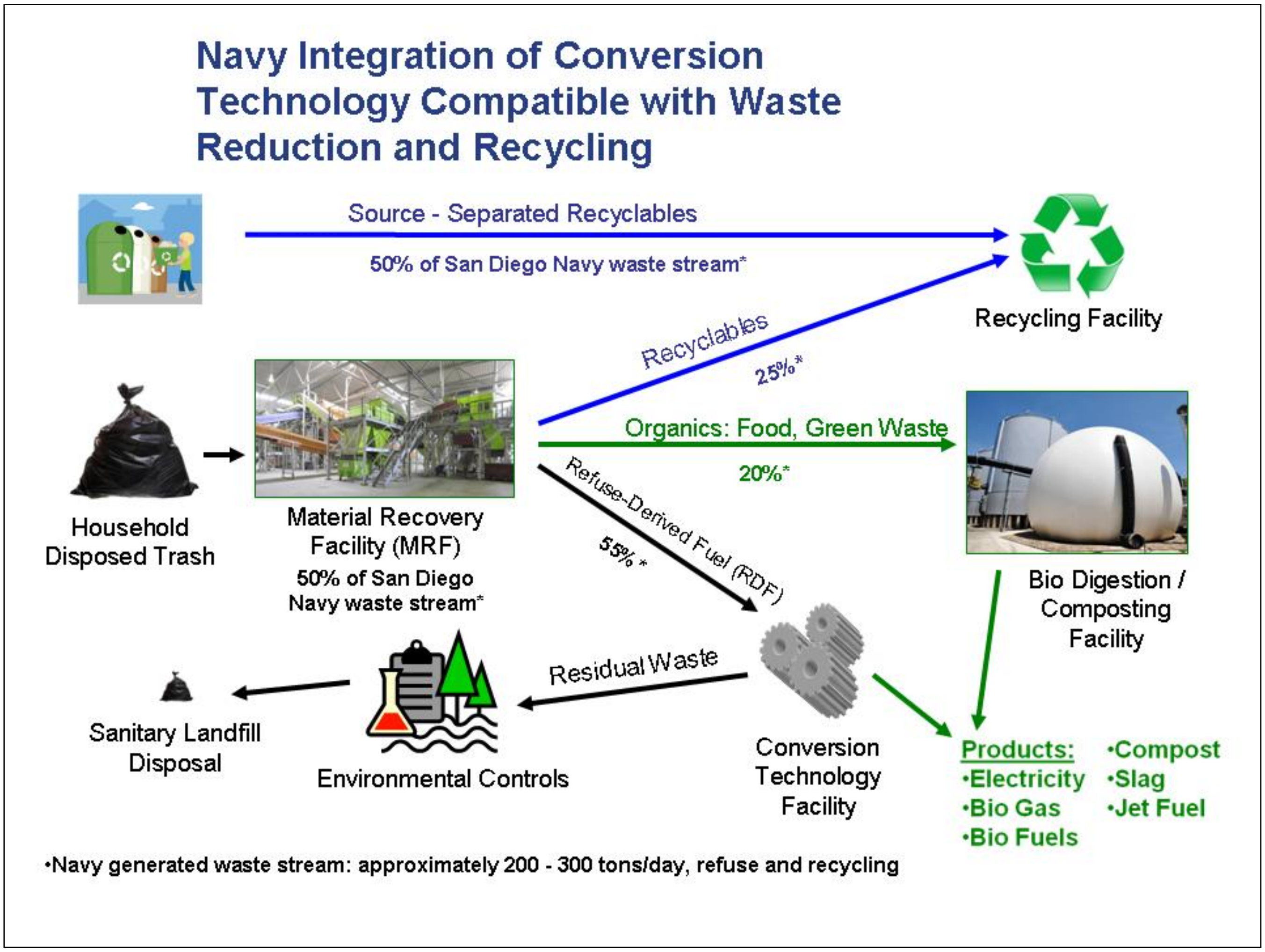

Figure 3. Waste Flow for Potential Conversion Technology Project in Metro San Diego
Source: Naval Base San Diego, NRSW (N. Butler / L. McLaughlin, October 2010)

The project concept shown above is consistent with the well-established "integrated materials recovery facility (MRF) with energy recovery" approach which would recover additional recyclables from the post-source-separated residual waste stream, and which would also provide the needed feedstock preprocessing to create both an organics fraction and also refuse derived fuel fraction, both which could be used for the generation of renewable energy. This project scenario would positively impact the Navy's renewable and alternative energy requirements, recycling mandates, and climate change goals.

Depending upon the type of "conversion technology" selected to recover the energy content, the estimated electrical energy output for a typical thermal conversion technology project is approximately 0.5 MWh per ton to over 1.5 MWh per ton of MSW, with the potential recovery of 100 MWh to 150 MWh per day of electrical energy from the disposed waste stream of the San Diego Navy Base (using a 1.0 MWh per ton factor). If all of the solid waste from the Navy Base San Diego is converted to electricity energy, significant progress towards the 50 percent renewable energy goal of 566 MWh per day will be made. Additional solid waste from local surrounding jurisdictions may be potentially available as additional energy feedstock. Table 2 is summarizing the annual amount of solid waste disposed of by local jurisdictions and the annual amount of potential electrical energy generation from a WtCE facility project.

Table 2. San Diego County Annual Solid Waste Disposal and Energy Potential

SAN DIEGO COUNTY - JURISDICTION ANNUAL DISPOSED TONS 2006 ACTUAL DISPOSAL TONS AND POTENTIAL ENERGY RECOVERY (BASED ON 0.5 MEGAWATT-HOUR OF ELECTRICITY GENERATED PER TON OF MSW)		
COUNTY – JURISDICTION	ANNUAL TONS DISPOSAL	POTENTIAL ENERGY RECOVERY (MEGAWATT-HOURS)
San Diego-Carlsbad	131,637	65,819
San Diego-Chula Vista	204,378	102,189
San Diego-Coronado	54,417	27,209
San Diego-Del Mar	15,392	7,696
San Diego-El Cajon	117,911	58,956
San Diego-Encinitas	78,018	39,009
San Diego-Escondido	146,888	73,444
San Diego-Imperial Beach	18,272	9,136
San Diego-La Mesa	60,902	30,451
San Diego-Lemon Grove	25,182	12,591
San Diego-National City	82,275	41,138
San Diego-Oceanside	165,500	82,750
San Diego-Poway	68,818	34,409
San Diego-San Diego	1,898,490	949,245
San Diego-San Diego-Unincorporated	593,170	296,585
San Diego-San Marcos	102,230	51,115
San Diego-Santee	55,737	27,869
San Diego-Solana Beach	14,802	7,401
San Diego-Vista	130,301	65,151

By increasing the amount of solid waste feedstock to be converted to electricity, a WtCE project will benefit from the economy-of-scale (see Figure 21). Part of the problem definition will be to determine if local jurisdictions should be included in a potential public-private partnership effort with the development of a Navy project.

In a study conducted by Battelle (Analysis of the Feasibility for Waste-to-Energy (WTE) Applications at Navy Sites, Contract N62743-07-D-4013), data related to the amount of waste was provided by the Naval Facilities Engineering Service Center (NAVFAC ESC) in a database for the Navy and Marine Corps bases throughout the U.S. for the years 1997 to 2008. Appendix E lists the calculated theoretical energy contained within the waste tonnage disposed of per year at landfills at the listed naval facilities.

Table 3 gives an approximate value of the potential amount of electricity that could be generated from the solid waste stream using waste-to-clean energy thermal conversion technology from each of the various Navy facilities in Metro San Diego. Table 3 assumes a factor of 0.5 MWh of electrical energy per ton of MSW. A table listing all U.S. Navy facilities is included in Appendix E.

Table 3. Potential Energy Equivalent from Thermal CT – Metro San Diego

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent from Thermal Conversion Technology Megawatt-Hours per Year			
		2006	2007	2008	Average	2006	2007	2008	Average
NAVY REGION SOUTHWEST	CA	8,100	9,557	8,965	8,874	***4,050***	***4,779***	***4,483***	***4,437***
NAS NORTH ISLAND		20,283	13,431	13,404	15,706	***10,142***	***6,716***	***6,702***	***7,853***
NAVMEDCEN SAN DIEGO		1,365	1,953	1,654	1,658	***683***	***977***	***827***	***829***
NAVBASE POINT LOMA SAN		2,537	3,431	2,531	2,833	***1,269***	***1,716***	***1,266***	***1,417***
SPACE AND NAVAL WARFARE		819	990	1,106	972	***410***	***495***	***553***	***486***

Note: Numbers may not add up due to rounding. Also note that these tonnages are based on 2008 data that may not be consistent with current 2010 disposal tonnages.

The available solid waste feedstock tonnage at the majority of naval facilities (including Metro San Diego) is not of sufficient volume to be able to make a project economically feasible for a stand-alone regional or a community sized project. Naval facility tonnages will also be subject to seasonality issues (e.g., when ships come in, war time vs. peace time, and other factors, etc.). Regional facilities serve a multiple number of communities and/or political jurisdictions are generally in the range of 750 tons per day or more. Community based facilities typically serve the solid waste processing requirements for a single community/jurisdiction (or only a few that have formed a joint agreement) are generally in the range of 250 tons per day to about 500 tons per day. For the Navy to have an economically feasible WtCE project based upon current technology costs, the Navy will need to partner with local jurisdictions to obtain an additional amount of feedstock.

2.2 Statutory / Regulatory and Policy Drivers

2.2.1 Energy Drivers

The two primary renewable energy goals for the Department of the Navy (DON) are: 1) the Energy Policy Act of 2005 (EPAct 2005), and 2) 10 USC 2911(e). EPAct 2005 requires three percent renewable electricity consumption, increasing to 7.5 percent by 2013 and 10 USC 2911(e), strives for 25 percent renewable energy produced or procured by Department of Defense (DoD) by 2025.

Energy reform has been made a Navy strategic imperative in a speech given by the Secretary of the Navy, Ray Mabus, on October 14, 2009, the importance of energy security and independence was highlighted:

> "*Moving from strategic to operational and tactical concerns, fossil fuel consumption has a deep impact upon our forces and our force structure, both in terms of the resources required to get fuel and to move it to the ships, tanks, aircraft, and equipment that need it, and in the Sailors and Marines whose duty it is to protect the ships or convoys moving the gas. We do not have*

operational independence and we are tied to a vulnerable logistics tail. The Commandant of the Marine Corps, General Conway said it best during the Marine Corps energy summit a few weeks ago when he described the fully burdened cost of a gallon of gasoline delivered to a piece of equipment in Afghanistan. It turns out that when you factor in the cost of transportation to a coastal facility in Pakistan – or airlifting it to Kandahar – and then you add the cost of putting it in a truck, guarding it, delivering it to the battlefield, and then transferring that one gallon into a piece of equipment that needs it – in extreme cases that gallon of gasoline could cost up to $400."

In addition, the Secretary of the Navy recognized the greenhouse gas (GHG) and related climate change effects from Naval facilities, ships, and aircraft.

"The stakes of the status quo extend even further, beyond the military, and cause second and third order effects on the environment. The carbon that's emitted from our ships, aircraft, and vehicles is a contributor to global warming and climate change. According to the projections endorsed by our own Task Force on Climate Change, global warming could result in an Arctic Ocean free of summer ice within 25 years. The security implications of this are dramatic. In short, we have not acted as very responsible stewards of our environment."

The Secretary of the Navy has (October 14, 2009) set forth very specific energy goals[3], which by 2020 produce at least half of the Navy's shore-based energy requirements from renewable sources:

- When awarding contracts, consider how much energy a building or system will use. Also use the overall energy efficiency and the energy footprint of a competing company as an additional factor in acquisition decisions.

- Demonstrate a "green" strike group composed of nuclear ships, surface combatants equipped with hybrid electric alternative power systems running biofuel, and aircraft flying only biofuels in local operations by 2012 and deploy it by 2016.

- By 2015, reduce petroleum in the Navy's commercial vehicle fleet by 50 percent, adding flex-fuels and electric vehicles.

- By 2020, produce at least half of the Navy's shore-based energy requirements from renewable sources.

- By 2020, use alternative energy sources for at least 50 percent of the Navy's total energy needs, including ships, tanks, planes, vehicles, and shore installations.

The need of alternative sources of energy has been highlighted even more with the events surrounding the leaking offshore drilling platform in the Gulf of Mexico.

[3] Honorable Ray Mabus, Navy Energy Forum. Wednesday, October 14, 2009 at Hilton Mclean, Virginia. http://www.navy.mil/navydata/people/secnav/Mabus/Speech/SECNAV percent20Energy percent20Forum percent2014 percent20Oct percent2009 percent20Rel1.pdf

On October 5, 2009, President Obama issued Executive Order[4] 13514 focused on Federal leadership in environmental, energy, and economic performance. This order was significant in that within its definition of renewable energy, it gave recognition that renewable energy can be produced from municipal solid waste. The applicable portion is shown below:

> EXECUTIVE ORDER (October 5, 2009)
>
> FEDERAL LEADERSHIP IN ENVIRONMENTAL, ENERGY,
> AND ECONOMIC PERFORMANCE
>
> Definitions:
> …
> (j) "renewable energy" means energy produced by solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project; …

The EPA ruled that MSW counts as a source of renewable energy as part of the EPA rules published in the Federal Register (Feburary 4, 2010, RFS2). The biogenic (derived from natural sources) portion of post-recycled MSW qualifies as "renewable biomass" for the purpose of meeting the federal mandate for the production of advanced biofuels, as discussed in Section 6.4 of this report.

The press release that announced the Executive Order (October 9, 2009) and the order itself gave recognition to the fact that energy, solid waste, recycling, and reducing GHG emissions are all related and an integral part of Federal environmental sustainability leadership.

A portion of the press release which ties together energy, solid waste, recycling, and greenhouse gases is shown below:

> **THE WHITE HOUSE**
>
> Office of the Press Secretary
>
> ---
>
> For Immediate Release   October 5, 2009
>
> **President Obama signs an Executive Order**
>
> **Focused on Federal Leadership in Environmental,**
>
> **Energy, and Economic Performance**

[4] Executive Order 13514. http://www.whitehouse.gov/assets/documents/2009fedleader_eo_rel.pdf

Demonstrating a commitment to lead by example, President Obama signed an Executive Order (attached) today that sets sustainability goals for Federal agencies and focuses on making improvements in their environmental, energy and economic performance. The Executive Order requires Federal agencies to set a 2020 greenhouse gas emissions reduction target within 90 days; increase energy efficiency; reduce fleet petroleum consumption; conserve water; reduce waste; support sustainable communities; and leverage Federal purchasing power to promote environmentally-responsible products and technologies.

"As the largest consumer of energy in the U.S. economy, the Federal government can and should lead by example when it comes to creating innovative ways to reduce greenhouse gas emissions, increase energy efficiency, conserve water, reduce waste, and use environmentally-responsible products and technologies," said President Obama. "This Executive Order builds on the momentum of the Recovery Act to help create a clean energy economy and demonstrates the Federal government's commitment, over and above what is already being done, to reducing emissions and saving money."

The Federal government occupies nearly 500,000 buildings, operates more than 600,000 vehicles, employs more than 1.8 million civilians, and purchases more than $500 billion per year in goods and services. The Executive Order builds on and expands the energy reduction and environmental requirements of Executive Order 13423 by making reductions of greenhouse gas emissions a priority of the Federal government, and by requiring agencies to develop sustainability plans focused on cost-effective projects and programs.

Projected benefits to the taxpayer include substantial energy savings and avoided costs from improved efficiency. The Executive Order was developed by the Council on Environmental Quality (CEQ), the Office of Management and Budget (OMB) and the Office of the Federal Environmental Executive, with input from the Federal agencies that are represented on the Steering Committee established by Executive Order 13423.

The new Executive Order requires agencies to measure, manage, and reduce greenhouse gas emissions toward agency-defined targets. It describes a process by which agency goals will be set and reported to the President by the Chair of CEQ. The Executive Order also requires agencies to meet a number of energy, water, and waste reduction targets, including:

- 30 percent reduction in vehicle fleet petroleum use by 2020;
- 26 percent improvement in water efficiency by 2020;
- 50 percent recycling and waste diversion by 2015;
- 95 percent of all applicable contracts will meet sustainability requirements;
- Implementation of the 2030 net-zero-energy building requirement;

- Implementation of the stormwater provisions of the Energy Independence and Security Act of 2007, section 438; and
- Development of guidance for sustainable Federal building locations in alignment with the Livability Principles put forward by the Department of Housing and Urban Development, the Department of Transportation, and the Environmental Protection Agency.

One negative aspect of many renewable energy sources is that they are intermittent in nature; renewable energy generated from solar and from wind technologies are not considered firm (constant and reliable) power because the power cannot be generated on a 24-hour basis. Energy generated from geothermal technologies is firm power, however, the availability of locations with geothermal potential are problematic. The generation of energy from the conversion of solid waste offers the potential of generating firm power at localized facilities in a scheme consistent with a distributed power generation approach.

2.2.2 Solid Waste Management / Recycling Drivers

The Navy has a 50 percent waste reduction and recycling goal to divert the amount of waste being disposed in landfills.

The primary solid waste goals are derived from Executive Order 13514 (portions shown below)

Sec. 2. Goals for Agencies: In implementing the policy set forth in section 1 of this order, and preparing and implementing the Strategic Sustainability Performance Plan called for in section 8 of this order, the head of each agency shall:

(e) promote pollution prevention and eliminate waste by:

(ii) diverting at least 50 percent of non-hazardous solid waste, excluding construction and demolition debris, by the end of fiscal year 2015;

(iii) diverting at least 50 percent of construction and demolition materials and debris by the end of fiscal year 2015;

Chapter 16[5] of OPNAVIST 5090.1C has specific guidance on solid waste management ashore.

The Navy Integrated Solid Waste Management Plan (ISWMP) Guide[6] contains specific guidance on developing solid waste management strategies at Navy installations. Below is an excerpt taken from the guide's executive summary:

Navy installations must make every effort to maximize non-hazardous solid waste diversion to

[5] OPNAVINST 5090. http://www.navy.mil/oceans/5090_1C_Manual.pdf
[6] Navy's ISWMP Guide, 2009. http://www.p2sustainabilitylibrary.mil/p2_documents/UG-2084-ENV_ISWMP_Guide_2009_04.pdf

reduce the volume of waste disposal and minimize the overall cost of disposal. The ISWMP Guide will ensure that Navy ISWMPs reflect a thorough understanding of the composition of their waste streams, available options for diversion or disposal, and associated costs and cost avoidance. In turn, ISW Managers will have the information needed to make systematic waste diversion or disposal decisions based on a more refined environmental management hierarchy in keeping with DoD and Navy policy.

By utilizing MSW as a feedstock for the generation of renewable energy, the solid waste is diverted from landfill disposal consistent with existing Navy mandates to maximize landfill diversion and minimize the overall cost of disposal. Credit for diversion by WTE is measured differently from state-to-state. For the purpose of this report, the discussions on the diversion rate measurement will be based upon the standards/protocols utilized in the State of California and by the U.S. Environmental Protection Agency (U.S. EPA).

The utilization of solid waste for energy recovery is consistent with the U.S. EPA waste management hierarchy[7]; a pictorial depiction of the approach is shown below (Figure 5):

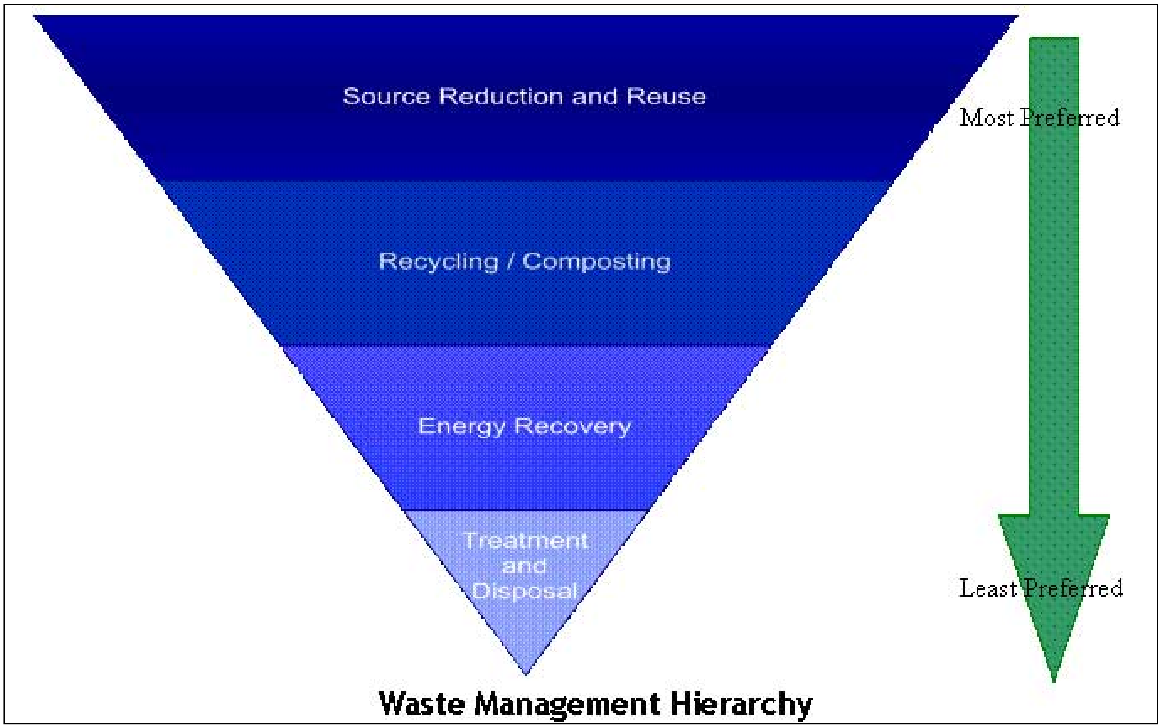

Figure 4. U.S. EPA Waste Management Hierarchy

The DoDs solid waste hierarchy--Reduce, Reuse, Recycle, and Disposal only as a last resort--is also consistent with the U.S. EPA's integrated waste management hierarchy. Any Navy Region project concept will be consistent with both the DoD and U.S. EPA integrated waste management hierarchies.

[7] U.S. EPA waste management hierarchy. http://www.epa.gov/wastes/homeland/hierarchy.htm

In addition to the Navy's recycling mandates, many states have set recycling and/or landfill diversion goals. California passed landmark legislation, the California Integrated Waste Management Act of 1989 (AB 939). Under this legislation, each jurisdiction was required to achieve a 50 percent diversion goal by the year 2000 and maintain/exceed that diversion rate. Some cities in California have set much higher diversion goals, (e.g., City of Los Angeles 70 percent diversion by 2013). Federal facilities are required to meet local recycling and environmental mandates. The implementation of a conversion technology project at Naval facilities will contribute to the diversion of waste from landfills.

2.2.3 California's Global Warming Initiative (AB32)

The United States is not a signatory to the Kyoto Protocol; however, many states have adopted similar goals in an effort to address climate change and global warming. Through California's assembly bill AB32 (Nunez/Pavley, 2006, the California Global Solutions Act) waste reduction/recycling and WTE programs are recognized as programs that can be implemented to reduce the carbon footprint. Landfill gas flaring and landfill gas-to-energy projects are also recognized by the California Climate Action Registry and the California Air Resources Board (Cal EPA) to provide a beneficial impact of reducing the impact of greenhouse gases.

2.2.4 Interface of Solid Waste Management/Recycling and Climate Change

The choice of recycling and solid waste management alternatives impacts the type and volume of GHG emissions. Organic materials decompose in a landfill to generate carbon dioxide and methane. In Europe, in recognition of the impact of GHG from landfills and their contribution to climate change, statutory bans have been implemented to prevent the disposal of organic materials in landfills. In the United States, there are currently no Federal or state landfill bans on organic wastes. In Europe, landfill bans on unprocessed waste and organic materials are the "statutory drivers" that have created the impetus for the implementation of incineration and conversion technology.

Life cycle assessment (LCA), also known as life cycle analysis, is an analytical tool that is utilized to determine the various environmental impacts associated with an operation, e.g., manufacture of a product such as an automobile, production of a chemical, operation of a hospital, operation of a campus, etc.

Figure 5 below is a diagram that depicts the components of a life cycle assessment:

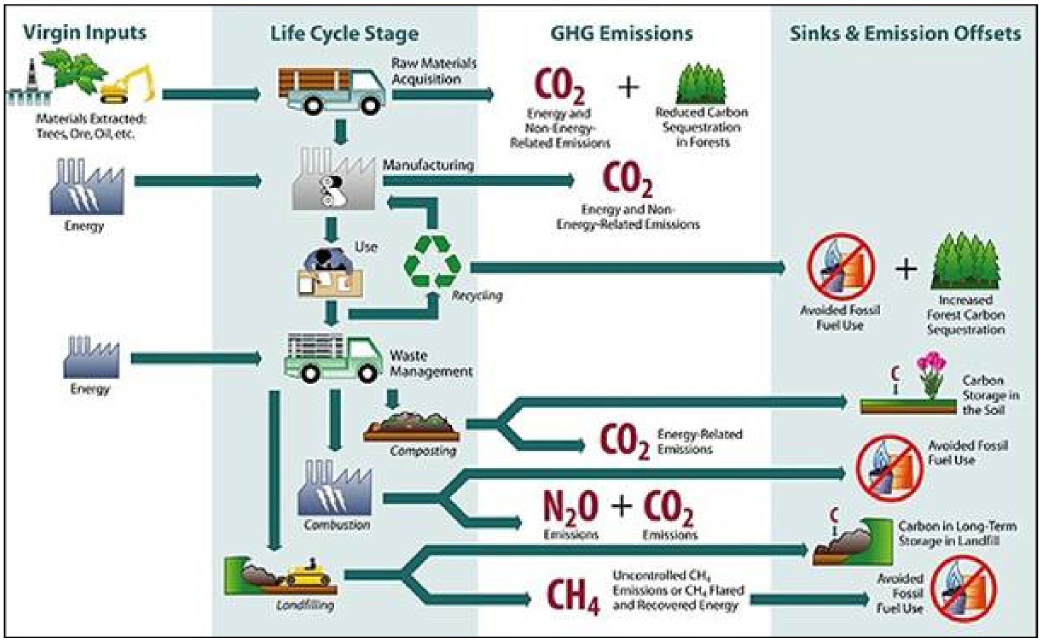

Figure 5. Life Cycle Assessment Diagram (GaBi)

Note the required level of analysis related to the recycling and waste management aspects within the approach of the LCA process. Waste reduction, recycling, and waste management are core programs of an environmental sustainability plan for any institution, business, or facility. The diagram also shows the potential avoided fossil fuel use and GHG emissions related to the management and disposal of waste. From a systems engineering perspective, waste can be viewed as a form of inefficiency of the system. The proper management and disposal of solid waste is an integral part of any environmental sustainability effort and has impacts on climate change. With the increased use of LCAs and/or other analytical tools used to understand the full burdened cost of a facility/operation, there will be a corresponding increase in the understanding of the impact of waste management practices upon GHG emissions and climate change.

3.0 CURRENT TECHNOLOGY

3.1 Overview of Conversion Technology

"Conversion technology" has been well established in Europe and Asia for more than 20 years, and has been an integral part of their waste management approach. Conversion technology facilities have been an accepted approach to meeting recycling mandates, landfill phase-out mandates, and GHG reduction (climate action goals). Many countries in Europe and Asia face conditions such as a lack of natural resources (e.g., lack of oil, high energy costs, etc.), and have a higher population density than the United States, which makes land availability for landfill disposal very problematic. In addition, international climate change initiatives (e.g., Kyoto Protocol, etc.), high tipping fees, and legislative/statutory mandates such as landfill bans of unprocessed waste, in addition to bans on the disposal of materials that have "energy value," have created a “technology driven” infrastructure to spur the development of alternative technological solutions to landfill disposal.

According to “Biocycle” magazine, approximately 70 conversion technology facilities treating bio-wastes or MSW were installed during the 2006 to 2010 period in Europe. The expected installed capacity by the end of 2010 will be about 6 million tons/year; for approximately 200 facilities in 17 European countries. Conversion of WtCE has been very well established as a standard practice in the European Union (and in Japan, where up to as much as 80 percent of the non-recyclable waste is incinerated or gasified).

Conversion technology projects were typically stand alone thermal (conversion and traditional combustion) facilities that focused on energy recovery, or stand alone biochemical facilities (e.g., anaerobic digestion) that focused on the highly decomposable fraction of the waste stream to produce biogas and/or compost / soil amendments.

In the opinion of many researchers, Japan , in the last 10 years, have implemented a significant number of the newest and most innovative full scale thermal conversion gasification technology projects for the purpose of generating renewable energy and maximizing the diversion of materials from landfills. Most of the facilities in Japan are developed as “community based” facilities, and are designed to handle a local community’s solid waste problem in combination with providing electrical energy to the local community and/or industry. It is interesting to note that in Japan, many of the newest thermal gasification facilities are actually designed to reprocess the inorganic bottom ash from existing WTE incinerators (even though ash has no fuel value) for the purpose of creating a glassy slag residue that can be utilized as a building product (thus having to avoid disposal of the incinerator ash in the landfill).

In contrast, in Europe, the traditional WTE mass burn incineration technology is still the predominate technology used for the generating energy from solid waste. Large scale regional facilities which benefit from economy of scale are the preferred approach to integrated solid waste management.

3.2 Current Navy Use of Waste-to-Clean Energy Technology

The Navy currently does not utilize any “conversion technology” that is considered a non-incineration thermal, chemical, biological, or mechanical conversion process, or a combination of those processes, to produce a clean burning fuel for the purpose of generating electricity and or a renewable fuel from either a solid waste feedstock or from carbonaceous materials not derived from fossil fuels.

The Navy currently has a number of bases which utilizes the traditional incineration technology as a form of disposal for the waste generated from those facilities. These WTE incineration facilities are typically part of the local waste management infrastructure of the local government and/or industry, and are not projects specifically developed by the Naval bases.

Table 4. Summary of Waste-to-Energy Navy Activities
(Source: Battelle Screening Study, 2010)

State	Base	Year	Waste Landfill (tons)	Incinerated Waste (tons)	Incineration Cost	Incineration Cost Per Ton
GA	MCLB ALBANY	2005	3,444	1,348	$1,617,512	$1,200
GA	MCLB ALBANY	2006	3,638	754	$904,800	$1,200
GA	MCLB ALBANY	2007	3,201	621	$422,073	$680
GA	MCLB ALBANY	2008	2,659.50	1,756.33		
HI	NAVAL STATION PEARL HARBOR	2005	3,322	3,629	$605,776	$167
HI	NAVAL STATION PEARL HARBOR	2006	2,396	2,834	$525,252	$185
HI	NAVAL STATION PEARL HARBOR	2007	1,885	1,787	$295,576	$165
HI	NAVAL STATION PEARL HARBOR	2008	809	2,518.83		
HI	MCB HAWAII KANEOHE BAY	2005	8,329	3,107		
HI	MCB HAWAII KANEOHE BAY	2006	8,522	2,803		
HI	MCB HAWAII KANEOHE BAY	2007	5,125	1,560	$142,092	$91
HI	MCB HAWAII KANEOHE BAY	2008	256.49	546.53		
HI	PEARL HARBOR NSY & IMF	2005	4,518	1,899	$160,769	$85
HI	PEARL HARBOR NSY & IMF	2006	2,612	1,494	$136,207	$91
HI	PEARL HARBOR NSY & IMF	2007	9,772	1,295	$118,410	$91
HI	PEARL HARBOR NSY & IMF	2008	3,641	1,157.00		
NC	MARINE CORPS AIR STATION	2005	7,888	68	$15,000	$221
NC	MARINE CORPS AIR STATION	2006	9,286	390	$19,500	$50
NC	MARINE CORPS AIR STATION	2007	8,216	0		
NC	MARINE CORPS AIR STATION	2008	8,606.00	1,109		
PA	NAVAL SUPPLY STATION	2005	1,700	0		
PA	NAVAL SUPPLY STATION	2006	1,911	0		
PA	NAVAL SUPPLY STATION	2007	2,228	73	$4,107	$56
PA	NAVAL SUPPLY STATION	2008	2,534.32	0		
TX	NAS JRB FORT	2005	1,803	29	$56,202	$1,938

State	Base	Year	Waste Landfill (tons)	Incinerated Waste (tons)	Incineration Cost	Incineration Cost Per Ton
	WORTH					
TX	NAS JRB FORT WORTH	2006	2,781	31	$59,898	$1,932
TX	NAS JRB FORT WORTH	2007	5,185	18	$33,776	$1,905
TX	NAS JRB FORT WORTH	2008	4,585.99	12.50		

Battelle (from Draft Battelle Report, Analysis of the Feasibility for Waste-to-Energy (WTE) Applications at Navy Sites, Contract N62743-07-D-4013)

3.3 Level of Technology Development

There are many stages in technology development. The technical operational reliability/predictability of a conversion technology and the economics of the operations vary significantly depending upon the stage of development. For the evaluation of conversion technology which generates renewable energy, technologies will be classified into the following five categories.

- Research and Development Stage Bench Scale
- Demonstration Stage
- Scale Up
- Commercially Available
- Fully Mature Commercially Available Technology

"Research and Development Stage" level technology is sometimes referred to as "basic science research" or demonstration of a "proof of concept at a laboratory bench scale." At this level, basic scientific and technical data are generated to determine the chemical and engineering principles behind the technology. The goal is to develop enough information to determine if the basic scientific principles are sound enough so that they can be developed into a potential practical application.

"Demonstration Stage" is the technology level where a "pilot plant" has been built to demonstrate the practical potential for commercial applicability. Typically, in the demonstration stage, the design and technical operating parameters of a technology are refined and optimized so that defensible technical and economic data can be generated for developing a full scale facility. A single "unit process" module (process line) is typically built and is operated on a continuous basis to test various feedstocks and operating conditions. Critical data (e.g., emissions, utility usage, mass and energy balance, etc.) is developed, not only for the operational procedures, but also for regulatory/permitting requirements of a full scale facility. During the demonstration stage, extensive analysis is conducted to determine the competitive technologies and the new technology's market potential. Technologies in the "demonstration stage" are often sometimes referred to as emerging or innovative technologies; not fully proven to be commercially viable, but at the stage of development which indicates the potential promise of commercial viability.

The "Scale Up" stage of a technology is a critical step to full commercialization. The purpose of a scale up is to have a single operating line, which represents the basic minimum "full sized" modular operation unit, to demonstrate feasibility of full commercial scale operations. Different technologies have different sizes and scalability. For some technologies, a full scale single process line module can be as much as 300 to 500 tons a day, whereas for another technology the full scale module is only 100 tons per day (or smaller).

Some technology developers will combine the demonstration stage and scale up stage together in order to expedite the commercialization of the technology. For example, a full commercial facility of 1,200 tons per day capacity can consist of three process lines of a "scale up" stage sized technology which has been demonstrated to operate at 400 tons per day. This represents a modular approach to scalability. Scale up can also be shown in other ways. For well known engineering processes in which scalability have been already technically proven, the scale up stage would only need be within the operating capacity and range of similar processes. For example, a full scale commercial facility with eight digestion tanks with a capacity of 20,000 gallons each has been successfully operating for a similar technology. A scale up facility doesn't need to be of 20,000 gallons if the engineering and other technical principles were shown to be directly scalable at a much smaller level. The ultimate size of the scale up facility depends upon the type of scalable processes within the specific technology and the level of risk associated with scaling process that the project developers are willing to assume.

"Commercially Available" technology refers to a technology that has been operationally proven to be technically reliable and economically feasible at a scale (or throughput) which is at or near its maximum limit. As a result of building additional facilities, the operational costs of a commercially proven technology generally decreases slightly because the experience learned from the first few plants are utilized to optimize the technical parameters and operations. When a technology has reached the commercially available technology stage, the technology is deemed not to have unknown technical issues that have not been dealt with before. When a number of commercially available scale projects have been built and the capital costs are quite predictable and operations are standardized, the technology is said to be mature. Environmental impacts, such as emissions, can readily be predicted and modeled, and can be controlled to meet regulatory standards reliably.

A "Fully Mature Commercially Available Technology" is a technology which has reached a stage in which it can be deemed to be an industry accepted standard approach. Typically, a fully mature commercially available technology will have more than 8 to 10 full scale reference facilities that can be visited. Some mature technologies can be ordered on a modular or "cookie cutter" basis.

To illustrate how the cost of renewable energy ($/kW) relates to the number of facilities (of a specific technology) and the stage of development from basic research to a mature technology, Figure 6, labeled "The "Mountain of Death": The Rise and Decline of Technology Costs through Commercialization" demonstrates the relationship of the $/kW in comparison with the stage of development of a technology.

If the $/kW is of primary importance in deciding which conversion technology to select for implementation, the Navy should be selecting conversion technologies that are "fully mature" and should not consider technologies that are commercially available but may only have a few full scale commercial facilities.

To showcase a demonstration-stage technology with potential for commercialization, the Navy will pay more on a $/kW basis than they would for a mature, optimized technology. However, if the purpose of the Navy is to create a case study for a benchmark commercial proven facility in the United States with the greatest chance for success, minimal risk and the lowest projected cost, then a fully mature technology needs to be selected. The amount of risk assumption and the purpose of a project are critical factors to be considered in the selection of an appropriate technology for a conversion technology project.

3.4 Current Thermal (Thermochemical) Conversion Technologies

Proven commercially available conversion technologies that are currently being utilized by existing facilities can be implemented in the United States to meet the Navy's need for the generation of clean renewable energy, to reduce the Navy's landfill disposed waste stream, and reduce the carbon footprint created by its waste management practices. The primary issue in development of a thermal conversion technology for a WtCE project is not entirely technical, but related to site preparation: siting and permitting of the technology and facility, and also working with the community on issues related environmental justice. The other factors that have to be considered are that in order to successfully site and permit a waste-to-clean energy project utilizing a thermal conversion technology, the Navy may need to develop a public-private partnership with local jurisdictions and/or additional bases (additional waste shed etc.) to have sufficient solid waste feedstock for an economically feasible project.

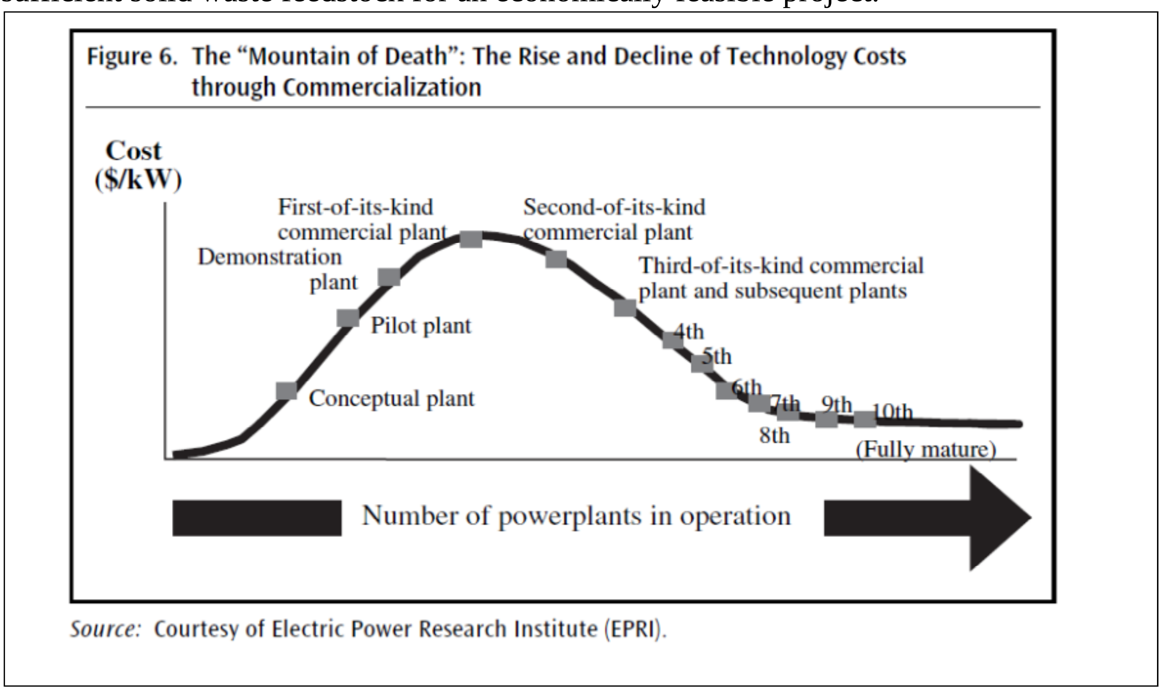

Figure 6. The "Mountain of Death": The Rise and Decline of Technology Costs through Commercialization

(Source: World Bank Working Paper #138, Accelerating Clean Energy Technology Research, Development, and Deployment, Lessons from Non-energy Sectors)

The Navy should utilize a proven mature technology because it will provide the most cost effective operations, and will provide reference facilities and track record for permitting purposes.

Thermochemical conversion technologies (thermal conversion technologies) utilize the energy/heat value of the organic components of MSW. The energy value is extracted in the form of heat, either through the direct combustion of the municipal waste feedstock or by the combustion of the synthesis gas formed by the thermal decomposition (gasification) of the organic materials. The heat is typically used to create high temperature steam in a boiler, just as in a typical electrical generation plant that utilizes natural gas, oil, and/or coal.

Thermochemical conversion technology that generates electricity, in its simplest form, is basically a combination materials recovery facility processing center and electrical generation facility that utilizes solid waste as the primary fuel (instead of natural gas, oil, and/or coal) to produce energy. The “refinery” produces the fuel, and the “utility” portion generates the electrical energy.

There is confusion by many members of the public on the difference between “incineration” and “gasification.” Incineration refers to <u>direct</u> combustion (with stoichiometric <u>excess</u> oxygen atmosphere) of MSW to create heat, whereas non-incineration thermal gasification refers to the conversion of MSW to a “synthesis gas” (a combustible gas, sometimes called “syngas”). In principle, gasification is the thermal decomposition of organic matter in an oxygen deficient atmosphere (in a stoichiometric <u>deficient</u> oxygen atmosphere) producing a gas composition (comprised of H_2, CO, CH_4, C_2, etc.) containing combustible gases, liquids and tars, charcoal, and air, or inert fluidizing gases. Gasification produces a synthesis gas that has fuel value and which in a separate process can be converted to liquid products such as chemicals and biofuels, and/or the synthesis gas can be combusted to create heat.

From a process engineering standpoint, incineration (mass burn technology) is considered a more robust and flexible type of technology because it is designed to accommodate a wider ranging composition of solid waste without the need for preprocessing or front end recycling. In other terms, the mass burn technology was designed to process a solid waste feedstock “as received.” A significant amount of recycling and other preprocessing (e.g., size reduction, blending, removal of inerts, etc.) may be required to produce an optimized feedstock for either thermal gasification or biological conversion technologies.

As a result of the more extensive preprocessing that is required to make a conversion technology feedstock from the mixed MSW the amount of actual feedstock to a biological or thermal technology process is a smaller percentage of the “as received” incoming mixed MSW materials. For example, out of 100 tons of mixed MSW that is received at an incineration facility, almost all of it (all 100 tons) can be put into the mass burn incinerator as feedstock (with limited items that need to be pulled out, e.g., water heaters, etc., things too large for the feed mechanism). On a per-ton input of feedstock, mass burn incineration technology may produce as much as 30 to 35 percent ash that will require disposal.

For a biological process such as anaerobic digestion, even organic materials such as plastic, rubber, and inorganic materials such as glass, ceramics, stones, etc., should be removed from the incoming mixed municipal solid materials because those materials are not readily decomposable to produce a biogas. This conversion technology requires more “preprocessing” to produce a feedstock which is a concentrated feedstock waste stream consisting of the readily biodegradable materials such as food, paper, grass, etc. The readily biodegradable portion represents only a portion of the incoming mixed MSW materials, and can be only about 40 to 60 percent by weight of the incoming materials.

In terms of mass balance for a thermal conversion technology, the inorganic materials are either dealt with prior to the “conversion” process with preprocessing, or dealt with after the “conversion” process as ash. The newer thermal gasification conversion technological approach utilizes preprocessing to remove much of the inorganic materials not only to optimize the feedstock, but also to reduce the amount of potentially harmful emissions that can result of the thermal conversion of solid waste.

Depending upon the specific thermal conversion technology and the amount of preprocessing to create the feedstock, the ash residual from thermal conversion technology may be significantly less. In several of the conversion technology facilities in Japan, ash from the older existing mass burn incineration facilities is actually “re-processed” as feedstock in the newer thermal gasification facilities in order to create a glassy slag which is then utilized as raw materials for creating building materials. This extra effort is designed to maximize the diversion of materials away from landfill disposal.

There is an effort to distinguish “incineration” from “gasification,” particularly in California, because there exists a statutory definition for the term “transformation” that encompasses incineration technology, and there is a separate definition in California for “gasification.” The type of the technology has significant impact upon the permitting requirements. In California, the permitting requirements for incineration facilities are specifically described in the regulations, whereas gasification facilities, at the present time, face a relatively unknown regulatory permitting path. In the year 2010 California legislative session, an Assembly Bill, AB 222 (Adams/Ma,) was considered and would have provided statutory clarity on permitting, diversion credit, as well as defining certain types of conversion technologies as “biorefineries.” (Note: This bill was modified to the extent that it did not meet the original intent of the bill and thus was subsequently withdrawn by the authors.)

Mass burn incineration technology has been implemented in the United States and in many other countries. The primary goals of incineration in the United States and many other countries are volume reduction and energy recovery. Volume reduction achieved by mass burn incineration is typically 10 to 1 (but can range up to 20 to 1 depending upon feedstock materials).

Figure 7 is a pictorial diagram that describes the major components of a traditional mass burn incineration WTE facility (City of Long Beach, California), and Figure 8 is a photograph of the exterior of the incineration facility.

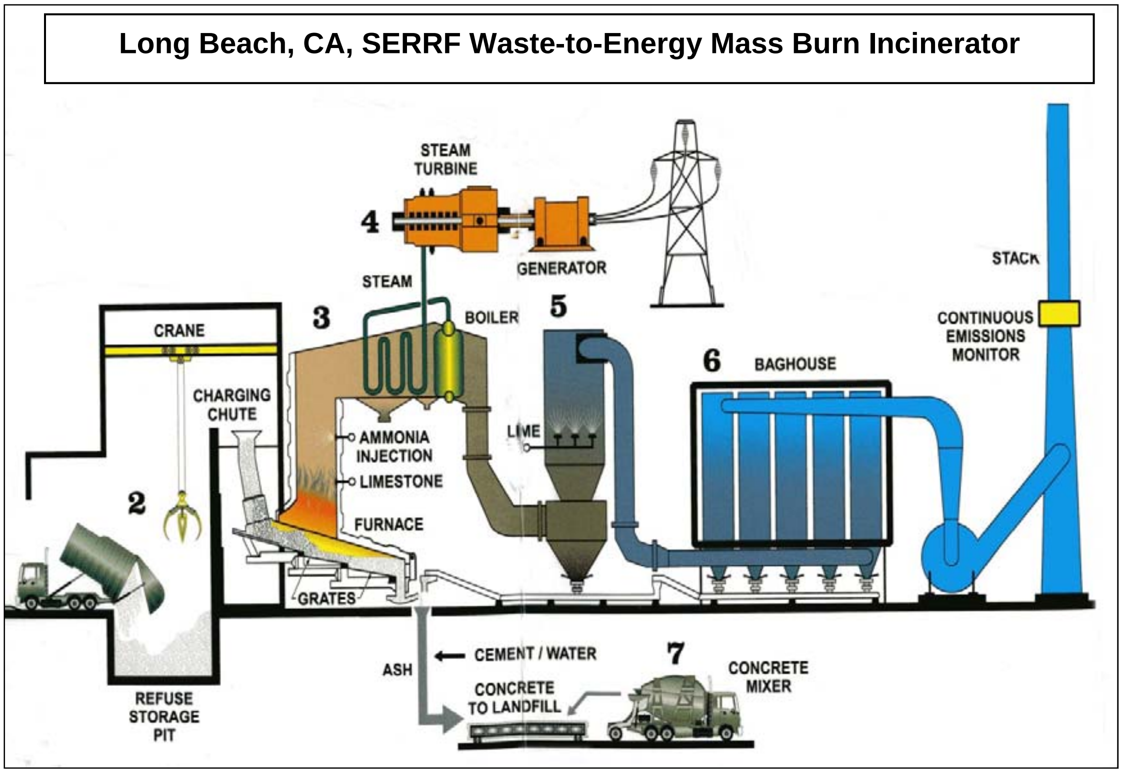

Figure 7. Pictorial of a Typical Mass Burn Incinerator Facility
(Note the direct combustion of the trash on the incinerator grate.)

Figure 8. Long Beach SERRF WTE Facility

Figure 9 shows the solid waste burning on the grate of the incinerator at the City of Long Beach Southeast Resource Recovery Facility (SERRF) on Terminal Island, (located adjacent to the former Naval facilities), City of Long Beach, California.

Incineration technologies are not addressed in this report. Incineration technologies are well established and have been commercial proven and been widely implemented in the United States and internationally for more than 50 years in the MSW industry. This report focuses on the potential use of the newer “non-incineration” conversion technologies to create renewable energy.

Figure 9. Combustion on the Grate of SERRF Incinerator
(UCLA Engineering Extension)

To illustrate how various gasification technologies are technically different from incineration, the following pictorial diagram shows where the synthesis gas (syngas) is produced in the gasifier (shown as a thermal converter in the picture of the IES demonstration plant diagram below), and then separately combusted (in the thermal oxidizer). The location of gasification process which produces the synthesis gas is separately labeled and the location where the combustion of the synthesis gas is also separately labeled in Figures 10 and 11.

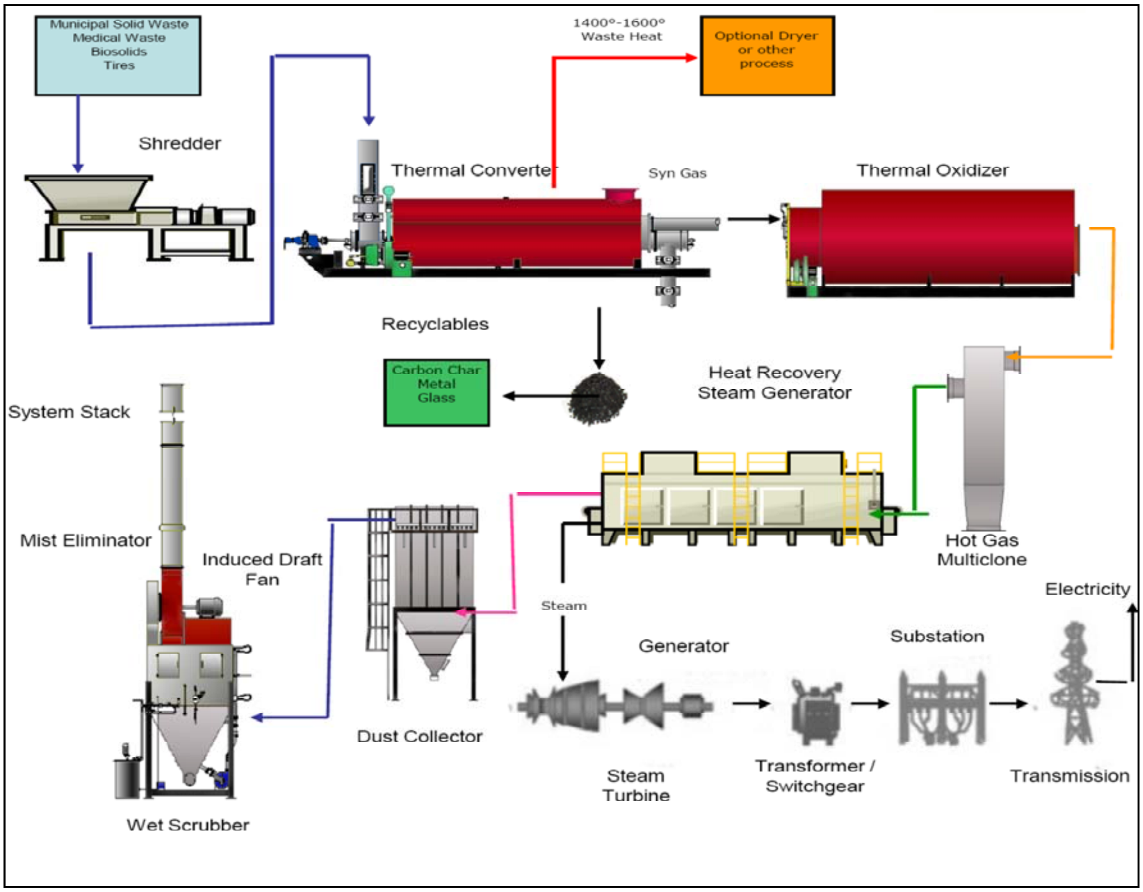

Figure 10. IES Gasification Demonstration Plant Flow Diagram

The IES thermal conversion technology produces a carbonaceous char from the organic materials in the feedstock. This thermal process is referred to as pyrolysis, and is typically operated at a lower temperature that does not remove all the carbon in the char.

It should be noted that the synthesis gas (sometimes called "syngas") that is produced from thermal conversion technologies (using MSW as a feedstock) can also be used to create liquid biofuels, such as ethanol, biodiesel, and Fischer-Tropsch (FT) fuels to meet the renewable liquid fuel goals set forth by the Secretary of the Navy. For the production of energy, synthesis gas is normally combusted to recover the heat content for use in the production of steam and energy generation. A separate study should be conducted by the Navy to evaluate the feasibility of using conversion technologies for the production of liquid fuels.

Figure 11 is a pictorial diagram of a thermal gasification technology referred to as an ash slagging thermal gasifier.

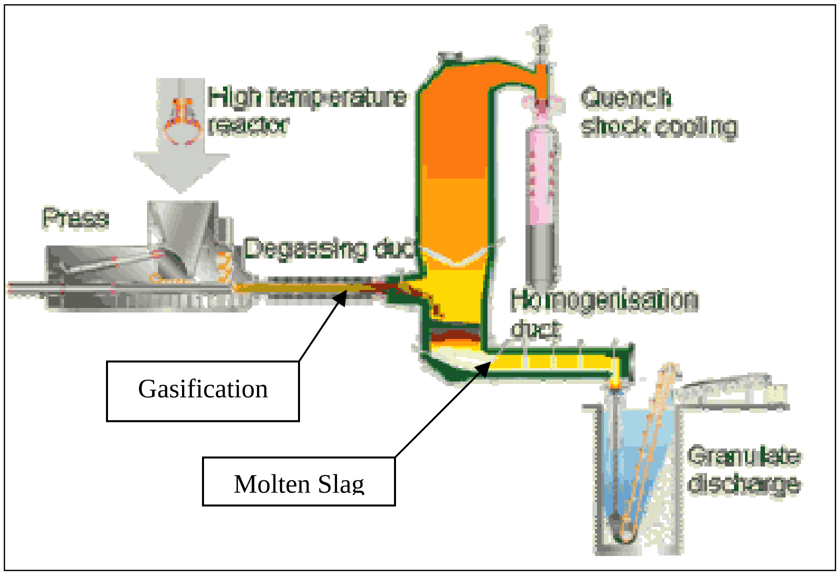

Figure 11. Thermoselect High-Temperature Gasification Technology Diagram

This gasification technology creates a molten slag from the inorganic fraction of the feedstock. The molten slag is quenched in water to create a glassy granulate which can be used as a raw material to make bricks, tiles, and other building materials.

Another example of a thermal conversion technology is the Ebara fluidized bed gasification technology, (Figure 12).

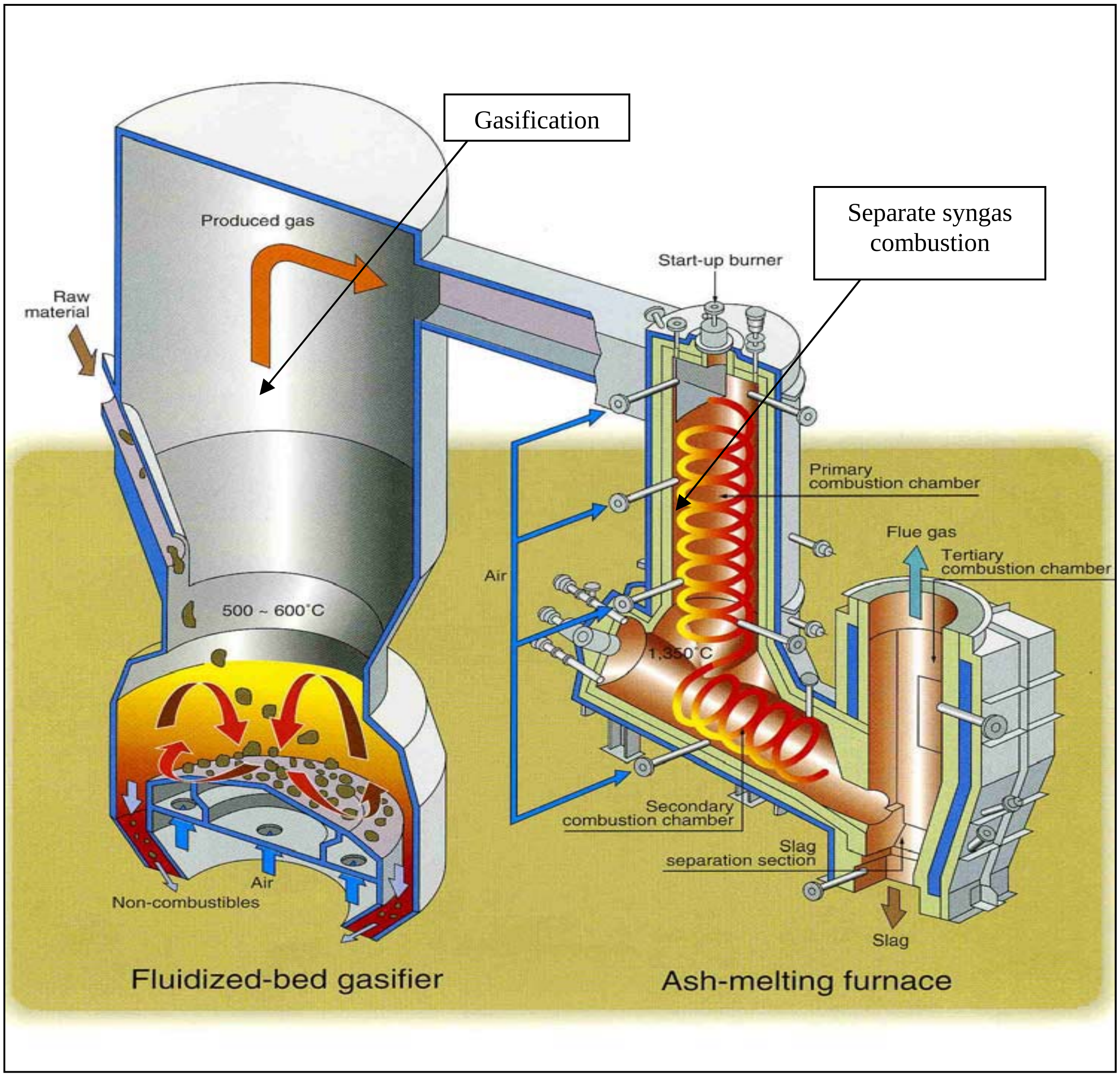

Figure 12. Ebara MSW Fluidized Bed Gasifier Diagram

Note that in the Ebara fluidized bed gasification technology, the gasification part of the conversion process is distinctly separated from the combustion portion of the process. From an engineering perspective, the gasification (production of the synthesis gas) is different from the direct combustion of solid waste on the grate of an incinerator.

Figure 13 is a diagram of the Plasco plasma arc thermal conversion technology. Note the use of the plasma arc for the refinement of the synthesis gas and for melting the ash into a slag.

Confusion between gasification conversion technology and incineration arises because the synthesis gas produced by gasification is eventually combusted at the same facility, as is in a traditional WTE incinerator facility. From the viewpoint of an overall facility, the

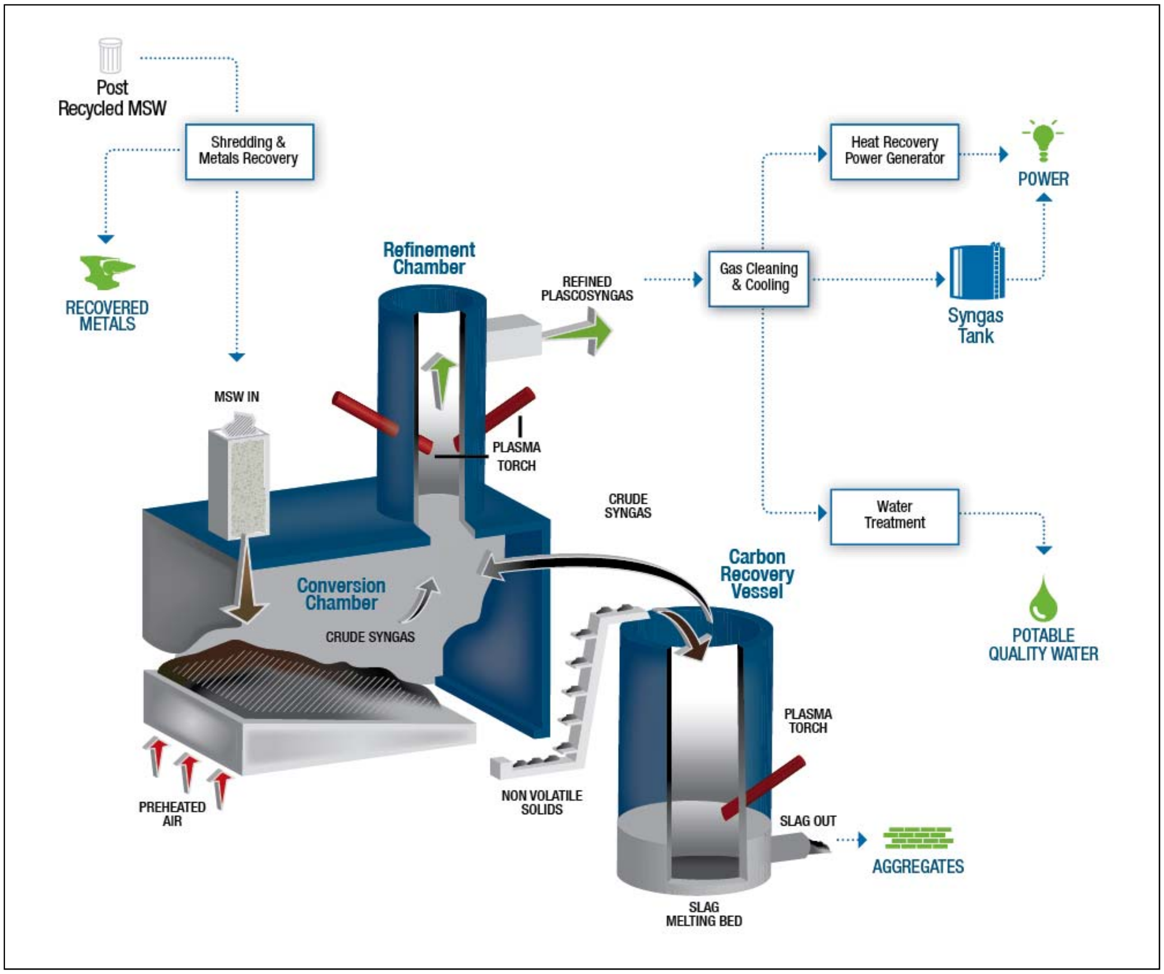

Figure 13. Plasco Plasma Arc Conversion Technology Diagram

confusion arises because "combustion" still takes place (even though it is the combustion of the synthesis gas). For conversion technology projects which are designed to generate electricity with the use of a boiler/generator, the term "staged combustion" is utilized by "incineration" opponents to describe the "conversion technology" project to denote the eventual separate combustion of synthesis gas which are generated by the gasification process. From an engineering standpoint, gasification and incineration are technically different, but within an overall non-technical perspective of an overall facility, syngas from gasification is eventually combusted to produce heat, and thus the conclusion by the public is that there is no difference between gasification and incineration.

The "technologies" to be evaluated in this IDR are for the generation of energy, and will be focused primarily on conversion technologies which utilize a thermal conversion process to convert solid waste into electrical energy. Thermal conversion technologies are generally considered the more effective for converting the carbonaceous materials in the waste stream into renewable energy.

Biological conversion technologies such as anaerobic digestion (produce biogas) typically are not capable of readily converting certain types of carbon based wastes, such as plastics, leather, rubber, and high lignin content wastes. For the purposes of this report only, the focus is on "conversion technology," non-incineration thermal conversion processes that are primarily designed to produce a clean burning fuel (e.g., syngas) for the purpose of generating electricity.

Appendix F contains a list of existing thermal conversion facilities that utilize a solid waste and/or biomass feedstock and process approximately 100 tons per day or more.

The cutoff threshold of 100 tons a day feedstock throughput was utilized because it represents an operational level that can be considered to be in the range of a fully commercial level facility. The list represents actual operational conversion technology facilities that would be considered "community-based" sized facilities, rather than large regional facilities (e.g., typically 1,000 plus tons per day of feedstock materials). These technologies can be used for regional, larger scale facilities by having additional processing lines and/or by increasing the capacity of individual process lines. Thermal processing technologies are designed to be modular and scalable.

Several different types of companies represent the broad range of conversion technologies utilized in the scale up and commercial scale projects listed in the appendix. These companies have the role of being the technology representative for the purpose of licensing technology and/or can also serve as project developers in the United States. These companies respond to requests for information from local governments, and sometimes take the primary responsibility of responding to "Request for Qualifications" (RFQs) and/or "Request for Proposals" (RFPs) issued by local government entities interested in developing a conversion technology project. These companies serve a critical role in the process of "technology transfer."

Technology transfer is the process of sharing of skills, knowledge, technologies, and facilities among and between universities, industry, governments and other institutions to broaden accessibility of scientific and technological developments to a wider range of potential users who can then further advance the knowledge base and increase the application of technology.

Appendix G provides a listing of "currently-proven commercial" (non-incineration) thermal technology developers compiled and maintained by Dr. Kay Martin of the BioEnergy Producers Association (BPA). BPA members participate as instructors in the UCLA Engineering Extension program and also serve as Advisors to the UCLA Engineering Extension's Recycling / MSW Management Certification Training Program, and have provided an update for the purpose of this report. (Note: This is an ongoing effort, and does not include every project developer and/or technology.)

3.5 Biochemical Conversion Technologies

This IDR focuses primarily on thermal processes, but a discussion of biochemical conversion technologies is necessary because of the public, social, and political realities that require the maximum effort be first spent on waste reduction and recycling, and then aerobic digestion (composting) of source separated and/or organics separated from the mixed municipal waste stream, including energy recovery of through the production of biogas from anaerobic digestion, and only as a “last option” the recovery of energy through the use of thermal technologies. So in order to utilize the most efficient way to convert carbon based materials into energy via thermal conversion technology, a “project” dictates the inclusion of other “low temperature” (non-thermochemical conversion technologies) as an integral part of the project.

Anaerobic digestion and anaerobic fermentation are considered low temperature (non-thermal) conversion technologies. Biochemical processes such as anaerobic digestion are utilized to produce a syngas from municipal solid waste. The synthesis gas is primarily composed of methane and carbon dioxide. The typical range for the amount of methane ranges typically from 50 to 60 percent methane by volume. The gas can be utilized as a fuel in an engine to produce energy. Most of the most recent integrated MRF conversion technology projects incorporate anaerobic digestion to convert the readily decomposable organics fraction of the waste stream into a biogas and stabilized digestate.

Anaerobic fermentation is also a biochemical conversion technology that can be used to convert organic fraction of the MSW stream to ethanol, fuel, and chemical applications and to other chemicals and products.

Table 5 lists various examples of anaerobic digestion conversion technologies that process approximately 100 tons per day or more of solid waste. This is only a partial listing of some of the larger facilities that are currently in operation. Appendix H also provides a list of biological/biochemical technology developers.

Table 5. Selected Examples of MSW Conversion Facilities Employing Anaerobic Digestion

ID #	Location	Company (Technology)	Start of Operation	Feedstock	Capacity t/y	Syngas / Waste Heat Utilization
1	Amiens, (France)	Valorga International (Urbaser)	1987	MSW	85,000	Electricity
2	Barcelona (Spain)	Valorga International (Urbaser)	2004	MSW	240,000	Electricity
3	Bassano (Italy)	Valorga International (Urbaser)	2003	44,000 t/y MSW, 8,200 t/y sorted waste, 3,000 t/y sludge	44,000 t/y MSW, 8,200 t/y sorted waste, 3,000 t/y sludge	Electricity
4	Hanovre (Germany)	Valorga International (Urbaser)	2006	MSW	100,000	Electricity
5	Mons (Belgium)	Valorga International (Urbaser)	2000	MSW	37,500	Electricity
6	Vitoria (Spain)	Dranco (OWS)	2006	MSW	120,000	Electricity
7	Pohlsche Heide (Germany)	Dranco (OWS)	2005	MSW	100,000	Electricity
8	Bassum (Germany)	Dranco (OWS)	1997	Industrial C & D	105,000 t/y	Electricity
9	Tel Aviv (Israel)	Arrow Bio	2003	MSW	150 t/d	Biogas
10	Sydney (Australia)	Arrow Bio	2008	MSW	150 - 300 t/d	Biogas
11	Munich(Germany)	Bekon	2007	MSW	25,000 t/y	Electricity

3.6 Components of a Conversion Technology Facility

Figure 14 shows the three major operational components at a conversion technology facility.

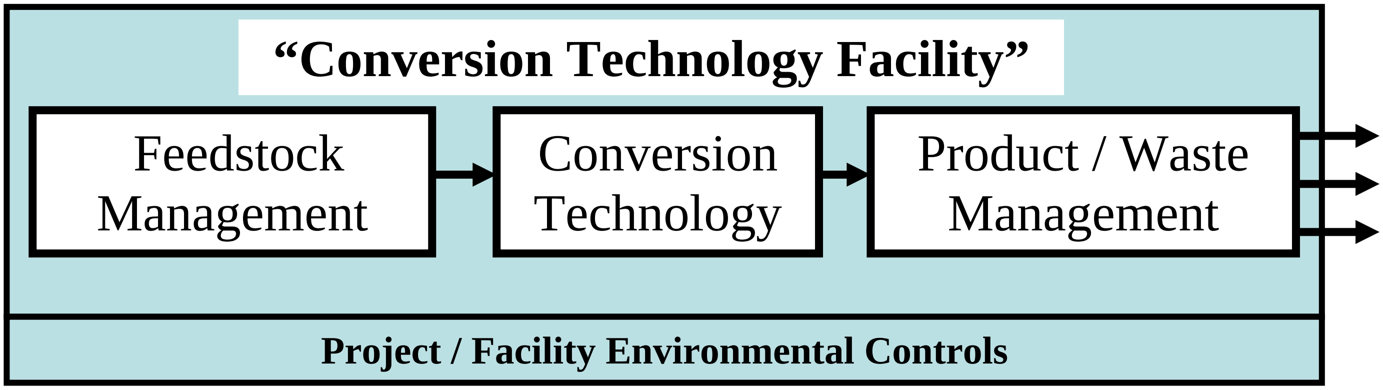

Figure 14. Conversion Technology Facility Major Operational Components

If a conversion technology facility is receiving post-recycled solid waste feedstock directly from a trash truck collection black bin waste, and/or receiving residuals from a MRF/transfer station, there are additional processing operations that are needed in order prepare an optimum feedstock.

The following is a description of the basic operations that are within the three major operational components of a CT facility after the feedstock materials are collected and delivered to a conversion technology facility:

- **Part 1: Feedstock Management:**
  1. Feedstock Unloading and Storage
  2. Processing to Remove Non-Acceptable Materials and Non-Processable Materials
  3. Processing to Remove Recyclables
  4. Recyclables Storage / Loading
  5. Handling and/or Disposal of Non-Recyclable Materials
  6. Processing to Refine Materials into a CT Feedstock(s)
  7. Handling and/or Disposal Non-CT Feedstock Materials
  8. Storage, Blending, and Metering of CT Feedstock(s) for CT Backend

- **Part 2: "Conversion Technology"**
  9. CT Process (includes power generation and/or biofuels production processes, and also includes Environmental Controls)

- **Part 3: Product / Waste Management**
  10. CT Product(s) Storage / Distribution
  11. CT Process Residuals for Treatment/Disposal

Operational components #1 to #8 are typically considered "preprocessing" (sometimes called "feedstock management"), and components #9 to #11 are considered the "CT Backend" (referred to as the "conversion technology," but the term "backend" also includes the power generation or biofuels production, management of emissions, waste, and residuals.). Successful conversion technology project development is dependent upon how all these components are seamlessly interfaced and integrated with each other from a systems engineering standpoint. Many conversion technology project developers focus only on components #9 to #11, but the composition of the post recycling solid waste feedstock and the level of additional “preprocessing” that is performed on the feedstock determines the quality and characteristics of the final optimized feedstock for the CT; and that will determine to a large extent the amount, type, and management requirements of CT process waste, emissions, and residuals (component #11). Black bin waste and MRF residuals are considered “solid waste”, and a CT facility that actually receives these feedstocks will be considered a “solid waste facility” under the current statutory and regulatory scheme in California. The feedstock status determines the permitting requirements.

For a new standalone conversion technology project or a conversion technology project that is co-located at an existing MRF/transfer station, all of the technical operational components (#1 to #11) will be physically sited at a single location (except for landfill disposal). For a new stand alone conversion technology project that is receiving mixed MSW that has not undergone processing to remove recyclables to the maximum extent possible, the preprocessing requirements will be more extensive than for a facility that is receiving post recycled solid waste; and the new facility will need a solid waste facility permit.

For a co-located CT at an existing MRF transfer station, the primary technical issue will be the space limitations and the integration of the CT Backend into the existing MRF/transfer station operations. Since these existing operational facility already have solid waste facility permit, the permit will need to be revised after the land use issues and environmental analysis has been adequately addressed.

Space permitting, existing MRF/transfer stations facilities can modify their existing operations / equipment layout to accomplish the preprocessing (steps #1 to #8) and deliver an optimized finished fuel to a separate stand alone CT Backend which is located at a different location. Such an independently located “regional” CT Backend can be fed by many MRF/transfer stations that produce a feedstock that meets the feedstock specifications set by the conversion technology process requirements (e.g., size, moisture, BTU value, etc.).

Of particular importance is operational component #6, Processing to Refine Materials into a CT Feedstock(s). Many transfer stations and/or MRFs consider their “residual” destined to landfill to be CT feedstock. However, this residual will contain many materials not suitable and not desirable to be in feedstock. The actual material composition of the “residuals” for each MRF/transfer station is dependent upon the feedstock and it specific recovery process design and materials recovery efficiency (as well as the impact of seasonal variations).

For example, the residual typically will contain small amounts of ceramics, glass, small batteries, etc., which are not beneficial in terms of energy value, and may potentially be detrimental to a thermal conversion process, e.g., adds to ash content, causes increased slagging, reduces thermal efficiency, etc. These same materials also may be potentially detrimental to biological processes. Heavy metals may be “leached” out from small batteries and glass may end up in the non-digested organic materials that end up as compost.

Processing to refine the post-recycling MRF/transfer station residual materials into a CT feedstock will remove some of these potentially deleterious materials. Recently developed new technologies can actually recover the smaller pieces of recyclable glass from MRF/transfer station residual materials, thus improving the thermal conversion fuel characteristics and also increasing material recovery and recycling.

Existing transfer stations/MRFs operations generally encompass components #1 to #5, and technology developers typically focus on #9 to #11. For a successful project, components #6 to #8 have to part of the addressed in the overall project development infrastructure. Components #6 to #8 are operational steps that create the optimal feedstock for the conversion technology backend.

3.7 Project Scenarios

There are three basic conversion technology project scenarios. These scenarios apply to thermal (e.g., gasification, transformation, etc.) and/or biological (e.g., anaerobic digestion, etc.) technologies. These scenarios describe various physical facility and operational arrangements only (and do not address business arrangements).

1) New Stand-Alone Combined Preprocessing and CT Backend Facility
2) Co-Located New CT Backend at Existing Transfer Station and/or MRF
3) Separate Existing/New MRF / Transfer and New Remote CT Backend
    i. Processing of Materials into CT Feedstock at CT Backend
    ii. Processing of Materials into CT Feedstock at Transfer Station/MRF

Any conversion technology project that utilizes a mixed MSW or a processed feedstock derived from MSW consists of basic core operational components that determine the project’s structure and operations. These core operational components can be co-located at the same physical location, or may be separate. Consolidation of all of the basic core operational components in a single location is the most operationally efficient mode, but there are groupings of operations that can be separated into different locations.

For the project scenarios where the processing of feedstock (in its final fuel form) is located separately from the CT backend, an additional process should be considered. Densification (e.g., pelletizing, cubing, etc.) as a processing option should be evaluated. Densification of refuse derived fuel increases the storage ability and enables more efficient materials handling and transportation. These benefits come with an increased cost of materials processing required of the densification process. The additional benefit of densification is that the feed materials will be of a much more uniform nature in terms of fuel value and materials handling qualities.

3.7.1 New Stand-Alone Combined Preprocessing and CT Backend Facility Project

A "New Stand-Alone Combined Preprocessing and CT Backend Facility" scenario would be a complete new facility at a site that is currently not processing any solid waste. This would be a complete new land use application and environmental review process with the appropriate regulatory and planning agencies. From an engineering standpoint, the facility would be designed from scratch and technical interface issues with the "existing" facility are not an issue. For some project developers, this scenario is preferred because they would not have to worry about integrating the existing preprocessing equipment and operations with the CT backend. Existing transfer stations/MRFs are not designed to produce a CT feedstock; they are designed specifically for recovery of recyclables, and for optimizing transport of residuals to disposal.

3.7.2 Co-Located CT facility with Existing Transfer Station / MRF

A "Co-Located New CT Backend at Existing Transfer Station and/or MRF" scenario is where the conversion technology is co-located at the same or adjoining property of the existing transfer station or MRF. Additional equipment and processing would need to be added to the existing facility to optimize the feedstock specific for the conversion technology selected. Additional storage capacity for the processed CT feedstock would also need to be constructed. This scenario is considered to be the preferred option for the County of Los Angeles Alternative Technology Task Subcommittee. There may be significant existing technical and physical limitations (for each existing transfer station / MRF) on what additional CT feedstock processing is needed and can be interfaced with the CT backend. The primary issue is space availability for the needed for the CT backend and its associated equipment and operations footprint.

3.7.3 Separate Existing/New MRF / Transfer and New Remote CT Backend

A "Separate Existing/New MRF / Transfer and New Remote CT Backend" project scenario has two variations depending upon where the additional (component #6) is located at the front end or the CT backend; 1) Processing of Materials into CT Feedstock at CT Backend, and 2) Processing of Materials into CT Feedstock at Transfer Station/MRF.

There may be significant regulatory and permitting issues where these "processing operations" take place after the materials recovery to optimize the feedstock for CT takes place. Part of the existing regulatory framework in the State of California is currently under review (Three-Part Test), and potential revisions may impact the permitting requirements.

3.7.4 Advantages and Disadvantages of Various Project Scenarios

There are advantages and disadvantages to each of the potential various project scenarios. Solid waste processing is basically an exercise in "materials handling." Solid waste processing and conversion technologies benefit from economy of scale and are most cost effective when the volume throughput is higher. The capital cost amortized on a per ton basis is lower, and so are the operational costs.

Besides the costs, many other factors need to be considered in deciding which project scenario is best for a Navy conversion technology project. Some of the basic factors that should be evaluated are:

- Availability of Guaranteed Waste stream / Watershed
- Siting Issues (New Location vs. Existing Facility Co-Location)
- Land Use Approval Issues
- Permitting / Regulatory Compliance Issues
- Level of Process Optimization Needed
- Ease of Technical Integration of Project Technology/Operational Components
- Availability Performance Guarantee (Performance Bonding / Surety)
- Overall Facility Reliability

Tables 6 through 9 summarize some of the advantages / disadvantages of the various potential project scenarios:

Table 6. New Stand-Alone Combined Preprocessing and CT Backend Facility

Advantages / Pros	Disadvantages / Cons
1. Plant design and operations can be optimized for the size and specific conversion technology selected. (Less operational integration issues between different operational components).	1. No existing waste shed, must compete for waste shed or get municipal/private commitment and/or flow control (unless project is with a municipality). If "flow control" is utilized by municipality, will impact existing contracts and infrastructure
2. May be easier to get a "systems performance" guarantee from the engineering/procurement/construction (EPC) vendor for the entire project.	2. New project means that land use application and environmental review will start from scratch.
3. No bifurcation of the CT feedstock preparation so no additional transportation required for linking the front end preprocessing and back end CT operations.	3. Overall cost may potentially be more than co-locating at an existing facility
4. New project / developer do not have any local operational history. Will need to depend upon existing reference facilities that are not local. An advantage if reference facility is a best management practices and has good operational / compliance history.	4. New project / developer do not have any local operational history. Will need to depend upon existing reference facilities that are not local. Disadvantage if references are not good for reference facilities.
5. Opportunity to create a "new" benchmark for the project developer	5. Community opposition may be organized for a new project
6. Opportunity to engage in stakeholder participation and incorporate environmental justice / community based mitigation measures.	6. Mitigation measures and other land use conditions may add substantial capital and operational costs to the project.
	7. Vested local interests may organize and support opposition to project on environmental and/or other grounds.

Table 7. Co-Located New CT Backend at Existing Transfer Station and/or MRF

Advantages / Pros	Disadvantages / Cons
1. Existing facility has existing wasteshed and project won't be competing for feedstock for existing facility that has dedicated MRF residual feedstock for CT Backend.	1. Preprocessing for producing CT feedstock needs to be integrated into existing process design. Residuals have to be processed to fuel specifications for selected CT backend.
2. Existing facility has solid waste facility permits which will need to be revised instead of starting from scratch.	2. There may be existing physical and operational constraints to adding additional equipment / operations, e.g., interference with existing / continuing operations.
3. Depending upon land use conditions and technology selected, permitting process may be significantly easier.	3. May need to find a systems performance guarantor that is willing to include the existing front end operational performance
4. Facility with good operational history and community relationships will benefit from previous relationship.	4. Facility with bad operational history and bad community relationship will be hindered in their expansion.
5. No bifurcation of the CT feedstock preparation so no additional transportation required for linking the front end preprocessing and backend CT operations.	5. Feedstock wasteshed may be limited by the existing contractual or business arrangements of the existing facility and/or jurisdictional processing capacity guarantees
6. Incremental capital cost of producing a CT feedstock with an existing facility is potentially lower than a new front end.	6. Environmental impacts will be a significant issue in the expansion / permitting of the CT Backend.
7. Potential backend CT fuel storage may require less storage if front end storage can be used as a "buffer" for feedstock.	7. Environmental justice issues related to cumulative impacts and historical environmental burdens will be an issue.
8. Facilities with relatively simple front end processing and materials recovery (and adequate space can be upgraded by adding the additional feedstock processing unit processes onto the back of the existing front end.	8. More difficult to incorporate newer processing technologies (e.g., glass color sorting technology) that require finer progressive fractionation processing control feed for effective materials recovery and/or removal.
	9. Existing facility front end may reach end of useful life sooner (mismatched amortization / depreciation)
	10. Economy of scale may not be realized if existing physical site and/or other constraints limit optimal facility sizing to benefit from economy of scale.

Table 8. Separate Existing/New MRF/Transfer and New Remote CT Backend
(Processing of Materials into CT Feedstock at CT Backend - See Note, Below)

Advantages / Pros	Disadvantages / Cons
1. Can have better control over the final back end CT feedstock processing, especially if receiving materials from various existing transfer stations / MRFs with different processes.	1. Transportation of transfer station / MRF residual must be transported to the CT backend for final CT feedstock preparation; the bifurcated operations require the transportation link. Residual will include significant non-CT fuel materials that need to be removed. (results in higher residual rate from this CT backend, x>10 percent).
2. No impact on the separate front end operations. (CT Backend receiving MRF/transfer station residuals without the benefit of any additional front end processing beyond what is occurring).	2. Materials transported may be classified as MSW, thus requiring a solid waste facilities permit for the CT's front end operations (and residuals > 10 percent).
3. Reduces landfilling requirements of front end facility.	3. If using feedstocks from multiple feeder facilities, feedstock materials may be very different (depending upon the level of existing processing at feeder facilities).
4. No interruption of existing / future operations, just a change of destination for trucks that would have gone to landfill.	4. Existing facility front end may reach end of useful life sooner.
5. Less "fuel blending" at the back end because of final CT feedstock control.	5. Increased capital / operational cost for splitting operations of front end and back end components of CT project.
	6. CT Backend will require both incoming feedstock process storage and also finished fuel storage.
	7. Operational and process integration is more difficult for bifurcated operational components when the front end is an existing operation that is not optimized for feedstock fuel processing for the back end CT technology.
	8. Backend has no control over residuals received from MRFs/Transfer Stations .
Note: This scenario assumes that the existing transfer stations and/or MRFs are not optimized to produce a CT feedstock, only providing their residue to the separate CT backend to be processed into the optimal CT fuel feedstock.	

Table 9. Separate Existing/New MRF/Transfer and New Remote CT Backend
(Processing of Materials into CT Feedstock at Transfer Station/MRF)

Advantages / Pros	Disadvantages / Cons
1. Less materials transported to CT Backend; only the optimized CT feedstock is transported to the CT Backend. (Note that there is less residual at the backend).	1. Transportation of transfer station / MRF processed CT feedstock requires a transportation link.
2. Less overall impact at CT backend site, no need for CT feedstock processing equipment (since the backend facility receiving only the finished feedstock materials).	2. Materials transported may be classified as MSW, thus requiring a solid waste facilities permit for the CT's front end operations.
3. Less volume of materials handled at the CT backend; e.g., less non-processables and non-recyclables, and recyclables handled at the CT backend since the preprocessing in not done at the CT Backend.	3. If using feedstocks from multiple feeder facilities, feedstock characteristics may be very different (depending upon the type of materials processed and the level of existing processing at feeder facilities).
4. Less CT feedstock storage required at CT Backend. (Smaller facility footprint)	4. CT Backend will still require final feedstock storage.
5. Less residual at the CT backend. (Materials transported to CT backend may be considered a "product" rather than MSW, will impact regulatory permit requirements).	5. Operational and process integration is more difficult for bifurcated operational components when the front end is an existing operation that is not optimized for feedstock fuel processing for the backend CT technology.
	6. Existing facility front end may reach end of useful life sooner.
Note: This scenario assumes that the MRFs / Transfer Stations produce a CT fuel feedstock ready to be fed into the CT process without any further processing.	

3.8 Integrated Facilities with Biochemical and Thermochemical Technologies

In the European Union and in Japan, the newest trend within the last 10 years in conversion technology projects is to develop "integrated facilities" that have a combination of conversion technologies and other project components that can address the entire MSW stream of a waste shed, e.g., including green waste, construction and demolition waste recycling, sewage sludge, and other types of wastes. Conversion technology projects are being developed in conjunction with other activities secondary manufacturing (e.g., ash reuse), and other projects. The terms "Recycling Parks" or "EcoTowns" (e.g., technology parks, etc.) are also used to describe these multi-faceted industrial developments focused on maximizing diversion from landfills. The ultimate goal of the integrated facilities or EcoTowns is to have “zero waste” sent for disposal at landfills.

Note that the term “zero waste” is used here to mean “zero disposal to landfill” or to mean “nothing wasted.” “Zero disposal to landfill” is not the same as “zero waste” (even though the end result may be that no waste is disposed at landfills). “Zero waste” in public policy discussions sometimes refers to a policy that promotes a fundamental change in how products and packaging are designed for environment sustainability. This means designing and producing products to maximize reuse, recycling, and minimum waste, where manufacturers accept responsibility for the entire life cycle of their product.

In the European Union, the newest facilities (e.g., EveRe Integrated Facility in Marseille, France, startup of operations in 2009) reflect the integrated solid waste facility design trend. It is now a widely-accepted project design philosophy to use an integrated facility approach to maximize beneficial use of the various components of the waste stream before the application of thermal treatment.

The integrated facility project design approach reflects a public, social, and political reality that mandates maximum waste reduction and recycling first, including aerobic digestion (composting) of source separated and/or organics separated from the mixed municipal waste stream, including energy recovery of through the production of biogas from anaerobic digestion, and only as a “last option” the recovery of energy through the use of thermal technologies. In discussions with the EveRe facility representatives and plant engineers (E. Llorente (Urbaser)), it was noted that public acceptance of the facility is more likely when “energy recovery” is the <u>last</u> option to be utilized before landfilling.

The “integrated facility” approach was utilized by the newest regional-scale EveRe Integrated Facility that provides a comprehensive waste management approach for the City of Marseille and surrounding cities/communities. This regional facility utilizes a suite of technologies to maximize the diversion of materials from landfill before the recovery of energy.

The facility recovers additional recyclables from the disposed mixed waste stream from various cities and then processes the residuals into an “organics” fraction for anaerobic digestion and a processed engineered fuel (e.g., refuse derived fuel) fraction that is used as feedstock for thermal conversion process that recovers energy. The organics stream is anaerobically digested to produce biogas. Source separated green waste is separately composted, or can also be anaerobically digested with or without food waste.

The following diagram (see Figure 15) shows the EveRe facility’s front end integrated MRF unit processing flowchart.

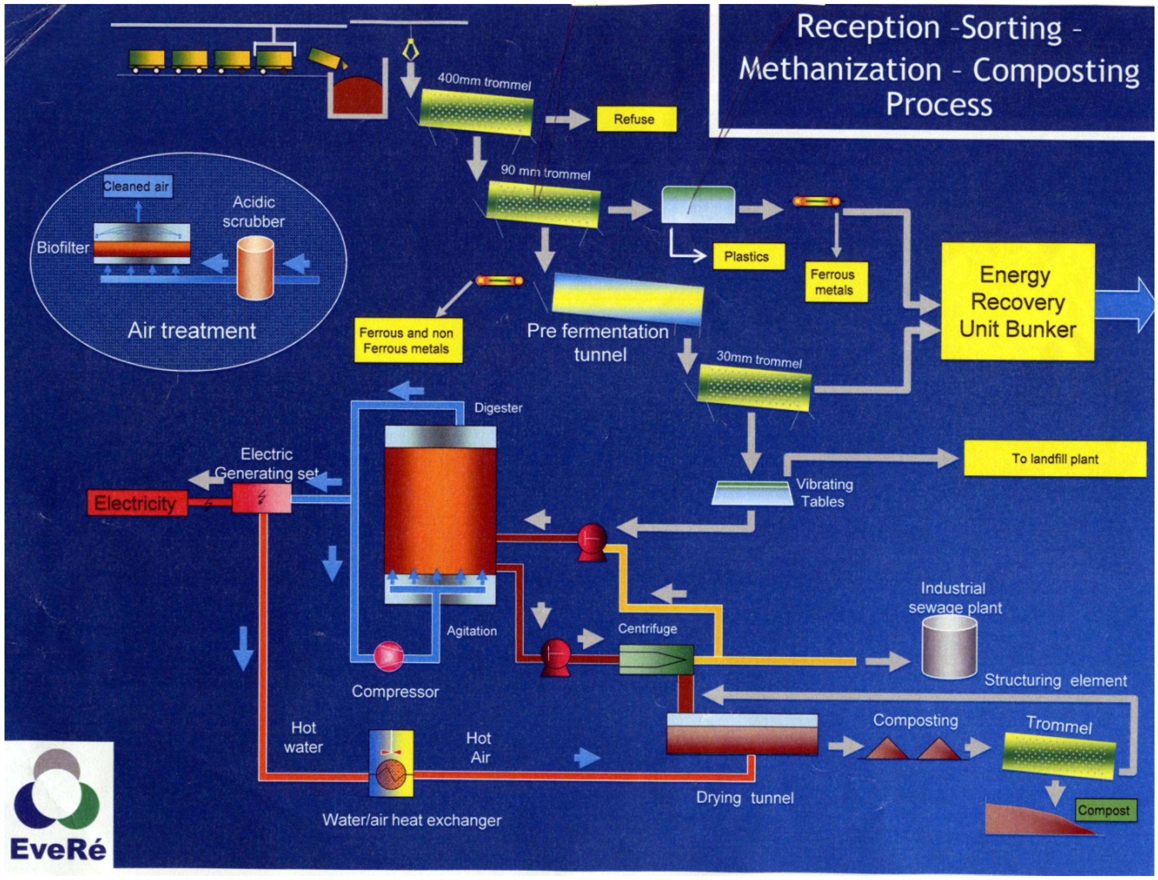

Figure 15. EveRe Facility Front End Integrated MRF Unit Processing Flow Chart
Source: EveRe Integrated Facility, Marseille, France (2010)

Figures 16, 17, and 18 are pictures of the EveRe Integrated Facility that begin its startup and facility acceptance and testing operations in 2009.

Figure 16. Ash Treatment Building, EveRe Integrated Facility (Marseille, France)

The facility incorporates a design philosophy to minimize manual labor and maximize automation, and incorporates green building design principles.

Figure 17. MRF Building of EveRe Integrated Facility (France)

Figure 18. Biogas Production from Organics Fraction at the EveRe Integrated Facility (France)

It is important to emphasize that an integrated MRF conversion technology project meets the combined environmental goals of maximizing recycling, minimizing landfill diversion, reducing GHG emissions, with "energy recovery" as the last waste management option to be utilized.

Based upon the performance experience of existing integrated MRF conversion technology facilities, a conservative estimate of the energy output from a potential Navy "Integrated MRF Conversion Technology EcoPark" project (per 100 tons of MSW input) is shown below. The facility would include anaerobic digestion and thermal conversion technologies. The model/spreadsheet provided by E. Llorente (Urbaser), and based upon the performance of several integrated MRF facilities in the European Union.

Table 10. Estimated Energy Output from Potential Navy "CT EcoPark"

FACILITY WITH MECHANICAL BIOLOGICAL TREATMENT (MBT)										
Megawatt Hours per 100 Short Tons (2000 lb) of MSW										
Input	Sorting		Destination			Primary Energy		Energy Use	Electricity Output	Electric Energy
100t MSW	6t	Recycled	To Recycler							
	50t	To MBT	Digestion	30t	Biogas(1)	14 MWh	1.1 toe	Motor	38%	5 MWh
			Landfill	15t	Refuse	To Landfill				
			Waste to Energy	3.75t	Organic matter	8 MWh	0.6 toe	WtE	25%	2.1 MWh
				1.25t	Fossil	7 MWh	0.6 toe			1.8 MWh
	44t	Refuse		26.25t	Organic matter	58 MWh	4.5 toe	WtE	25%	15 MWh
				8.75t	Fossil	51 MWh	4.0 toe			13 MWh
				9t	Inerts	To Landfill				
MTB+Refuse=	94t			94t		138 MWh	10.8 toe			36 MWh
t=short ton (2000 lb)			Biogas(1):	3524ft^3/t-4485ft^3/t Energy is calculated with 3524				110 Nm^3/metric ton = 3524 ft^3/short ton		
toe=short tons oil equivalent				50% methane (range is from 50% to 60% for anaerobic digestion biogas)				4000 kcal/Nm^3 = 449 BTU/ft^3		
A.D.=anaerobic digestion				LCV:449 BTU/ft^3 (assumes 50% methane)				860 kcal/kWh = 3413 BTU/kWh		

Courtesy of Eduardo Llorente (Urbaser)

IMPORTANT NOTE: The calculations are based upon the lower end range of output and fuel values, (e.g., 50 to 60 percent methane content in biogas, use 50 percent; and 110 cubic meters per metric ton of organics fraction to 140 cubic meters per metric ton of organics fraction, use 110 cubic meters per metric ton of organics fraction). The waste composition assumes a very successful source separated front end recycling system (e.g., incoming feedstock is similar to “black bin” post recycled residual waste stream).

3.9 Conversion Technology Project Design Approaches

The selection of biochemical and thermochemical technologies within an overall integrated MRF conversion technology facility (EcoPark) project is dependent upon the specific goals and objectives of the project developer and host. This is a critical task because the technologies need to be operationally reliable and meet the performance standard set forth to meet those goals. The operational reliability of conversion technology processes is to a great extent dependent upon the type and level of preprocessing done to optimize the feedstock for the selected technology. Setting appropriate performance requirements and goals are important design factors because of the potential for competing project goals.

To illustrate the concept of competing goals within a project, the goals of “maximizing diversion from landfill” and “optimizing feedstock for operational reliability” will be discussed. For a thermochemical conversion technology, there are materials that should not be in an optimal feedstock (e.g., materials such as glass, metals, ceramics, etc.) and a process designer would remove these materials as part of the feedstock preprocessing (MRFing) step in an effort to optimize the feedstock.

However, if maximum diversion is desired, these inorganic materials may actually be included as part of the feedstock, or even additional non-optimal feed materials such as sewage sludge and/or bottom ash from other facilities so that they can be processed. Not only does the addition of these reduce the fuel value and require additional “blending and mixing procedures” to make the overall fuel value more consistent, but would result in additional bottom and fly ash, thus requiring a technology that would convert the inorganic materials into a useful product (hence diverting it from landfill).

The design implication for this scenario would be to incorporate a thermal conversion technology (e.g., fluidized bed gasifier) that requires a higher fuel value feedstock and that would create a molten slag that could be converted into a product with beneficial use (e.g., aggregate, etc.). A higher fuel value feedstock implies more preprocessing and a specific effort to include non-recyclable plastics. Another implication is that different types of thermal conversion technologies may be incorporated within a single facility, each with its unique process advantage. A much more detailed discussion on feedstock preprocessing is provided in Section 6.3 of this report.

Figure 19 illustrates which technology is more appropriate depending upon several basic factors that are commonly used for deciding between incineration technology and the newer gasification technology:

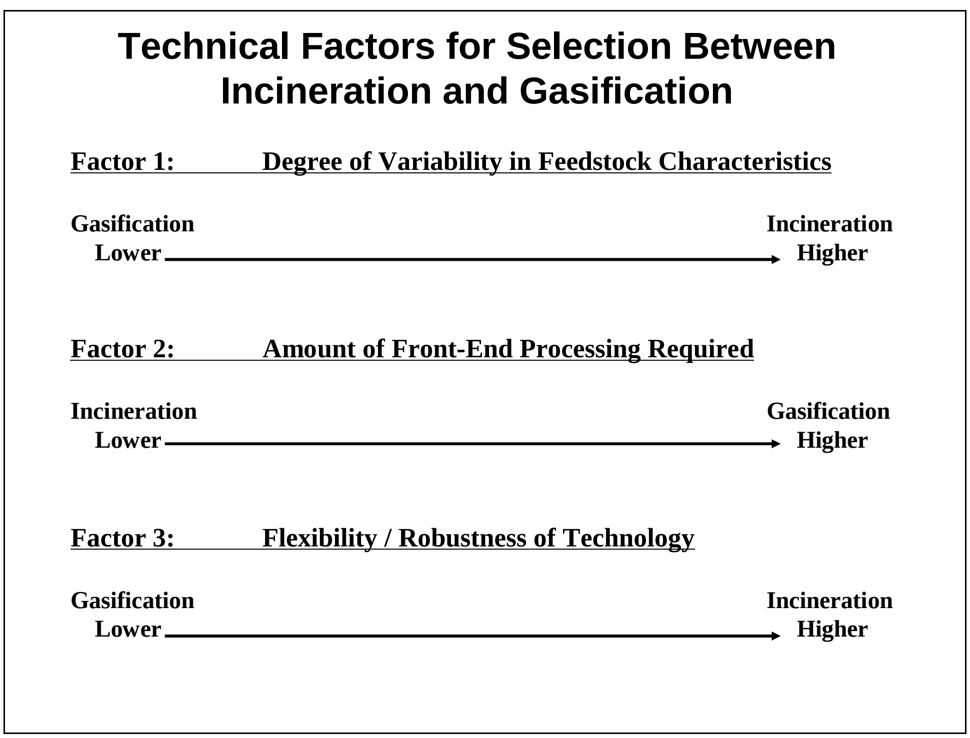

Figure 19. Technical Factors for Selection Between Incineration and Gasification

One of the most innovative approaches is to combine the advantages of both the incinerator and the gasifier in a single facility. This can be done by designing a plant that has two process lines, one gasifier line and one incinerator line. This innovative approach allows a single facility to have the flexibility/robustness and also have the maximum diversion from landfill thru the vitrification of the ash with the gasification technology.

3.10 Cost of Conversion Technology Facilities

For planning purposes, the budgetary capital cost estimate for developing and constructing an integrated waste management “EcoPark” (integrated MRF with conversion technologies) project utilizing anaerobic digestion and thermal conversion technologies for the generation of electricity can range between $350,000 per ton per day of throughput capacity to over $1 million per ton per day of throughput capacity depending upon the size the types of technologies (not including the cost for land). The following chart shows the impact that the size of the facility has upon the potential capital cost (note that cost of land is not included). The economy of scale has a significant impact for the smaller sized facilities. Generally, facilities at the 1,000 tons per day or greater input tonnage of MSW are considered to be at the level where the economy of scale makes a difference (see Figure 20 below, the slope becomes more “level” at around the 1,000 ton per day level).

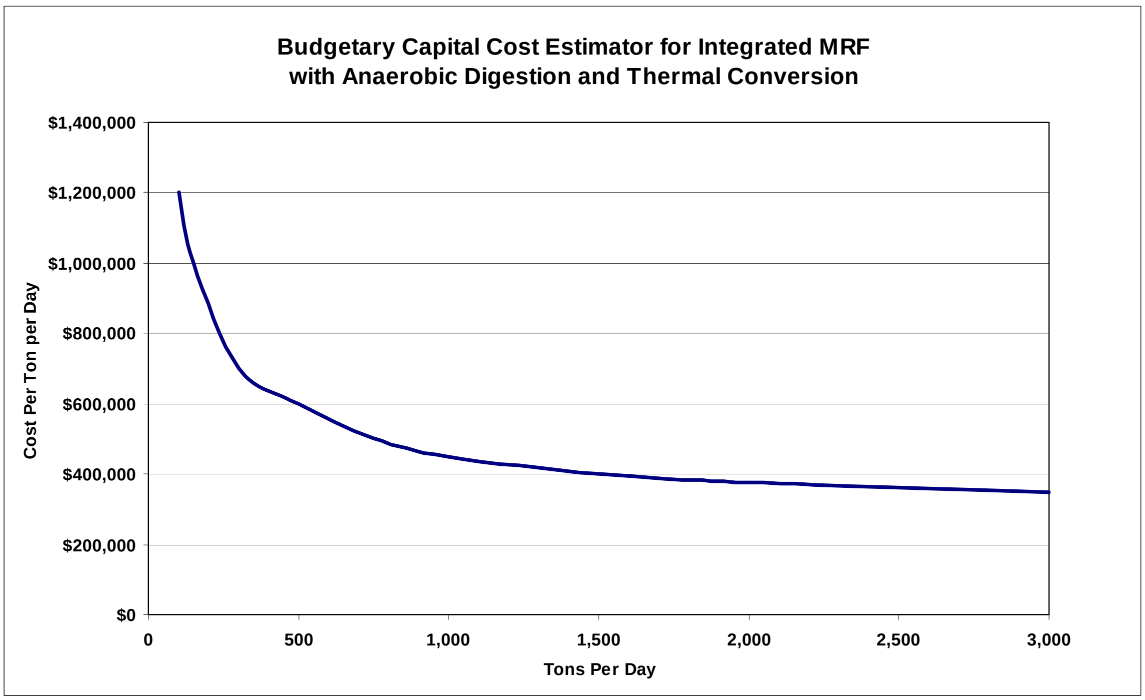

Figure 20. Conversion Technology Facility Capital Cost Relative to Facility Size
(UCLA Engineering Extension, MSW Management Technology Course)

For budgetary planning purposes, depending upon the size of facility and the mix of selected conversion technologies, the estimated per ton operational and maintenance costs range from $150 per ton to over $200 per ton for an integrated MRF with anaerobic digestion and thermal conversion technology project (based upon budgetary estimates of various project developers and case studies of existing facilities).

Figure 21 combines a budgetary capital cost estimator with the size of a facility, and also the operating cost ($/ton) based upon the daily throughput tonnage.

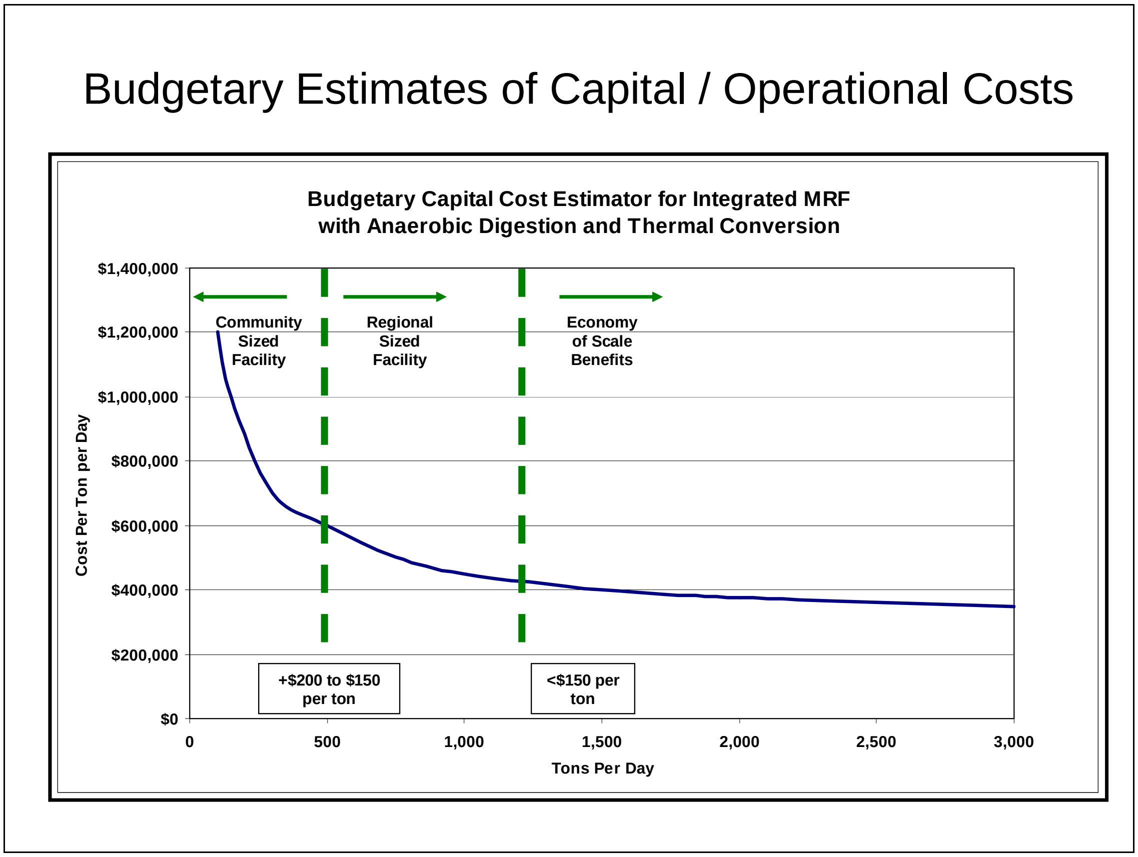

Figure 21. Budgetary Estimate of CT Facility Capital and Operational Costs

The above $150 to $200 per ton tip fee represents (in 2010 dollars and would be increased over the 20 year operating life of the facility), adjusted to the consumer price index or some other inflation normalization formula utilized in the trash industry for long term service contracts. This tipping fee cost would cover the amortization of the capital cost of the facility (e.g., design, permitting, procurement, construction, and operations/maintenance).

This “tipping fee cost” does not include any local jurisdiction fees or special land use conditions that may be imposed, and does not include any regulatory fees and other statutory fees that may be imposed (e.g., emission offsets, cap and trade costs, etc.) It should be emphasized that the pre-construction costs of project development (e.g., “soft costs”) will be higher than the costs experienced in the European Union and in Asia (e.g., Japan, Taiwan, etc.) due to the permitting uncertainties, required environmental mitigation, project fees, environmental justice issues, and potential/actual legal challenges, and the demands resulting from stakeholder / community involvement programs.

Waste-to-clean energy (WtCE) should not be directly compared to landfill disposal in an integrated waste management approach. The integrated waste management approach and its primary goal to divert waste from landfill with the implementation of waste reduction, recycling, composting, and energy recovery, emphasizes the implementation of all of those practices in a systematic / holistic approach. In a straight comparison of landfill tipping fee cost to the cost of an "integrated MRF / WtCE" project, landfill disposal is significantly less.

The cost analysis should focus two aspects of the overall costs, 1) the long term stabilization of the overall disposal cost of trash (e.g., avoided landfill disposal costs), and, 2) on the incremental costs of the other benefits that would be achieved by taking the integrated MRF / WtCE facility approach. In other words, is the cost of additional progress in achieving over a potential landfill diversion (recycling goal) of 90 percent plus, and reducing GHG emissions towards the Navy's climate change / sustainability goals, and also achieving progress towards the Navy's renewable energy goals.

Since the start of the recession (2008), the volume of trash being generated and disposed at landfills has decreased significantly, with landfills experiencing 20 to 30 percent plus drops in tonnage. This makes long term predictions of the cost of tipping fees difficult from region to region. The principal investigator for this project has researched the availability of projected landfill disposal tipping cost projects and/or models. Because of the recession and the "uncertainty" of the competitive tipping fee structure, no long term models were available for this project. However, using Southern California / San Diego area as a discussion example, a hypothetical case study example can demonstrate the recommended cost analysis approach.

<u>Example:</u>

Cost of tipping fee at landfills: $100 /ton
Cost of tipping fee at Integrated MRF / WtCE Facility: $150 /ton

At $100 /ton tipping fee:
- Cost per ton differential: $150 /ton minus $100 per ton = $50 per/ton
- Energy Produced Per Ton MSW: 0.5 MWh /ton (for discussion purposes)

At $50 /ton tipping fee:
- Cost per ton differential: $150 /ton minus $50 per ton = $100 per/ton
- Energy Produced Per Ton MSW: 0.5 MWh /ton (for discussion purposes)

So, $50 per ton cost differential gives you 0.5 MWh of electricity, GHG reduction towards the sustainability and climate change goal, and increased recycling rate and increased avoidance of landfills. On a pure energy basis, without consideration for any costs that the Navy would have had to incur for achieving greenhouse gas reduction towards the sustainability and climate change goal, and increased recycling rate and increased avoidance of landfills, the Navy would get green energy at $0.10 per MWh. Taking all of the potential goals that can be achieved is a holistic systems approach to evaluating the cost effectiveness of this project.

At $50 /ton tipping fee:
Cost per ton differential: $150 /ton minus $50 per ton = $100 per/ton
Energy Produced Per Ton MSW: 0.5 MWh /ton (for discussion purposes)

So, $100 per ton cost differential gives you 0.5 MWh of electricity, GHG reduction towards the sustainability and climate change goal, and increased recycling rate and increased avoidance of landfills. On a pure energy basis, without consideration for any costs that the Navy would have had to incur for achieving GHG reduction towards the sustainability and climate change goal, and increased recycling rate and increased avoidance of landfills, the Navy would get green energy at $0.20 per MWh.
Taking all of the potential goals that can be achieved is a holistic systems approach to evaluating the cost effectiveness of this project.

The additional benefit of developing a project is to stabilize the long term disposal costs. By stabilizing the “tipping fee” (and allowing it to increase according to a formula (e.g., consumer price index, CPI, or etc.) for a set period of time (for example 20 years), The Navy will benefit from the overall cumulative cost reduction when compared to the overall disposal cost when it is at the mercy of the fees that landfills will charge. Landfill tip fees will increase at a higher rate than of the rate set by the formula for the conversion technology project

3.11 Recommended Commercially Available Thermal Conversion Technologies

Caveat: Within the limited budget and time constraints of this IDR, it was not possible for the members of the project team to conduct site visits to every facility to evaluate the actual technologies. The project team also relied upon recommendations and evaluations of other industry peers in developing the following list of mature commercially available non-incineration thermal conversion technologies (see Table 11).

Table 11. Recommended Commercially Available Thermal Conversion Technologies

#	Type of Technology	Feedstock	Technology Developer
1	Fluidized Bed Gasification	Refuse Derived Fuel	Ebara, JFE Engineering, EPI
2	Gasification	Mixed Waste and/or Refuse Derived Fuel	Ntech Environmental, JFE Engineering, Thermoselect, IWT, Nippon Steel
3	Gasification / Plasma	Mixed Waste and/or Refuse Derived Fuel	Hitachi-Zosen, Westinghouse/Geoplasma

Note: The University of California at Los Angeles Engineering Extension and the United States Navy (Naval Facilities Engineering Service Center) do not endorse any specific company or technologies or facilities described in this document. The technology and/or facility descriptions are for the purpose of illustrating examples of various technologies that are available for the conversion of municipal solid waste into clean renewable energy.

Please note that the above list (Table 11) is for non-incineration thermal conversion technologies (does not include any combustion type incinerator technologies).

4.0 EMERGING AND DEVELOPMENTAL TECHNOLOGY

4.1 Definition of Emerging Technology

The scientific basis of generating electrical energy from the incineration and thermal conversion of MSW has been well established and been put into commercial applications for over 50 years. The primary differences between the various conversion technologies and/or the traditional mass burn incineration technologies are in technical variations and approaches in the components of the thermal incineration and conversion process. Typically the major “components” to a thermal conversion / incineration facility are the following:

- Fuel Processing and Feeding
- Heat Generation, Capture, and Transfer
- Air and Emissions Control
- Ash and Byproduct Handling
- Integration with Other Technologies

“Emerging technologies” generally denote significant technological developments that broach new territory in one or more significant ways within their field/industry.

Emerging technologies goes significantly beyond incremental improvements to existing approaches and technologies.

For the purpose of this report, an "emerging technology" is any technology that is 1) a significant technology development that can be considered to broach new territory within the waste-to-clean energy / renewable fuels conversion technology industry, 2) which has been scientifically proven and demonstrated at a level beyond a laboratory bench scale, and is ready for a "demonstration scale" or "scale up" level project that can be used for proofing the technology for a full scale commercial facility and operations and, 3) can have a significant impact on meeting the combined goals of renewable energy, waste recycling, and GHG emissions reduction / climate change goals.

According to the classification used to determine the stage of development of a technology, emerging technologies considered for this IDR were technologies that had been scientifically proven and demonstrated at a level beyond a laboratory bench scale, and were ready for a "demonstration scale" or a "scale up" level project that can be used for proofing the technology for a full scale commercial facility and operations, but were not yet operating at a full scale commercial level.

Stages of Technology Development

- Research and Development Stage
- Bench Scale
- Demonstration Stage
- Scale Up

"Emerging Technology"

- Commercially Available
- Fully Mature Commercially Available Technology

Figure 22. Stages of Technology Development - Emerging Technology

An "emerging technology" poses technological and economic risks for the Navy's first full scale commercial WtCE project because the design and operational optimization has not been achieved. An emerging technology can be pursued by the Navy under its research and development and/or innovative technology demonstration programs.

It is important to recognize that the Navy can potentially play in critical national leadership role in fostering the optimization and commercialization of an emerging conversion technology which can generate renewable energy and meet other environmental goals. In the United States, innovative technology developers face a long and difficult path from basic science research to full scale commercialization.

Appendix I lists "Emerging" Non-Incineration Technologies that are in the demonstration and/or scale-up phase of technology development. These are not considered commercially mature because they do not have multiple full scale commercial operating facilities, but are far enough along that they can potentially become commercially available within the next 10 years.

For the purpose of this report, "Developmental Technology" refers to the combined levels of "Research and Development" level, and the "Bench Scale" level of technology development. Basic scientific and technical data still need to be generated to determine the chemical and engineering principles behind the technology. However, these technologies can represent significant advances in the industry if they become proven to be commercially (technically and economically) viable, so that an effort should be maintained to monitor and track advancements in these technologies.

Stages of Technology Development

- Research and Development Stage
- Bench Scale

"Developmental Technology"

- Demonstration Stage
- Scale Up
- Commercially Available
- Fully Mature Commercially Available Technology

Figure 23. Stages of Technology Development - Developmental Technology

At this stage of development, the primary focus is on determining if the scientific theory can be turned into practice. Economic feasibility is still an unknown because the technical parameters still need to be proven and optimized. Also note that many of these technologies are being tested on materials that are not municipal solid waste.

Getting a technology that has been successfully operated at a bench scale with a feedstock that is very uniform in physical and chemical characteristics to properly perform with an extremely heterogeneous feedstock such as municipal waste can be extremely difficult, particularly if the feedstock for the developmental technology needs to be very uniform. Note that most technology researchers and developers are not "waste processing specialists". At this level of technology development, it is important to understand what can and cannot be processed by the technology.

Appendix J lists the "Developmental" Non-Incineration Technologies that are in the either in the "research and development" level or at a "bench scale" level of development.

In the following section, an example of an emerging technology that the Navy should consider pursuing is described.

4.2 Combined Thermal Gasification / Biocatalytic Conversion Technology

An innovative emerging technology that meets the above criteria is the INEOS Bio (formerly BRI) two stage conversion technology process that combines the use of a conventional thermal gasification front end to produce a synthesis gas, and an innovative back end in which the synthesis gas is utilized as a gaseous feedstock for a biocatalytic (biochemical fermentation) conversion process to produce ethanol. This is an example of the integration of an established proven technology with an innovative emerging technology.

INEOS Bio ethanol technology[8] converts a wide range of low cost, organic materials, including vegetative, household and commercial wastes into bioethanol for use as a renewable road transport fuel. This technology represents a combination hybrid approach (biochemical and thermochemical) that can produce both renewable energy and also a renewable liquid fuel.

A full scale commercial facility will begin ground-breaking on February 9, 2011, in Vero Beach, Florida. This facility will generate 8 million gallons of bioethanol per year from biomass including yard, wood and vegetative wastes.

Figures 24 through 26 provide an overview of the process:

[8] INEOS Bio Homepage http://www.ineosbio.com/57-Welcome_to_INEOS_Bio.htm

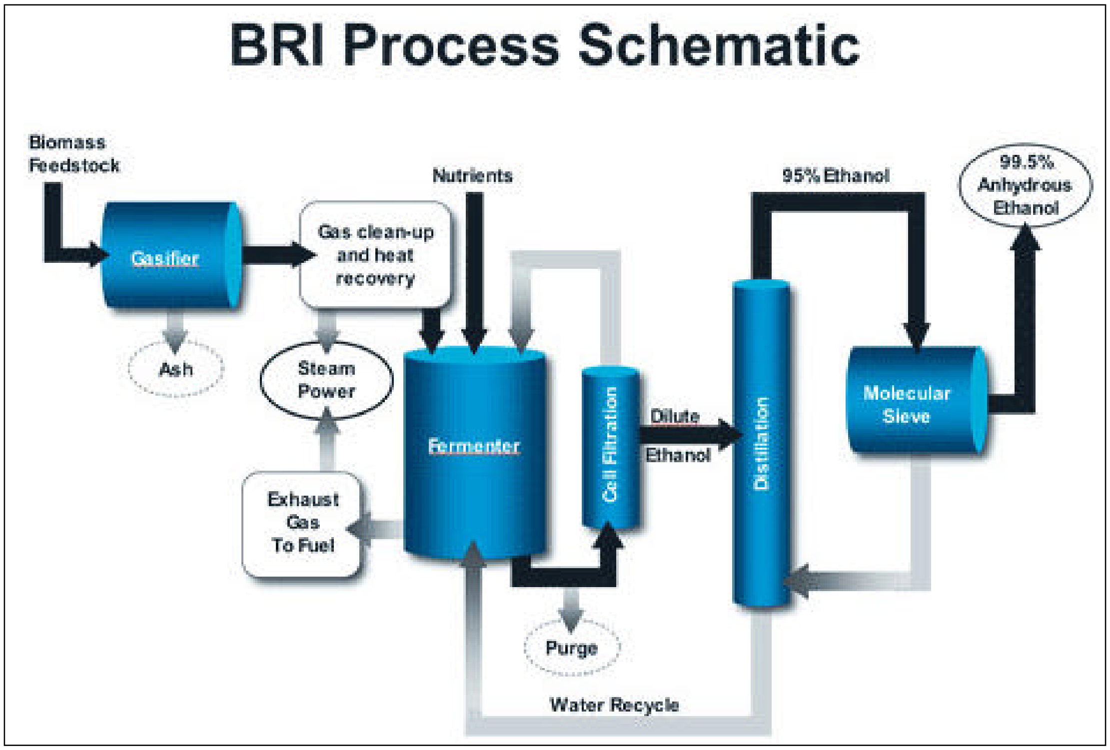

Figure 24. INEOS Bio Combined Thermal Gasification/Biocatalytic Conversion Technology (Fayetteville, Arkansas)

Figure 25. BRI/INEOS Two-Stage Stepped Hearth Gasifier (Fayetteville, Arkansas)

Figure 26. BRI/INEOS Fermentation Vessel (Fayetteville, Arkansas)

The bacteria are found in nature where they have evolved to efficiently convert carbon monoxide and hydrogen to ethanol. The operative organism is a naturally occurring anaerobic bacterium that is associated with coal mines. The bacteria consume the synthesis gas from the thermal gasification process and produces ethanol as a byproduct. The bacteria are harmless to people and to the environment and are totally safe to handle in an industrial process.

Through 7 years of ongoing pilot plant testing, the process has achieved yields in the range of 80 to 90 gallons of bioethanol per bone-dry, ash free ton of biomass. Yields can be increased substantially when using non-biogenic feedstocks, such as used tires, in conjunction with biomass. This technology can have significant implication for the Navy as it is able to produce both electricity and also a liquid fuel.

4.3 Other Emerging Technologies

Many emerging technologies should be monitored and evaluated periodically to track their progress to becoming a commercially available technology. In addition to following "technology development," the Navy should have an ongoing effort to track various projects that are being developed by local government and private industry. Many of the emerging/developmental technologies are specifically designed from the start to process solid waste, but many of the emerging and developmental technologies were not originally specifically designed for processing municipal solid waste, but because of the potential energy recovery, the technology developers are "adapting and optimizing" their technologies to be able to process municipal waste.

In addition to evaluating the performance of the technologies, it is also important to evaluate the technology developer's awareness and understanding the myriad of issues and factors involved with the successful commercialization and transfer of technology to a commercially available technology, and eventually to a successfully implemented project. One of the most important technical issues is the level of "preprocessing" that is needed to produce a feedstock that will optimally and reliably to work with their specific technology. This means that the project developer has to understand what should be in the feedstock, but also what should not be in the feedstock. The process of creating a feedstock that ensures reliable generation of clean energy is as much a part of the overall "technology package" as is the thermal conversion technology unit itself.

The project team recommends that the Navy monitor and evaluate the progress of the following emerging and developmental thermal conversion technologies (Table 12).

Table 12. Recommended Emerging and Developmental Thermal Conversion Technologies

#	Technology Developer	Type of Technology
1	INEOS / BRI	Thermal / Biocatalytic Conversion
2	Plasco Energy	Plasma Arc
3	International Energy Solutions (IES)	Gasification
4	GEM America	Thermal Cracking

5.0 TECHNOLOGY GAPS

5.1 Statutory Policy Gaps

The statutory and regulatory infrastructure which reflects the environmental policy goals of a country (and/or of a city and/or of a state) is a powerful tool that creates incentives and mandates for technological progress. Statutory / regulatory infrastructure in European Union countries and Japan are the primary "technology drivers" for conversion technology. For example, Germany was one of the first countries that instituted a phased landfill ban on the disposal of decomposable (organic) materials. The goal was to minimize the production of greenhouse gases (carbon dioxide and methane) from landfills. This "technology forcing function" in the form of a landfill ban mandated the development of alternative technological solutions, such as the comprehensive implementation of WTE conversion facilities which converts the organic portions of the waste stream to energy.

The European Union has implemented policies that prohibit the disposal of materials that cause biological reactions (e.g., generation of greenhouse gases) and materials that can cause deleterious chemical reactions. Another policy that is that has a significant technology forcing function is the prohibition of landfilling for materials with energy value (e.g., plastics, etc.).

Figures 27 and 28 are examples where Germany and the City of Yokohama (Japan) demonstrated their success in landfill diversion by showing the reduction of GHG in million metric tons of CO_2 equivalent. Below are examples of the documentation of landfill diversion and recycling progress from Germany:

Figure 27. Germany Landfill Disposal Reduction (Resulting from Landfill Ban)

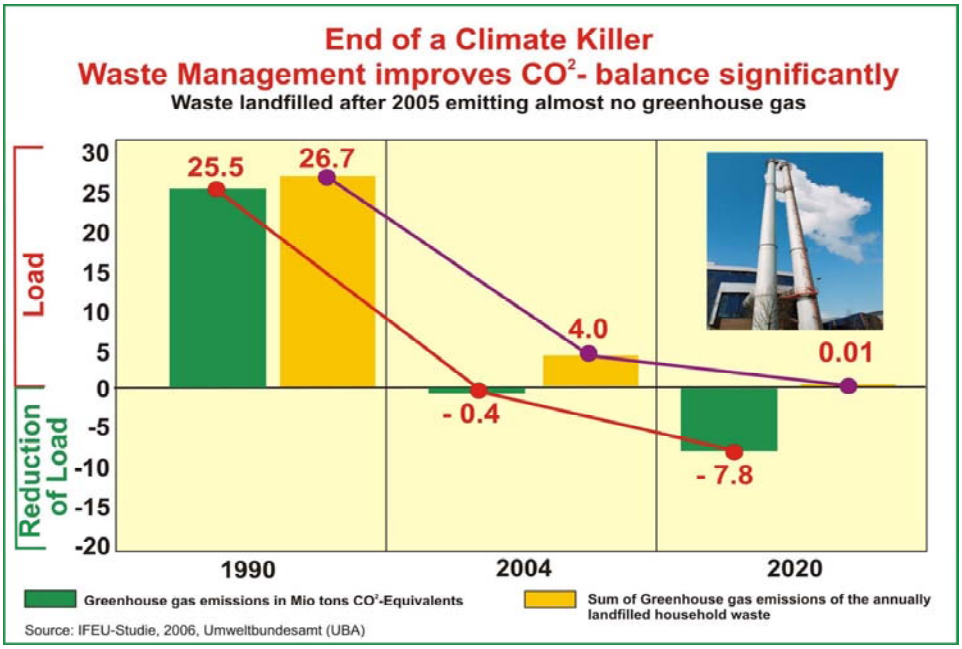

Figure 28. Germany GHG Reduction Tied To Landfill Diversion

Solid waste management progress in Germany and Japan is partially measured in terms of the decrease in carbon dioxide emissions. Figure 29 is an example of an overhead used by the City of Yokohama.

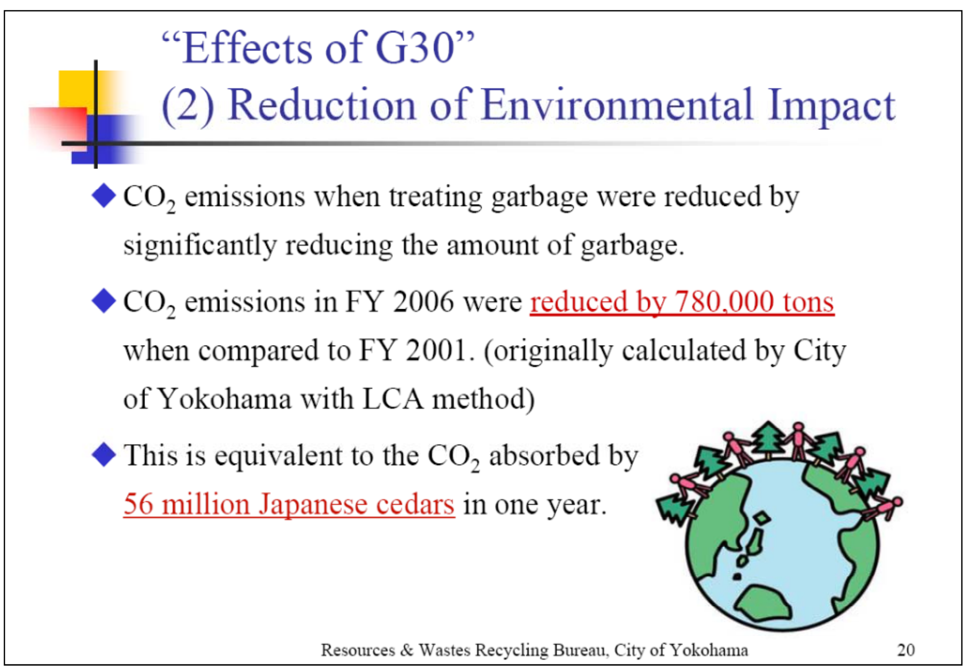

Figure 29. GHG Reduction (Yokohama, Japan)

There are no Federal or State landfill bans on organic wastes and there are also no disposal bans on materials with energy value in the United States. There is recognition by the U.S. Environmental Protection Agency that the carbon footprint from the incineration of solid waste and energy recovery is lower than that of landfill disposal. The EPA has a climate change, GHG calculator, WAste Reduction Model[9] (WARM), which provides an estimate of the carbon dioxide equivalent reduction by the implementation of recycling and waste-to-energy programs.

One specific statutory / regulatory driver that has created some interest in the generation of renewable energy from solid waste is the passage of renewable energy portfolio standard goals for utilities. Many states have set minimum renewable portfolio standards (RPS) for utilities. In California, the goal set by AB 32 is 33 percent. Given the long distance transmission and availability issues related to solar and wind energy, some utility companies are considering the use of a more local, or community-based alternative to producing renewable energy. Only a few utilities have taken on the task of investigating the feasibility of such a project.

The "regulatory fees" imposed on landfill disposal in the European Union and in Japan drive the cost of landfill disposal upwards of $200 per metric ton. In Australia, a regulatory fee on landfill disposal of $70 per metric ton is imposed. These fees create an economic incentive and a much more level fee structure that enables conversion technology projects to be economically competitive with landfill disposal.

Without such statutory / regulatory drivers which have created the technical and economic infrastructure that foster the development of conversion technology projects, the development of conversion technology projects will have to economically compete against the relatively cheap cost of landfill disposal in the United States.

5.2 Technical Impossibility in Statutes (California)

California has extensive statutory issues related to the use of thermal gasification conversion technologies that does not exist in any other state. As of July 2010, the California Public Resources Code Section 40117 contains a non-workable definition of "gasification" (see below).

> *Public Resources Code, Section 40117. "Gasification" means a technology that uses a noncombustion thermal process to convert solid waste to a clean burning fuel for the purpose of generating electricity, and that, at minimum, meets all of the following criteria:*
>
> *(a) The technology does not use air or oxygen in the conversion process, except ambient air to maintain temperature control.*
>
> *(b) The technology produces no discharges of air contaminants or emissions, including greenhouse gases, as defined in subdivision (g)*

[9] EPA Information: WARM http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html

of Section 38505 of the Health and Safety Code.
(c) The technology produces no discharges to surface or groundwaters of the state.
(d) The technology produces no hazardous waste.
(e) To the maximum extent feasible, the technology removes all recyclable materials and marketable green waste compostable materials from the solid waste stream prior to the conversion process and the owner or operator of the facility certifies that those materials will be recycled or composted.
(f) The facility where the technology is used is in compliance with all applicable laws, regulations, and ordinances.
(g) The facility certifies to the board that any local agency sending solid waste to the facility is in compliance with this division and has reduced, recycled, or composted solid waste to the maximum extent feasible, and the board makes a finding that the local agency has diverted at least 30 percent of all solid waste through source reduction, recycling, and composting.

This definition is considered a "technical impossibility" because of the requirements cannot be met by any existing technology. For example, the requirement that the technology produce no greenhouse gases (e.g., carbon dioxide, methane, etc.) cannot be met. If the technology/facility in question requires electricity (e.g., any device plugged into the wall) generated from an electrical utility, then the technology is responsible for the emissions of the carbon dioxide produced by the electrical utility company (considered a Scope 2 Emissions in California when conducting a carbon inventory).

The requirement that no hazardous waste be produced by the technology is another example of a requirement that is not required of any other technology or process and technically impossible. Facilities are allowed to generate hazardous wastes, but have to manage it according to the regulations (e.g., proper identification, storage, proper treatment/disposal, etc.). What is considered "hazardous waste" is defined by statutes, regulations, listed in regulatory documents, and/or defined by its characteristics. What makes this statutory provision impossible, besides the fact that all waste processing facilities generate some hazardous waste, is that "definitions" change over time, and a specific material that may not be considered hazardous by current definitions and existing lists may become hazardous in the future.

5.3 Regulatory Uncertainty Related to Permitting (California)

There is no clear permitting path for conversion technologies in California. At the present time in California, an incineration facility (classified as a "transformation" facility for the purpose of permitting) is considered a waste disposal facility and the permitting requirements for an incinerator are clearly defined within the State and local regulations. The determination of whether a thermal gasification conversion technology facility is a transformation facility and/or a disposal facility has tremendous permitting implications.

Even with the additional layer of air permits at the local air district, the permitting requirements for WTE incineration projects are readily understood, and a number of waste-to-energy incineration facilities have been constructed and are still in operation. Because California has specifically separated “gasification” from the traditional form of incineration, thermal conversion project developers have been concerned that there is no specific regulatory guidance on what permits are needed for such a facility.

Given the fact that there is an existing statutory definition for thermal gasification is a technical impossibility, and that the regulatory path is uncertain, the exact classification of a thermal gasification conversion technology facility is considered by some to be in a regulatory “void” (not addressed by regulations, because a gasification technology doesn’t meet the “regulatory definition” and thus cannot be called as such). Developers of full scale and demonstration scale thermal conversion technology facilities have publically testified that they have gone to other states to permit and build these facilities because of statutory uncertainties in California.

6.0 OTHER INSIGHTS

6.1 Community Education / Outreach

It is important to note that that community education and outreach activities are considered a significant part of the overall facility design and operations of an integrated facility. Figures 38 through 38 are examples of incorporation of community activities and community education / outreach of various conversion technology facilities:

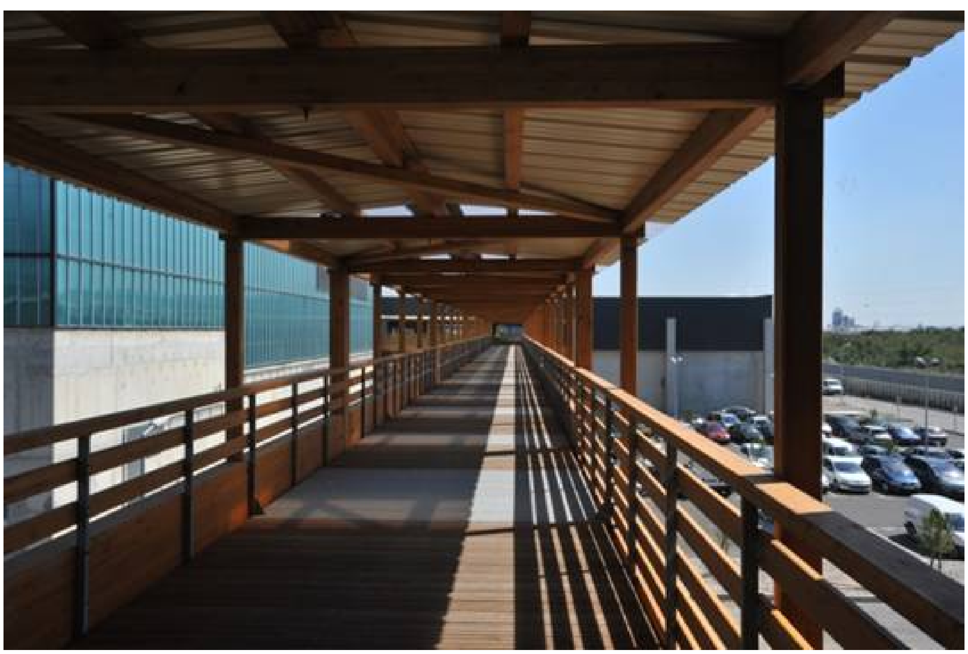

Figure 30. Operations viewing walkways at EveRE Integrated Facility for community tours (France)

Figure 31. Visitor Center at Valdemingomez Technology Park (Spain)

Figure 32. Recycling Education Room, Visitor Center at Valdemingomez Technology Park (Spain)

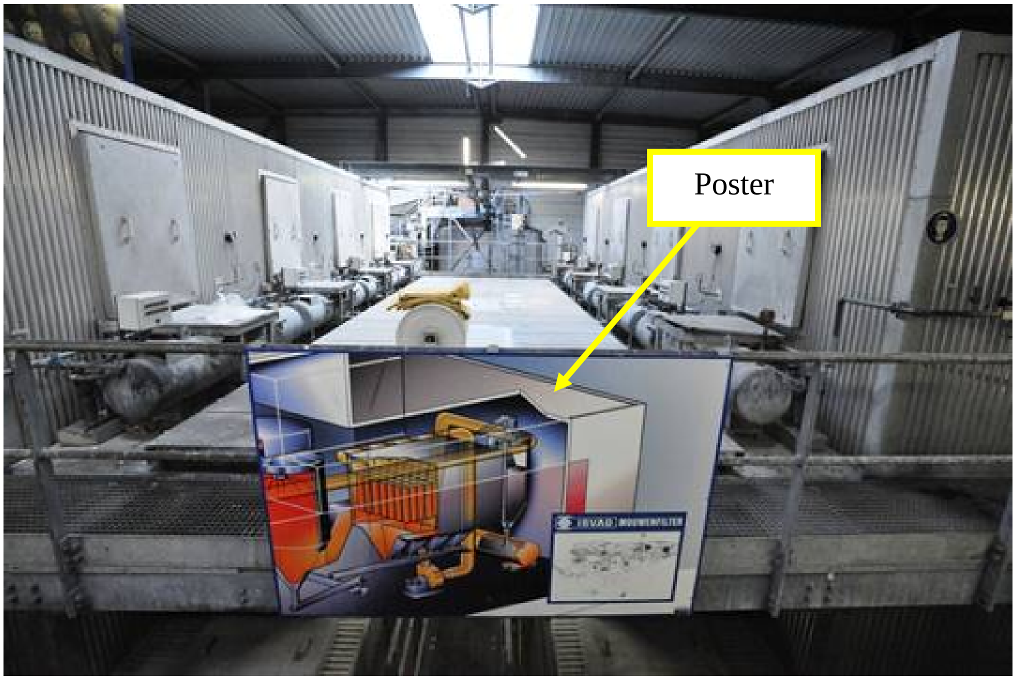

Figure 33. Process and equipment explanation posters inside ISVAG Facility (Belgium)

Figure 34. Environmental Education Center at Kasama Eco-Frontier Gasification Facility (Japan)

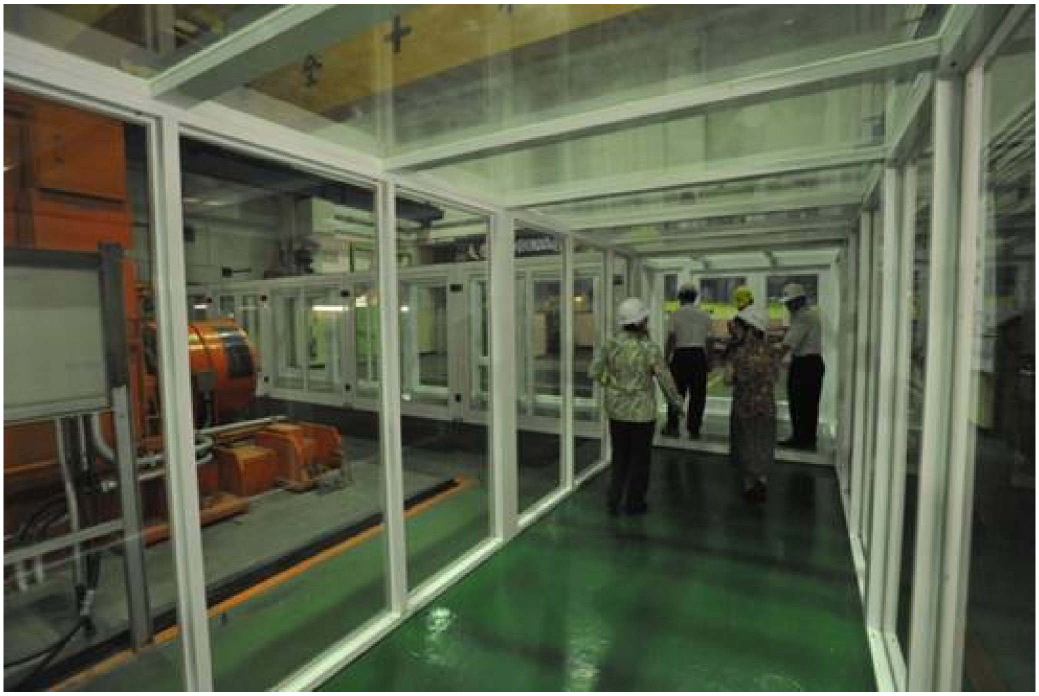

Figure 35. Enclosed walkways for community tours at Bali Incineration Facility (Taiwan)

Figure 36. Thermal gasification facility (Kawaguchi City, Japan) with "community center" and swimming pool

Figure 37. Thermal gasification facility (Kawaguchi City, Japan) with community thrift shop

Figure 38. Thermal gasification facility (Kawaguchi City, Japan) with community "tea room"

It is important to re-emphasize that that community education and outreach facilities and activities are considered by project engineers and developers to be an integral part of the facility design and operations of any successful "eco town" or integrated facility project.

Figure 39 is the view from the Ebara Facility (Kawaguchi City, Japan); the facility is located in a residential area and within a block of a school. This facility is an excellent example of a thermal gasification conversion technology project that has been successfully integrated into the local community.

Figure 39. View from thermal gasification facility

Siting of thermal conversion technology across street from residential area and grade school (Ebara Facility, Kawaguchi City, Japan).

The participation of successful education/outreach and community stakeholder could result in successful siting and permitting of community-based conversion technology projects in urban areas.

6.2 Post Recycling Residual Feedstock Requirements / Policies

For the purposes of this report, "post-recycled" solid waste is the feedstock designated for conversion technologies. Examples of "post recycled solid waste" are:

- materials from the "black bin" or trash bin of a residential three bin system, where there is also a recycling bin and a yard waste recycling bin, or
- the residuals from a recycling center that are bound for disposal, or

- residuals from a mixed waste materials recovery facility ("dirty MRF") that are bound for disposal (after the recyclables have been removed)
- materials (which have had recyclables removed) that are collected from businesses

The recycling industry, environmentalists, and many policy makers have the belief that conversion technology projects will weaken or destroy the waste reduction and recycling infrastructure. The goal of having the "post recycled solid waste" requirement is to mandate recovery, to the maximum reasonable extent possible, of the marketable recyclable materials. Sometimes, the terminology "MRF first" is utilized by some policy/legislative and environmental organizations to describe the priority of recovering of marketable recyclables before the solid waste residuals can be CT feedstock.

The primary concern expressed by some in the recycling industry even in this scenario, is that the "ease and convenience" of conversion technology as a catch all before the landfill lessens the importance of the waste reduction activities/programs and recycling programs that occur further up in the chain of events.

The pictorial flow diagram (Figure 40) shows how conversion technology processing the "trash bin" (a.k.a. "black bin") waste meets the requirement of recovering the recyclables to the maximum extent possible. Note that the conversion technology is separate from the recycling program and the green waste/food waste recycling program, and is processing only the materials currently bound for disposal. The control of what goes into the trash bin is totally dependent upon the actions of the generators (e.g., residents).

In Figure 40, the more waste reduction and recycling that is accomplished by the resident / household (the generator), the less black bin trash will be bound for conversion technology and/or landfill disposal. Conversion technology does not compete against recycling and waste reduction, it competes against landfill disposal. The final makeup of the conversion technology feedstock is dependent on the generator's (residents) waste reduction and recycling actions. The "household disposed trash" represents what is remaining after the residents' post waste reduction and post-recycling activities.

What many environmentalists argue is that the "convenience" of having conversion technology (as "recycling") will create a disincentive to waste reduction and recycling activities (e.g., … "it will be diverted anyway, so why do I have to do anything?"). However, this belief is not supported by the facts; some of the highest levels of recycling are achieved in Germany, Netherlands, and other countries in the European Union, as well as in Japan, where conversion of WTE is an integral part of the waste management system.

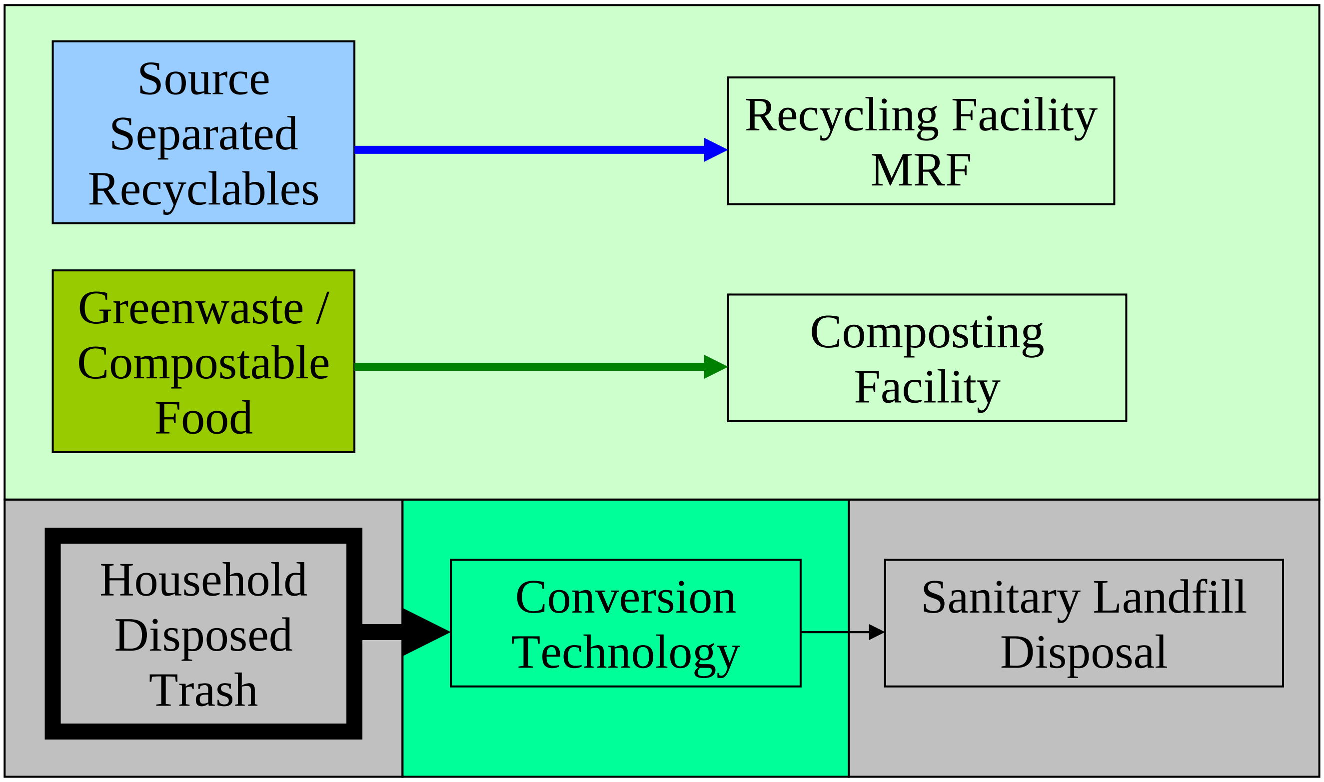

Figure 40. Conversion Technology Compatibility with Recycling
(Source: Testimony before the California State Assembly Natural Resources Committee, UCLA Engineering Extension Recycling / MSW Management Program, Professor E. Tseng)

Actual documented programmatic results show that the "integrated materials recovery approach" in which source separated recycling programs, combined with additional materials recovery during the preprocessing of the post-recycled waste stream, and combined with biological conversion technologies (e.g., anaerobic digestion and/or composting), combined with energy recovery, and combined with the policy of phasing out and banning disposal of unprocessed waste at landfills, provides the highest levels of diversion from the landfill and also achieves the highest rates of traditional materials recovery from recycling.

The results compiled by EUROSTAT on waste generation and the diversion achieved through recycling and waste-to-energy are provided on the following page (Figure 41).

(Note: EUROSTAT is the statistical office of the European Union. EUROSTAT provides the European Union with reliable and objective statistics that enable comparisons between countries and regions. EUROSTAT also provides the public and media statistics for an accurate picture of contemporary society and to evaluate the performance of politicians and others.)

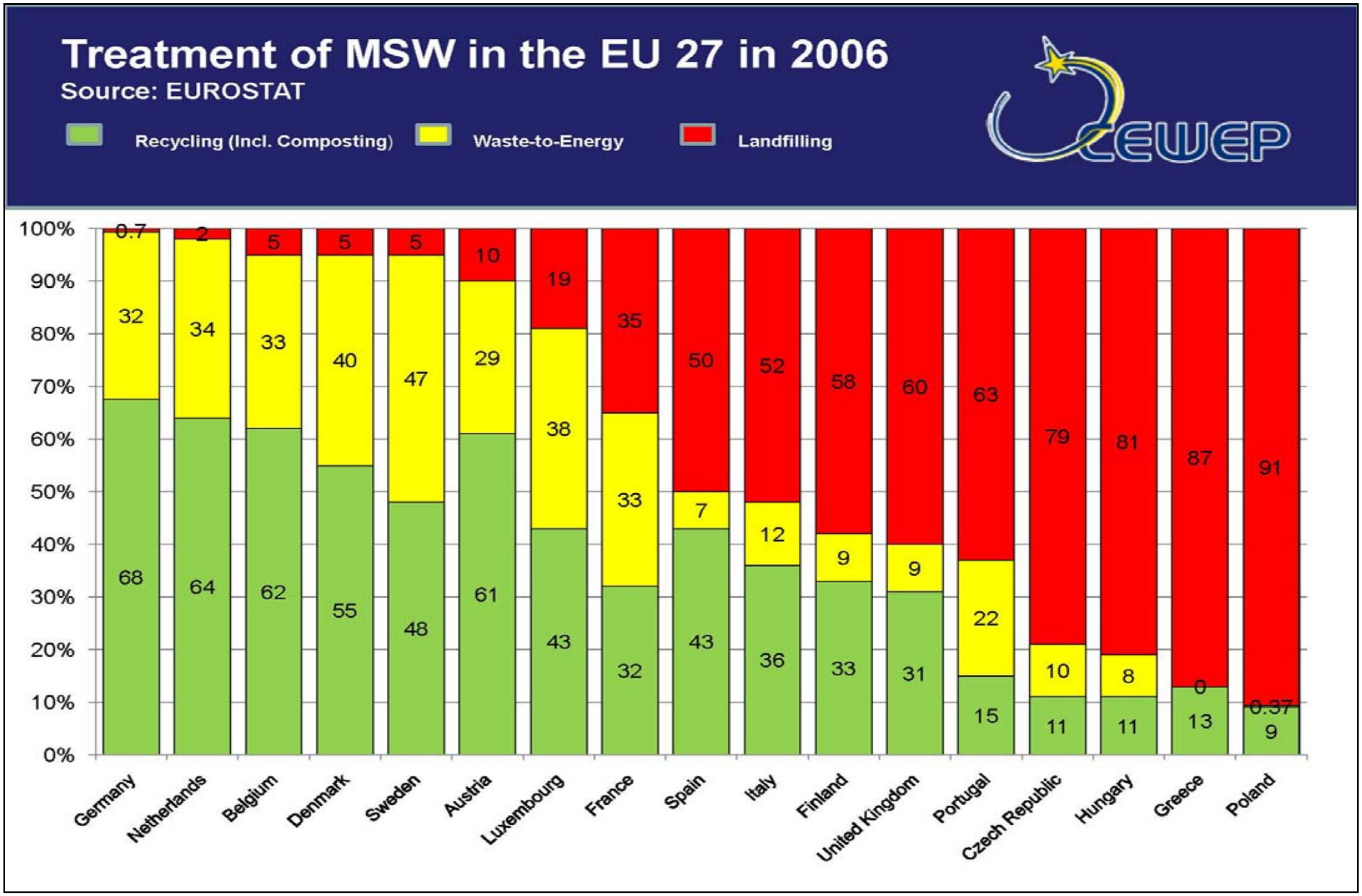

Figure 41. Treatment of MSW in the EU 27 in 2006
(Coby Skye, UCLA Engineering Extension, Conversion Technology Presentation, October 2010)

6.3 Municipal Solid Waste as a Feedstock for Conversion Technology

The MSW stream is comprised of many types of materials, and the actual "feedstock" for conversion technologies that is derived from solid waste will go through a significant amount of additional processing before the solid waste can becomes an optimal "feedstock." Depending upon the specific kind of conversion technology chosen, only a portion of the MSW stream may be suitable. Project developers refer to the additional processing that is required to produce a feedstock suitable for the "conversion technology" as "CT preprocessing". This includes the steps needed to meet a fuel specification that would be given by the conversion technology vendor. The specification may include fuel value, materials feed size distribution, moisture content, ash content, and other physical and chemical characteristics.

Each type of conversion technology has a preference for certain components in the mixed MSW stream. Materials that would be considered "non-processable" in a biochemical/biological conversion technology would be an ideal feedstock material in a thermochemical/thermal conversion technology, for example, plastic is not readily biodegradable in a biochemical conversion technology such as anaerobic digestion, but would be an ideal source of high fuel content feedstock in a thermochemical gasification conversion technology.

Conversion technology project developers need to recognize the different types of feedstock preparation approaches/operations required to produce a preferred feedstock for their selected technology. For example, if a "thermal gasification" type of technology is selected, the inorganic (metals, glass, etc.) portion of the waste stream does not have a high fuel value and thus would not be a suitable feedstock. For a biological process such as anaerobic digestion, even part of the "organic fraction" would not be suitable; although plastic and textile/leather are organic, they decompose so slowly within the "digestion process" that they should be removed from the process feedstock.

The importance of preprocessing mixed MSW into an optimal feedstock for the selected conversion technology should not be underestimated. Preprocessing to remove non-acceptable and non-processable materials will improve the reliability of the overall systems performance, and most importantly, for thermal gasification conversion technology projects, the emissions will be improved. For a thermal gasification project, the goal of preprocessing will be to concentrate the high value heat content materials (e.g., paper, plastics, etc.) into the feedstock, while removing high moisture, low heat content materials (food waste, glass, metals, etc.), and creating a thermal feedstock of homogeneous size and mixed materials of consistent heating value.

A detailed waste shed and waste composition analysis is included in the Appendix. As part of this IDR, a waste shed tonnage projection and waste composition analysis was conducted for each individual city in San Diego County. The calculated volumes and composition of the various transfer stations within San Diego County is also provided. The CD that is provided with this IDR includes additional waste characterization and tonnage volume for each of the detailed materials types (for each individual city in the County of San Diego).

To illustrate the concept of an optimal feedstock for an anaerobic digestion conversion technology, a waste characterization study conducted by Cape May County (1991) will be used to show the ideal feedstock materials in a mixed MSW stream. For anaerobic digestion conversion technology project, the "compostable" portion of the mixed MSW stream is generally considered to be the readily decomposable portion of the waste stream that would be the optimal input feedstock. The "preprocessing" operations would be designed to remove the "non-compostable" materials from the mixed MSW.

Table 13. Estimated Composition and Moisture Content of MSW

TABLE 1
Estimated composition and moisture content of MSW in Cape May County

Waste category	Percentage of total—by weight (a)	Moisture content (b)
Compostable		
Newspaper	4.1%	30.2%
Corrugated cardboard	3.4%	23.7%
Kraft paper	1.9%	29.4%
High-grade paper	0.6%	11.5%
Magazines	1.1%	10.4%
Other paper	23.3%	34.3%
Yard waste	4.9%	45.9%
Food waste	15.8%	63.9%
Disposable diapers	4.0%	66.2%
Fines	2.3%	40.9%
Other organics	4.5%	46.1%
Total or overall—compostable	66.1%	43.6%
Noncompostable		
PET bottles	0.3%	3.2%
HDPE containers	0.4%	8.0%
LDPE bags and film	3.0%	20.3%
Other plastic	7.8%	16.1%
Textiles/rubber/leather	5.3%	17.4%
Wood	3.8%	16.6%
Glass containers	3.6%	0%
Tin cans	1.3%	0%
Household batteries (c)	0.1%	0%
Other ferrous	3.6%	0%
Aluminum cans	0.6%	0%
Other aluminum	0.9%	0%
Other nonferrous	0.1%	0%
Other inorganics	3.1%	0%
Total or overall—noncompostable	33.9%	10.2%
Total or overall—combined	100.0%	32.3&

(a) Based on the sorting of 254 samples of MSW averaging 229 pounds in the summer and fall of 1990 and the winter and spring of 1991.
(b) Values greater than zero based on laboratory results for four seasonal composite samples of each waste category. Inorganic materials assigned moisture values of zero for purpose of calculating overall values.
(c) Alkaline and carbon-zinc batteries only. Nickel-cadium batteries in "other nonferrous."

Note the higher levels of moisture content (by weight percent) of the readily compostable/decomposable materials which form the ideal feedstock materials. In contrast, the most ideal feedstock materials for a thermal gasification conversion technology project are found in the non-compostable portion. Certain materials, such as paper, are ideal for both biochemical and thermochemical conversion technologies.

Emissions of heavy metals (e.g., mercury, etc.) resulting from the thermal conversion of solid waste can be reduced by preprocessing of the mixed waste stream by removing components of the trash stream that are the sources of the metals. Table 14 shows that the majority of the mercury is in batteries.

Table 14. Distribution of Detected Metals among MSW Components

TABLE 3
Distribution of detected metals among MSW components (a)

Waste category	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
Compostable								
Newspaper	0.2%	0.0%	0.0%	0.2%	0.0%	0.3%	0.0%	0.6%
Corrugated cardboard	0.4%	0.0%	0.0%	0.1%	0.6%	0.2%	0.9%	0.5%
Kraft paper	0.3%	0.0%	0.0%	0.1%	0.3%	0.1%	0.0%	0.1%
High-grade paper	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Magazines	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.3%
Other paper	4.3%	0.0%	0.4%	3.3%	2.1%	0.4%	0.0%	3.5%
Yard waste	2.0%	0.0%	0.1%	0.1%	0.7%	0.2%	0.6%	1.1%
Food waste	0.8%	0.0%	0.0%	0.4%	0.0%	0.1%	1.6%	0.8%
Disposable diapers	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
Fines	2.6%	1.0%	0.1%	1.1%	6.1%	0.1%	1.8%	2.1%
Other organics	2.7%	1.9%	0.2%	1.3%	1.3%	5.0%	2.6%	1.7%
Total compostable	13.9%	2.9%	0.9%	6.8%	11.1%	6.3%	7.5%	11.0%
Noncompostable								
PET bottles	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
HDPE containers	0.0%	0.0%	0.1%	0.0%	0.9%	0.0%	0.0%	0.1%
LDPE bags and film	0.6%	0.0%	1.2%	0.2%	12.9%	0.1%	0.0%	0.9%
Other plastic	1.4%	20.8%	0.2%	0.2%	1.5%	0.1%	0.0%	1.4%
Text./rubber/leather	2.0%	32.8%	8.0%	0.4%	2.5%	0.4%	1.2%	9.0%
Wood	58.0%	0.0%	0.8%	0.3%	4.0%	2.1%	0.0%	2.0%
Glass containers	0.0%	0.0%	0.0%	0.0%	3.0%	0.2%	0.0%	0.0%
Tin cans	2.6%	7.1%	2.7%	1.4%	4.5%	0.3%	7.5%	0.5%
Household batteries	0.4%	2.1%	0.0%	2.8%	0.3%	88.9%	0.0%	55.0%
Other ferrous	18.8%	16.4%	85.4%	1.6%	5.8%	0.6%	49.8%	10.2%
Aluminum cans	0.0%	0.0%	0.2%	0.2%	0.2%	0.1%	1.3%	0.1%
Other aluminum	0.0%	0.0%	0.2%	0.6%	0.2%	0.2%	1.6%	0.2%
Other nonferrous	0.5%	17.9%	0.1%	85.4%	51.7%	0.0%	30.4%	9.4%
Other inorganics	1.74	0.0%	0.3%	0.1%	1.5%	0.7%	0.7%	0.2%
Total noncompostable	86.1%	97.1%	99.1%	93.2%	88.9%	93.7%	92.5%	89.0%

(a) Based on tables 1 and 2.

A simple way is reduce emissions of mercury in a thermal conversion technology project would be to remove the batteries by using a combination of a screen to separate the small mercury batteries into the undersize fraction and to use a density separator to further remove the heavier portion of the undersize fraction. The engineering principle utilized in the preprocessing of solid waste to create an optimal fuel is called "progressive fractionation." Preprocessing concentrates the material components that have the desired characteristics for an optimal conversion technology feedstock and also removes the problematic and undesirable materials from the feedstock.

Preprocessing also provides an opportunity to recover additional recyclables such as metals (ferrous and non-ferrous), glass, and other materials that do not contribute to the energy value of solid waste, but does have marketable commodity value as a recyclable raw material. Additional traditional recycling recovery is achieved by preprocessing of conversion technology feedstock.

The American Society for Testing and Materials (ASTM) developed a classification scheme for the utilization of MSW as a "**R**efuse **D**erived **F**uel" (RDF) based upon the level of "processing" done to prepare the as-discarded MSW into a feedstock that is suitable for use as a feedstock fuel.

Table 15 describes the ASTM's RDF designations and the descriptions of the fuel (in terms of the level of processing and potential use).

Table 15. ASTM RDF Designations

Refuse Derived Fuel Designations (in ASTM E 955-88)	
ASTM Designation	**Description**
RDF-1	Wastes used as fuel in as-discarded form
RDF-2	Wastes processed to coarse particle size with or without ferrous metal separation
RDF-3	Shredded fuel derived from MSW that has been processed to remove metal, glass, and other inorganic materials
RDF-4	Combustible waste processed into powder form, 95 weight percent passing 10 mesh (2 mm)
RDF-5	Combustible waste densified (compressed) into the form of pellets, slugs, cubettes, or briquettes
RDF-6	Combustible waste processed into liquid fuel
RDF-7	Combustible waste processed into gaseous fuel

Note that these ASTM classifications are focused on the processing of MSW for the specific purpose of creating a refuse-derived fuel.

RDF-1 refers to an "as-discarded" form of MSW. This could mean either a trash stream from a jurisdiction/generator that does or does not have a recycling program. The term "as-received" waste is also used by many industry practitioners. RDF-1 is the most common feedstock to mass burn incineration facilities. Mass burn incinerators are designed to incinerate as-discarded MSW without additional processing (except removal of hazardous and non-acceptable items as required by law).

RDF-2 is also referred to by many industry practitioners as "c-RDF" or "crude-RDF." Processing to make RDF-2 simply involves coarse shredding for the purpose of creating a more uniform sized and homogenous feedstock, with the option of using a magnet to remove ferrous metals for recycling and ash reduction.

RDF-3 is also referred to as f-RDF or "fluff-RDF" and/or "process engineered fuel" or "PEF". There are many levels of processing for RDF-3. The primary purpose of processing is to recover metals for recycling and to reduce the ash content by removing inorganic materials. The level of processing required is dependent upon the systems process requirements and performance specifications (e.g., 95 percent of combustibles to be recovered for energy conversion and to minimize landfill disposal of decomposable materials, 90 percent recovery efficiency of ferrous metals recovery, and by other considerations of recyclables, etc.). At higher levels of processing there is more of an emphasis on materials recover, ash reduction, and creating a fuel with higher energy content.

Most materials recovery facilities (MRFs) are designed specifically for the recovery of recyclables and can also be viewed to be a form of a RDF-3 production facility, except that the focus is on recovering recyclables rather than on RDF production. The "post recycled" MRF solid waste residuals can be seen as an unfinished form of RDF-3 that has not been optimized for use as a fuel. Additional processing is necessary, e.g., such as removal of inorganics, to complete the process of converting post recycled solid waste into a RDF.

RDF-4 is the powdered form of RDF-3, and usually involves extensive processing to remove the inorganic and abrasive materials. Extensive size reduction equipment is the norm, and even dryers are used to "brittle" paper for easier size reduction. This form of RDF is not recommended for consideration by conversion technology developers because of the explosion risks associated with powdered combustible materials storage and handling.

RDF-5 is sometimes referred to as densified-RDF or d-RDF. RDF-5 is simply RDF-3 size reduced further and densified in a pelletizer, briquetter, or cuber. The process of creating the densified RDF fuel reduces the overall moisture content of the materials and creates a uniform material characteristic of physical size and density which gives a much more predictable fuel value and improved handling characteristics. One of the primary purposes of densification is to improve the physical "handling" properties of the refuse derived fuel for the purpose of long term storage and/or for more cost efficient transportation.

Figures 42 through 44 show some of the forms of RDF-5:

Figure 42. "Cube" form of RDF-5
(UCLA Engineering Extension Photo)

Figure 43. Top view of various forms of "densified RDF" RDF-5
(UCLA Engineering Extension Photo)

Figure 44. End view of various forms of "densified RDF" RDF-5
(UCLA Engineering Extension Photo)

The need to produce RDF-5 from RDF-3 may arise when RDF-3 is transported to a remote conversion technology facility that is separate from the RDF-3 production facility and/or when RDF needs to be inventoried or stored for a significant amount of time. RDF-5 typically has about half of the heating value of coal (6,000 BTU/lb, HHV).

RDF-5 has alternative uses besides being utilized as a conversion technology or WTE combustion technology fuel feedstock. RDF-5 has been successfully used as a compost bedding material for co-composting with sewage sludge.

RDF-6 refers to MSW feedstock that is converted to biofuels and/or other liquid products (e.g., ethanol, FT-fuels, etc.). Biochemical conversion technologies such as anaerobic digestion and acid hydrolysis can produce ethanol as an end product. Thermal technologies such as gasification can be combined with biochemical technology such as digestion in a two stage process to produce a liquid fuel such as ethanol.

RDF-7 refers to MSW feedstock that is converted to a gaseous fuel, such as biogas or syngas. Thermal conversion technologies such as pyrolysis and gasification produce a syngas that can be directly utilized in an engine to produce power. A high-BTU syngas can also be used as a natural gas substitute for combustion in a traditional boiler to produce steam and power.

Depending upon the technologies and end products, only a portion of the post-recycled solid waste will be appropriate to be in the feedstock RDF. “CT preprocessing” is the processing of the post recycled solid waste into a usable RDF feedstock for a specific technology. For example, for an anaerobic digestion process to produce methane, the ideal portion of the feedstock would be the readily decomposable organic materials (e.g., food waste, paper, but not plastic).

For a thermal conversion process, the ideal portion of the post recycled solid waste feedstock would be the non-marketable / non-recyclable paper and also the higher heat value non-marketable / non-recyclable plastic portions of the waste stream. Post recycled solid waste composition studies allow a conversion project technology developer to estimate how much of the waste stream is actually appropriate for the selected technology and end product(s).

6.4 Biogenic / Non-Biogenic Feedstocks and Renewable Energy

The many different materials found in MSW are commonly classified into two categories: biogenic (derived from natural sources, including paper, wood, green waste, food waste, etc.) and non-biogenic (e.g., plastic, tires, etc.). The debate about whether energy produced by MSW feedstock should be counted as renewable centered on these definitions. This issue was debated at both the Federal and at the State (California) level and has potential significant financial consequences related to the energy sales.

From 1988 to 2005, the heat content and non-biogenic proportion of MSW has steadily increased over time. The following (Table 16) from the U.S. Department of Energy shows the proportions of biogenic wastes and non-biogenic waste from 1995 to 2005:

Table 16. Municipal Solid Waste Heat Content and Biogenic/Non-Biogenic Shares

Municipal Solid Waste (MSW) Heat Content and Biogenic/Non-Biogenic Shares, 1989-2005			
Year	**Heat Content (Million Btu/Ton)**	**Shares of Total MSW Energy**	
		Biogenic	**Non-Biogenic**
1989	10.08	0.67	0.33
1990	10.21	0.66	0.34
1991	10.40	0.65	0.35
1992	10.61	0.64	0.36
1993	10.94	0.64	0.36
1994	11.15	0.63	0.37
1995	11.11	0.62	0.38
1996	10.94	0.61	0.39
1997	11.17	0.6	0.4
1998	11.06	0.6	0.4
1999	10.95	0.6	0.4
2000	11.33	0.58	0.42
2001	11.21	0.57	0.43
2002	11.19	0.56	0.44
2003	11.17	0.55	0.45
2004	11.45	0.55	0.45
2005	11.73	0.56	0.44

Source: http://www.eia.doe.gov/cneaf/solar.renewables/page/mswaste/msw_report.html

A rough estimate of the energy output from a conversion technology utilizing post-recycled solid waste as feedstock can be estimated by factoring the waste stream with the energy share percentage proportion that represents biogenic wastes. For the year 2005, approximately 56 percent of the energy output produced by a conversion technology project would count as renewable energy if only the biogenic portion of the municipal waste feedstock is utilized as fuel.

This issue was recently settled upon final clarification of the EPA rules published in the Federal Register (Feb 4, 2010, RFS2), the biogenic portion of post-recycled MSW qualifies as "renewable biomass" for the purpose of meeting federal mandates for the production of advanced biofuels. This rule (along with pending legislation in California, e.g., AB 222, Adams/Ma 2010) necessitates a characterization of the feedstock stream to determine the portion of the solid waste which is biogenic (derived from natural sources, paper, wood, green waste, food waste, etc.) and which is non-biogenic (e.g., plastic, tires, etc.). This characterization is needed because the income stream derived from the energy sales is dependent upon how much of the waste stream is deemed “renewable biomass”.

Figure 45 is a photograph of the non-marketable plastics that is in a residual waste stream that has been processed to remove biodegradable organics such as food, paper, metal, and marketable plastics. This is an example of the non-biogenic portion of the feedstock that would not qualify as renewable biomass.

Figure 45. Example of non-recyclable, non-biogenic "plastic"materials

Stationary combustion units using MSW and mixed fuels (biogenic fuels with fossil fuels) are allowed to use ASTM D6866 to measure the biogenic CO_2 in their emissions. According to the EPA's Mandatory Reporting Rule[10]:

> “Perform the ASTM D7459-08 sampling and the ASTM D6866-08 analysis at least once in every calendar quarter in which MSW is combusted in the unit. Collect each gas sample during normal unit operating conditions while MSW is the only fuel being combusted for at least 24 consecutive hours or for as long as is necessary to obtain a sample large enough to meet the specifications of ASTM D6866-08.
>
> Separate CO_2 emissions into the biogenic and non-biogenic fraction using the average proportion of biogenic emissions of all samples analyzed during

[10] Beta Analytical. http://www.betalabservices.com/renewable-carbon/us-epa.html

the reporting year. Express the results as a decimal fraction (e.g., 0.30, if 30 percent of the CO_2 from MSW combustion is biogenic). If there is a common fuel source of MSW that feeds multiple units at the facility, performing the testing at only one of the units is sufficient." – Page 56405

"For units that use CEMS to measure the total CO_2 mass emissions and combust a combination of biogenic fuels (other than MSW) with a fossil fuel, ASTM D6866-08 and ASTM D7459-08 may be used to determine the biogenic portion of the CO_2 emissions." – Page 56406

"When ASTM Methods D7459-08 and D6866-08 are used to determine the biogenic portion of the annual CO_2 emissions from a unit that co-fires biogenic (other than MSW) and non-biogenic fuels, you shall report the results of each quarterly sample analysis, expressed as a decimal fraction (e.g., if the biogenic fraction of the CO_2 emissions is 30 percent, report 0.30)." – Page 56409

6.5 Other Potential Feedstock Materials

6.5.1 Tires

There are other specific material types that are not included within this study, but need to be mentioned as potential feedstocks. Within the definition of municipal solid waste, tires (e.g., passenger cars, truck tires, etc.) are considered a "special waste" because they require special handling. Discarded whole tires disposed in the MSW stream that arrive at a transfer station/MRF are typically removed by transfer station/MRF floor sorters and treated as non-processible material in facilities designed to recover recyclables. Whole tires are banned from landfill disposal; they can only be disposed in a landfill when they are cut up into smaller pieces because whole tires that are buried in a landfill eventually work their way to the landfill's surface.

There are many large problematic "tire piles" that pose both a public health and environmental health risk. Tires are considered a nonbiogenic waste, but have one of the highest energy content of any material in the MSW stream. Tires are currently utilized as a supplemental fuel for the generation of heat in cement kilns. Tires are processed in existing WTE facilities and blended with MSW and/or RDF. The West Palm Beach Resource Recovery Facility, a RDF waste to energy facility, has a separate processing line specifically for tires. The project research team recommends that tires should be considered as a potential feedstock.

6.5.2 Navy Plastic Disks

Another potential feedstock is the plastic waste (i.e., plastic waste processor (PWP) disks,) which is offloaded from U.S. Navy ships (see Table 17). Public Law No: 103-160, national Defense Authorization Act for the Fiscal Year 1994) requires zero plastic discharge into the waters at sea. According to the *NSWCCD-63-TM-2008/50 Rev 1*

November 2009, IDR on Disposal of Navy Shipboard Plastic Waste, Revision 1 report, The amount of total plastic waste generated onboard all surface ships in the U.S. Navy is estimated to be 2,910 tons annually.

Table 17. Navy Plastic Disk Generation Rates

Class	No. of Hulls	Average Crew Size	Underway Generation Rate (lbs/Sailor/day)	Assumed Days Underway	Plastic Generated Underway per Year per Class	Assumed Homeport Crew Size (% of Full Crew)	Homeport (lbs/day)	Assumed Days Homeport	Plastic Generated Homeport per Year per Class (lbs)	Total Generated per Class per Year (lbs)
Note (1)	Note (1)	Note (1)	Note (2)	Note (3)		Note (4)		Note (3)		
CVN 65	1	5,830	0.2	102	119,165	0.3	327	263	85,936	205,101
CVN 68	9	5,680	0.2	110	1,119,528	0.3	318	256	731,241	1,850,769
CG 47	22	364	0.2	120	192,913	0.5	34	245	182,923	375,836
DDG 51	53	361	0.2	113	432,980	0.5	34	252	453,834	886,813
FFG 7	21	300	0.2	113	142,569	0.5	28	252	148,088	290,657
LCC 19	2	1,450	0.2	69	40,223	0.5	135	296	79,826	120,049
LHA 1	3	3,004	0.2	110	197,363	0.2	112	256	85,848	283,211
LHD 1	7	3,002	0.2	131	552,248	0.2	112	234	183,142	735,390
LPD 17	4	1,196	0.2	117	111,754	0.2	45	248	44,676	156,430
LPD 4	6	1,320	0.2	117	185,011	0.2	49	248	72,971	257,982
LSD 41	8	917	0.2	113	166,014	0.5	86	252	173,273	339,286
LSD 49	4	856	0.2	120	82,484	0.5	80	245	78,256	160,740
AS 39	2	1,351	0.2	22	11,835	0.5	126	343	86,461	98,296
MCM 1	14	84	0.2	80	18,887	0.5	8	248	27,798	46,685
PC 1	10	28	0.2	91	5,110	0.5	3	274	8,213	13,323
TOTAL (lbs)					**3,378,083**				**2,442,485**	**5,820,568**
TOTAL (tons)					**1,689**				**1,221**	**2,910**

Notes:
(1) Ship data taken from Naval Vessel Registry Website.
(2) Plastic waste generation rate from NAVSEA Design Supplement (NDS 1101 - Plastoc Waste).
(3) Assumed at sea and homeport days taken from NAVSEA Navy Surface Ship Waste Disposal Costs Report, Revision IIIA, April 2006 (where available).
(4) Assumed homeport crew size taken from NAVSEA Navy Surface Ship Waste Disposal Costs Report, Revision IIIA, April 2006.

Approximately 1,677 tons per year are processed with PWP equipment which compresses the waste into a large flat plastic disk approximately three inches thick and 20 inches in diameter, weighing between 9.4 and 15.6 pounds or as much as 20 to 30 pounds each, depending upon the PWP equipment model. Figure 46 provides the estimated distribution of the PWP disks that are offloaded at the various U.S. homeports:

According to the IDR report (*Disposal of Navy Shipboard Plastic Waste, Revision 1*), the disks contain a mixture of plastics (50 percent) and other materials such as paper (28 percent), aluminum (4 percent), cloth (5 percent), food (5 percent), steel (3 percent), and 5 percent other miscellaneous non-plastic materials. Except for the Norfolk and Pearl Harbor homeports where the disks are incinerated at local facilities, the disks are currently being disposed in a landfill through the existing waste collection and management system that services the homeport areas.

The volume / tonnage of PWP disks at any one location will not support the operations of a full scale commercial conversion technology facility. The single largest homeport tonnage is the San Diego homeport, which accounts for 34.7 percent of the PWP disks, is only 582 tons of materials per year (which represents less than 2 tons per day). However, this material can be "blended" with the thermal conversion technology feedstock to boost the energy value. Care must be taken to maintain an operational equilibrium by keeping the overall thermal fuel value characteristics of the blended thermal feedstock as uniform as possible to insure unintentional flare-ups.

Figure 46. Estimated Distribution of PWP Disks Offloaded at U.S. Homeports
(NSWCCD-63-TM-2008/50 Rev 1 November 2009, IDR on Disposal of Navy Shipboard Plastic Waste, Revision 1)

6.5.3 Special Waste and Medical Waste

Waste incineration and thermal conversion technology facilities are capable of processing various other types of feedstocks besides municipal waste. Generally, the limitations on the feedstock are not so much of a technical limitation of the process, but the limitations are more of a regulatory and/or political or other constraint.

Special wastes are often incinerated or gasified as a public service, for example, the destruction of contraband drugs and evidence after the judicial trial is completed. Special considerations are needed for these types of periodic events, such as the organization of security for transport, processing, and confirmation of destruction.

Medical wastes pose a bio-infectious risk, and are often incinerated or gasified as a feedstock by itself or blended with municipal waste. Medical waste has a high proportion of plastic and has high fuel value so that medical waste needs to blended and metered carefully to prevent thermal spikes or flare-ups. Typically, special isolated medical waste tracking and feedstock processing areas are an integral part of a conversion technology facility that processes medical waste. These facilities are highly automated to minimize interaction with workers. Figure 47 is a picture of a medical waste unloading / processing facility that is specially set aside area of a MSW thermal gasification facility.

Figure 47. Eco-Frontier Kasama-City, Japan, MSW Gasification Facility, medical Waste Receiving and Unloading Section
(Courtesy of JFE Engineering)

In considering whether or not special wastes and/or medical waste can potentially be a feedstock, the project developer needs to be aware of the significant additional regulatory/permitting, social, and political issues and implications that would be raised in the development of the project which would handle these additional hazardous materials.

6.6 Environmental Impacts

There are unavoidable environmental impacts with construction and operations of WtCE projects utilizing thermal conversion technologies. One of the greatest concerns is that of air emissions from the thermal conversion of municipal waste. The Los Angeles County Department of Public Works has compiled an environmental fact sheet which demonstrates that conversion technologies are a superior option to traditional solid waste management practices such as landfilling and WTE and more than capable of meeting the most stringent air quality standards[11].

The three key findings are:

- Conversion technologies are capable of fully complying with the most stringent air emissions standards
- Conversion technologies actually make our air CLEANER
- Conversion technologies can help us address climate change

[11] http://www.socalconversion.org/pdfs/Conversion_Technology_Environmental_Factsheet.pdf

One of the most complete studies of emissions data from various thermal conversion technologies from around the world was commissioned by the BioEnergy Producers Association, and conducted by University of California at Riverside (under the Direction of William Welch, College of Engineering - Center for Environmental Research and Technology). The entire report can be accessed online[12]

6.7 Environmental Justice

Environmental justice analysis is an emerging field of law, and is now a regulatory requirement in the land use analysis for waste management projects.

The United States Environmental Protection Agency defines environmental justice as: "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

Fair treatment means that no group of people, including a racial, ethnic, or a socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies.

Meaningful involvement means that: (1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns of all participants involved will be considered in the decision making process; and (4) the decision makers seek out and facilitate the involvement of those potentially affected."

A detailed environmental justice analysis in the format of a presentation is included as an attachment in the Appendix. The analysis was conducted with the Year 2000 Census data, and should be updated when the 2010 Census data becomes available. The environmental justice analysis was conducted for San Diego County, so that the information can be utilized by Naval Base San Diego in the potential development of an actual conversion technology project. As part of this IDR, a CD is also provided that includes additional detailed environmental justice analysis data for each individual city and each individual census tract/block in San Diego County.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Findings / Conclusions

[12] UC Riverside Report on Emissions from Thermal Conversion Technologies. http://socalconversion.org/pdfs/UCR_Emissions_Report_62109.pdf

- Finding/Conclusion 1: Waste Stream Volumes

At the present time, individual Naval Base San Diego does not generate sufficient disposal tonnage (approximately 100 to 150 tons per day disposal) to benefit from the economy of scale for a integrated MRF and thermal conversion technology facility, and a private-public partnership should be pursued with local jurisdictions to increase the wasteshed and potential feedstock volume for an economically feasible community-based facility or a larger multi-jurisdictional and multi-base regional facility.

- Finding/Conclusion 2: Commercially Availability Technologies

Waste-to-clean energy thermal conversion technologies are commercially available and have documented proven reliable operations. Waste-to-clean-energy thermal conversion technologies are capable of fully complying with the most stringent air emissions standards and will beneficially impact climate change. The preprocessing front end is a technical, political, and social requirement for a thermal conversion process. Waste-to-clean-energy thermal conversion technologies require more preprocessing (feedstock optimization) of the mixed MSW than the traditional mass burn incinerators, so an integrated materials recovery facility approach is essential for the reliable operation of the process.

- Finding/Conclusion 3: Project Concept Description

The type of project that would most likely be permitted would be an "integrated MRF conversion technology" facility that would produce an organics fraction for an anaerobic digestion to biogas process, and produce a fuel fraction for a thermal conversion technology (and/or potentially in combination with an incinerator).

The capital costs required for the development, and construction of a integrated MRF conversion technology project are significant, ranging from almost $400,000 per ton per day of throughput capacity to over $1 million per ton per day of throughput capacity, and is a major large scale infrastructure project. The operational costs will range between $150 to over $200 per ton (in 2010 dollars) depending upon the size and type of technologies selected. The overall capital and operational cost are significantly impacted by the economy of scale.

At the present time, integrated MRF conversion technology projects are not cost competitive with cheap landfill disposal tipping fees. More critically, the <u>infrastructure</u> that provides legal, regulatory/statutory, economic, and policy drivers does not exist in United States. A project will only be economically feasible over a long-term (e.g., 20 year) approach, when viewed from the standpoint of long term avoided landfill disposal costs and long-term landfill disposal rate increases, and for the purpose of meeting the combined goals of distributed power and renewable energy generation, improved recycling recovery, maximizing landfill diversion, and reducing GHG emissions.

The complexity of developing a successful conversion technology project requires a long term holistic systems vision and understanding of the complex interrelated technical, social, cultural, political, and regulatory issues, and strategic urgency, in addition to having the leadership fortitude to see the project to completion. It is the opinion of the principal researcher of this project, that this is the perfect project for the Navy.

7.2 Recommendations

- Recommendation 1: Assume Leadership Role

The Navy should continue a leadership role advocating "green" options (i.e., WtCE) for solid waste management in collaboration with Component regional Environmental Coordinators who are responsible for interfacing and working with State and local government.

- Recommendation 2: Project Concepts for Naval Base San Diego

Naval Base San Diego should consider development of either a community based facility or a regional facility depending upon the potential involvement of local jurisdiction and available feedstock. The Navy should work with the local private industry infrastructure (e.g., collection companies, existing MRFs/transfer stations, etc.) to determine whether the project can or should be "bifurcated."

Below are two diagrams representing the initial recommended project concepts and scenarios to be developed, the first one showing an integrated MRF conversion technology facility (e.g., EcoPark concept) at a single location, and the second diagram show a project scenario of a bifurcated project. (Note: Mechanical biological treatment (MBT) is the European designation of an integrated MRF front-end preprocessing that processes a mixed waste stream and produces both an organic fraction and fuel fraction for anaerobic digestion and thermal conversion technologies.)

In both project scenarios, it is important for the Navy to work with the local industry infrastructure to potentially offset the capital cost requirements if possible.

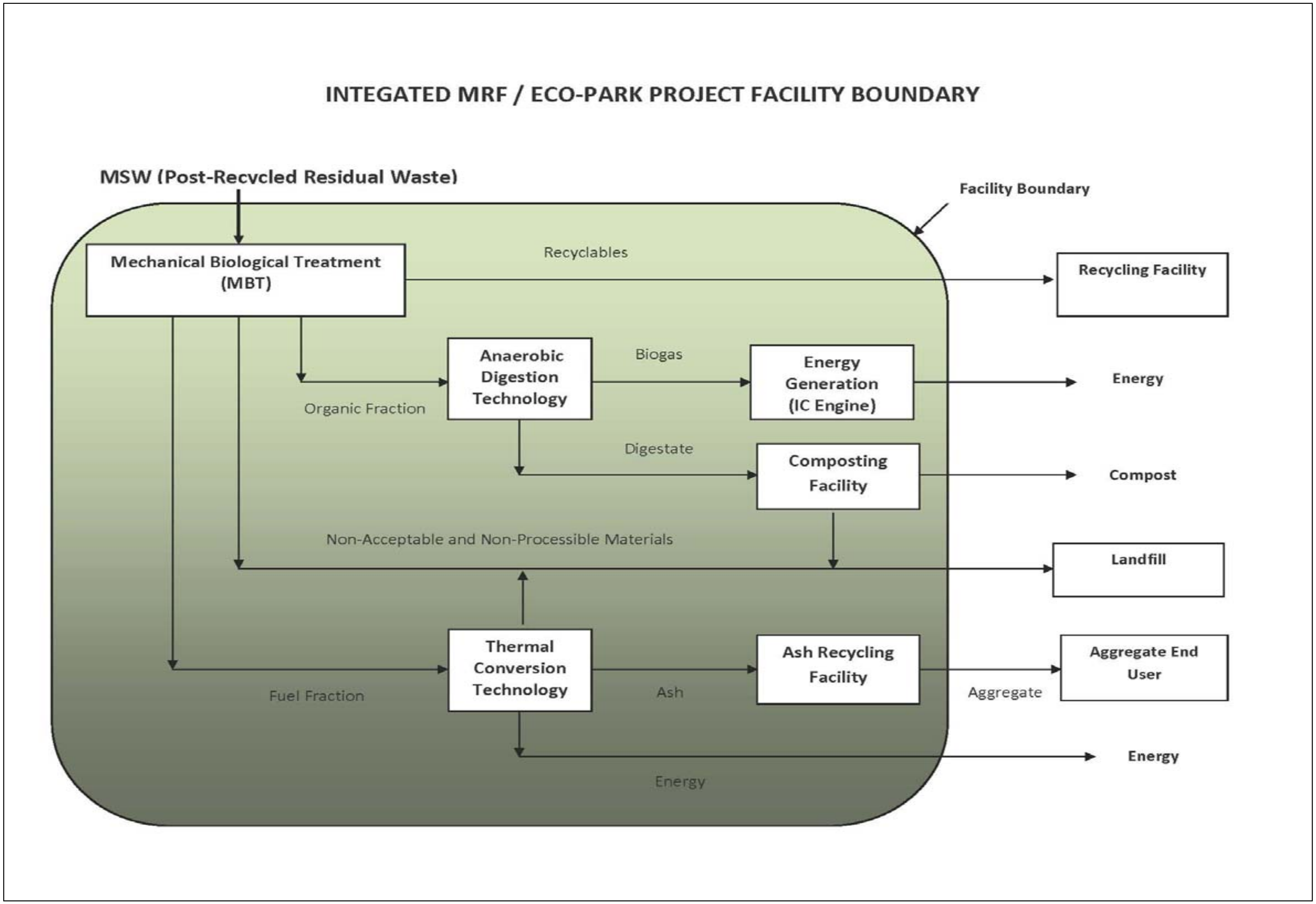

Figure 48. Recommended Project Concept 1: Single Location Integrated MRF Conversion Technology Facility ("EcoPark")

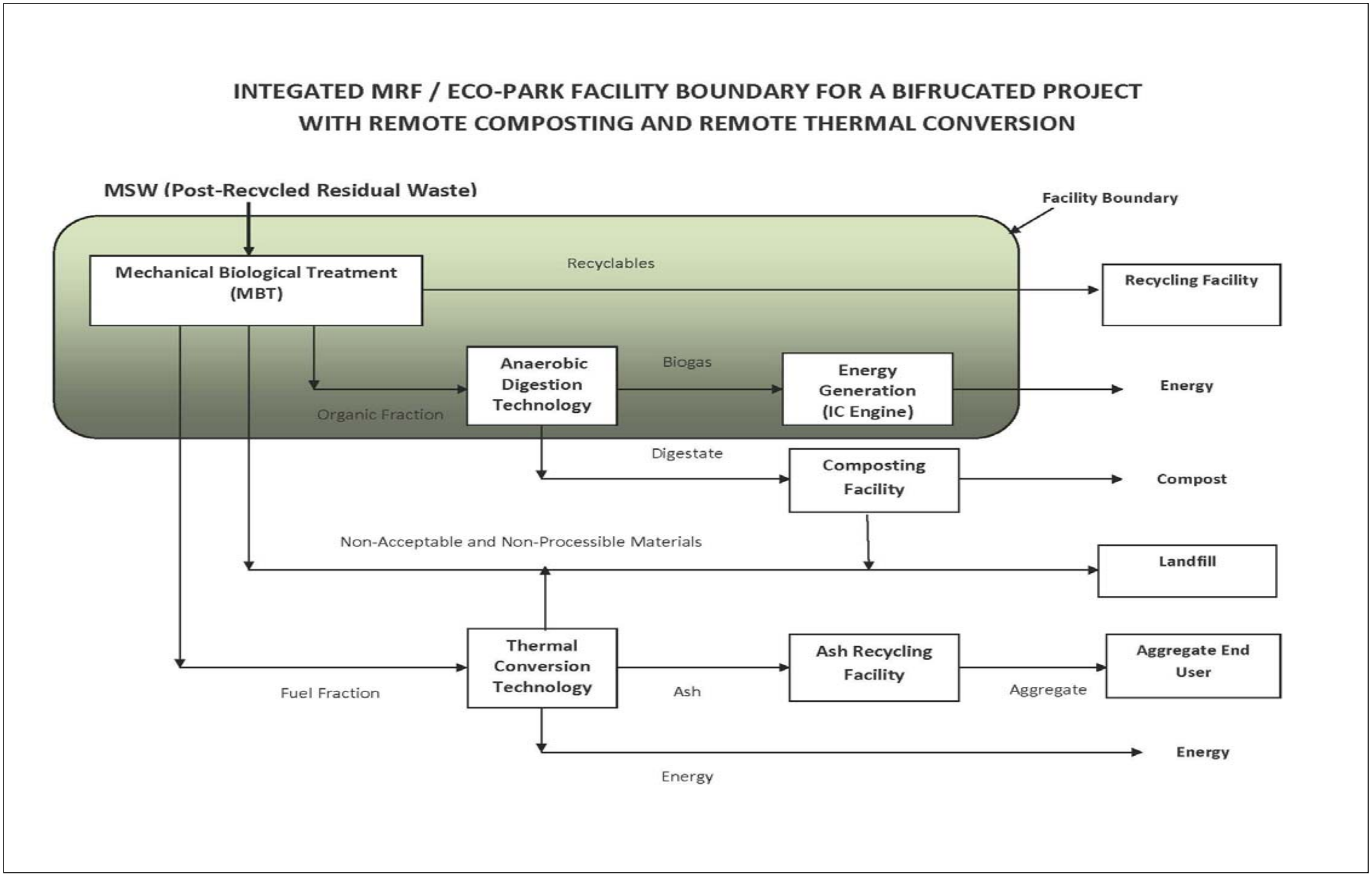

Figure 49. Recommended Project Concept 2: Bifurcated Integrated MRF Conversion Technology ("EcoPark")

- Recommendation 3: Technology Goals / Objectives

The Navy should adopt, as the highest priority, the process design goal of optimizing the various feedstocks for maximum operational reliability of the conversion technology. Maximum reliability will result in additional materials being disposed as non-recyclable or non-processable materials (resulting in less landfill diversion). As the first full scale Navy WtCE conversion technology facility, only proven mature commercially available technologies should be considered for the first set of projects.

The recommended thermal conversion "technology" should be a dual thermal conversion process line; one process line consisting of an incinerator and one line consisting of a gasifier. This combined "thermal technology" approach provides the reliability, flexibility, and robustness of a time proven technology (and best for feedstock with widely varying characteristics, etc.), and allows for conversion of bottom ash and other materials by a gasifier into vitrified slag, thus achieving maximum diversion from landfill.

- Recommendation 4: Emerging Technologies

The Navy should work jointly with INEOS Bio for demonstration of this conversion technology that combines the use of a conventional thermal gasification front end to produce a synthesis gas, and an innovative biocatalytic (biochemical fermentation) conversion process back end to produce ethanol. This technology represents a combination hybrid approach (biochemical and thermochemical) that can produce both renewable energy and also a renewable liquid fuel. A separate program under a research and development program can be used to demonstrate emerging technologies.

- Recommendation 5: Installation Consideration of WtCE Technologies

Following will be considered for installation:

- Optimize solid wastes recovery and recycling practices
- Remove objectionable wastes (e.g. food wastes, consumer batteries) that may reduce the energy value of the remaining solid wastes
- Assess and characterize remaining solid wastes to estimate energy value and requirements for pre-processing technologies (e.g. shredding, grinding)
- Conduct a feasibility study of suitable and sustainable WtCE alternatives
- Initiate action supporting alternatives recommended in the feasibility study
- Start Contract Negotiations

- Recommendation 6: Waste-to-Liquid Fuel Technologies

The Navy should conduct another IDR project to investigate the potential feasibility of creating liquid fuels from MSW. The scope of this IDR was focused on the thermal conversion of municipal waste-to-clean electrical energy, but there are established and emerging technologies that can produce a variety of liquid fuels from MSW. These technologies are capable of producing biodiesel, ethanol, Fischer-Trosph fuel, and other fuels from municipal solid waste.

These technologies can readily be incorporated into an integrated MRF conversion technology EcoPark project.

- Recommendation 7: Monitoring of Technologies and "Projects"

The Navy should have an ongoing effort to track and evaluate emerging/developmental technologies in addition to developing an ongoing effort to monitor and evaluate the various projects that are being developed by local government and private industry. The "lessons learned" from these projects will be invaluable for the Navy in the development and implementation of their own projects.

8.0 REFERENCES

8.1 Reference Materials / Documents

1) Powering America’s Defense: Energy and the Risks to National Security, Center for Naval Analyses (May 2009)

2) New and Emerging Conversion Technologies, Report to the Legislature, California Integrated Management Board (June 2007) http://www.socalconversion.org/pdfs/CIWMB_2007_CT_Study.pdf

3) Conversion Technology Evaluation Report, Los Angeles County Department of Public Works (August 2005) http://www.socalconversion.org/editor/pdfs/CT_Eval_Report.pdf

4) Diverting Waste from Landfill, Effectiveness of Waste Management Policies in the European Union, European Environment Agency (2009)

5) Evaluation of Environmental Impacts of Thermochemical Conversion Technologies Using Municipal Solid Waste Feedstocks, University of California, Riverside, College of Engineering –Center for Environmental Research and Technology (March 2009)

6) Evaluation of Emissions from Thermal Conversion Technologies Processing Municipal Solid Waste and Biomass, Final Report, Prepared for BioEnergy Producers Association, University of California, Riverside, (June 2009)

7) The Impact of Municipal Solid Waste Management on Greenhouse Gas Emissions in the United States, by Susan Thorneloe, Keith Weitz, Subba Nishtala, Sherry Yarkosky, and Maria Zannes , (2002), ISSN 1047-3289, Air and Waste Management Association

8) Waste Gasification in Practice: Twinrec Fluidized Bed Gasification and Ash Melting- Review of Four Years of Commercial Plant Operations, by Adrian Selinger, and Christian Steiner, Ebara Corporation

9) Tokyo Super Eco Town Project Outline (2010), Tokyo Metropolitan Government

10) (Brochure) Asahi Clean Center, Kawaguchi City

11) (Brochure) MBA-Steckbriefe, Fact Sheets on German MBT Plants (2010/2011Center for Research, Education and Demonstration in Waste Management

12) (PowerPoint presentation) Short Introduction in the German Federal Licensing Procedure, ETA Consulting (2010)

13) (Brochure) Municipal Solid Waste Treatment Systems, Ebara Corporation

14) (Brochure) Bioenergy via Dry Fermentation, Bekon Energy Technologies, GmbH & Co. KG

15) (Brochure) Eco Frontier Kasama, High Temperature Gasifying and Direct Melting Furnace Plant (2010), (Translated by JFE Engineering Corporation)

8.2 Personal Communication

Eduardo Llorente
Urbaser SA
Espana, Spain

Dan Michalopoulos, PhD
Technology Director
INEOS Bio

Burkart Schulte, Managing Director
Gesellschaft zur Verwertung organischer Abfalle (GVA)
Minden-Lubbecke, Germany

Yasuhiko Hara
Ebara Environmental Plant Co. Ltd.
Tokyo, Japan

Shigeo Hishinuma,
Tokyo Metropolitan Government
Tokyo, Japan

Sawada, Director,
Kawasaki EcoTown
Kawasaki, Japan

Kazumasa Wakimoto, Chief Engineer
JFE Engineering Corporation

Richard Adams
WSN Environmental Solutions
Spring Farm, Australia

Brian Elkins
Solid Waste Authority of Palm Beach County
West Palm Beach, Florida

Jocelyn Lin, Professor
UCLA Engineering Extension, Advisory Board Member
International Environmental Law, University of West Los Angeles School of Law

Greig Louis Smith, Los Angeles City Councilmember
Nicole Marie Bernson, Senior Policy Advisor
Twelfth District, City of Los Angeles

Coby Skye, Project Engineer
Los Angeles County, Department of Public Works

Kay Martin, Ph.D., Vice President
Bioenergy Producers Association

John Trotti, Editor
MSW Management Magazine
UCLA Engineering Extension, Advisory Board Member

Denis Keyes, Senior Statistician / Environmental Justice Analyst
Ecotelesis International, Inc.

Dan Cummings
INEOS Bio
Isile, Illinois

Skip Bambard, Project Engineer, AECOM
Professor, UCLA Engineering Extension Technology Course
Member, Board of Directors, Sunshine Canyon Landfill Local Enforcement Agency

Gary Petersen, Board Member
Governor Arnold Schwarzenegger Environmental Appointee
CalRecycle (formerly California Integrated Waste Management Board)

Wayne Tsuda, Director
Local Enforcement Agency, Environmental Affairs Department
City of Los Angeles

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APPENDIX A

CalRecycle Uniform Materials Definitions

http://www.calrecycle.ca.gov/WasteChar/MatDefs.htm

Agricultural Crop Residues means plant material from agricultural sources. Examples include orchard and vineyard prunings, vegetable by-products from farming, residual fruits, vegetables, and other crop remains after the usable crop is harvested. This type does not include processed residues from canneries, wineries, or other industrial sources.

Aluminum Cans means any food or beverage container made mainly of aluminum. Examples include aluminum soda or beer cans, and some pet food cans. This type does not include bimetal containers with steel sides and aluminum ends.

Ash means a residue from the combustion of any solid or liquid material. Examples include ash from fireplaces, incinerators, biomass facilities, waste-to-energy facilities, and barbecues. This type also includes ash and burned debris from structure fires.

Asphalt Paving means a black or brown, tar-like material mixed with aggregate used as a paving material.

Asphalt Roofing means composite shingles and other roofing material made with asphalt. Examples include asphalt shingles and attached roofing tar and tar paper.

Batteries means any type of battery including both dry cell and lead acid. Examples include car, flashlight, small appliance, watch and hearing aid batteries.

Branches and Stumps means woody plant material, branches and stumps that exceed 4 inches in diameter from any public or private landscape.

Brown Glass Bottles and Containers means brown-colored glass containers with or without a California Redemption Value (CRV) label. Examples include whole or broken brown soda and beer bottles, and whole or broken brown wine bottles.

Brown Goods means generally larger, non-portable electronic goods that have some circuitry. Examples include microwaves, stereos, VCRs, DVD players, radios, audio/visual equipment, and non-CRT televisions (such as LCD televisions). **Note**: This type was classified under Remainder/Composite Metal in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Bulky Items means large hard to handle items that are not defined elsewhere in the material types list, including furniture, mattresses, and other large items. Examples include all sizes and types of furniture, mattresses, box springs, and base components.

Carpet means flooring applications consisting of various natural or synthetic fibers bonded to some type of backing material. This type does not include carpet padding. **Note**: This type was classified under Remainder/Composite Organic in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Clear Glass Bottles and Containers means clear glass beverage and food containers with or without a CRV label. Examples include whole or broken clear soda and beer bottles, fruit juice bottles, peanut butter jars, and mayonnaise jars.

Colored Ledger means colored bond, rag, or stationery grade paper. When the paper is torn, the fibers are colored throughout. Examples include colored photocopy and letter paper. This type does not include fluorescent dyed paper or deep-tone dyed paper such as goldenrod colored paper.

Computer-related Electronics means electronics with large circuitry that is computer-related. Examples include processors, mice, keyboards, laptops, disk drives, printers, modems, and fax machines. **Note**: This type was classified under Remainder/Composite Metal in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Computer Paper means paper used for computer printouts. This type usually has a strip of form-feed holes along two edges. If there are no holes, then the edges show tear marks. This type can be white or striped. Examples include computer paper and printouts from continuous feed printers. This type does not include white ledger used in laser or impact printers, nor computer paper containing ground wood.

Concrete means a hard material made from sand, aggregate gravel, cement mix and water. Examples includes pieces of building foundations, concrete paving, and concrete blocks.

Durable Plastic Items means plastic items other than containers and film plastic that are made to last for more than one use. These items may bear the numbers 1 through 7 in the triangular recycling symbol. Examples include plastic outdoor furniture, plastic toys and sporting goods, CD's, and plastic housewares such as mop buckets, dishes, cups, and cutlery. This type also includes building materials such as house siding, window sashes and frames, housings for electronics such as computers, televisions and stereos, fan blades, impact-resistant cases such as tool boxes and first aid boxes, and plastic pipes and fittings.

Film Products means plastic film used for purposes other than packaging. Examples include agricultural film (film used various farming and growing applications, such as silage greenhouse films, mulch films, and wrap for hay bales), plastic sheeting used as drop cloths, and building wrap. **Note:** This type was classified under Film Plastic in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Flat Glass: means clear or tinted glass that is flat. Examples include glass window panes, doors and table tops, flat automotive window glass (side windows), safety glass, and architectural glass. This type does not include windshields, laminated glass, or any curved glass.

Food means food material resulting from the processing, storage, preparation, cooking, handling, or consumption of food. This type includes material from industrial, commercial, or residential sources. Example include discarded meat scraps, dairy products, egg shells, fruit or vegetable peels, and other food items from homes, stores, and restaurants. This type includes grape pomace and other processed residues or material from canneries, wineries, or other industrial sources.

Green Glass Bottles and Containers means green-colored glass containers with or without a CRV label. Examples include whole or broken green soda and beer bottles, and whole or broken green wine bottles.

Grocery and Other Merchandise Bags means plastic shopping bags used to contain merchandise to transport from the place of purchase, given out by the store with the purchase. This type includes dry cleaning bags intended for one-time use. **Note**: This type was classified under Film Plastic in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Gypsum Board means interior wall covering made of a sheet of gypsum sandwiched between paper layers. Examples include used or unused, broken or whole sheets. Gypsum board may also be called sheetrock, drywall, plasterboard, gypboard, gyproc, or wallboard.

HDPE Containers means natural and colored HDPE (high-density polyethylene) containers. This plastic is usually either cloudy white, allowing light to pass through it (natural) or a solid color, preventing light from passing through it (colored). When marked for identification, it bears the number 2 in the triangular recycling symbol and may also bear the letters HDPE. Examples include milk jugs, water jugs, detergent bottles, some hair-care bottles, empty motor oil, empty antifreeze, and other empty vehicle and equipment fluid containers.

Industrial Sludge means sludge from factories, manufacturing facilities, and refineries. Examples include paper pulp sludge and water treatment filter cake sludge.

Leaves and Grass means plant material, except woody material, from any public or private landscapes. Examples include leaves, grass clippings, plants, and seaweed. This type does not include woody material or material from agricultural sources.

Lumber means processed wood for building, manufacturing, landscaping, packaging, and processed wood from demolition. Examples include dimensional lumber, lumber cutoffs, engineered wood such as plywood and particleboard, wood scraps, pallets, wood fencing, wood shake roofing, and wood siding.

Magazines and Catalogs means items made of glossy coated paper. This paper is usually slick, smooth to the touch, and reflects light. Examples include glossy magazines, catalogs, brochures, and pamphlets.

Major Appliances means discarded major appliances of any color. These items are often enamel-coated. Examples include washing machines, clothes dryers, hot water heaters, stoves, and refrigerators. This type does not include electronics, such as televisions and stereos.

Manures means manure and soiled bedding materials from domestic, farm, or ranch animals. Examples include manure and soiled bedding from animal production operations, race tracks, riding stables, animal hospitals, and other sources.

Miscellaneous Plastic Containers means plastic containers made of types of plastic other than HDPE (high-density polyethylene) or PETE (polyethylene terephthalate). Items may be made of PVC (polyvinyl chloride), LDPE (low-density polyethylene), PP (polypropylene), PS (polystyrene), or mixed resins. When marked for identification, these items may bear the number 3, 4, 5, 6, or 7 in the triangular recycling symbol. Examples include food containers such as bottles for salad dressings and vegetable oils, flexible and brittle yogurt cups, syrup bottles, margarine tubs, microwave food trays, and clamshell-shaped fast food containers. This type also includes some shampoo containers, vitamin bottles, foam egg cartons, and clamshell-like muffin containers.

Mixed Residue means material that cannot be put in any other type or category. This category includes mixed residue that cannot be further sorted. Examples include clumping kitty litter and residual material from a materials recovery facility or other sorting process that cannot be put in any other material type, including remainder/composite types.

Newspaper means paper used in newspapers. Examples include newspaper and glossy inserts found in newspapers, and all items made from newsprint, such as free advertising guides, election guides, and tax instruction booklets.

Non-Bag Commercial and Industrial Packaging Film means film plastic used for large-scale packaging or transport packaging. Examples include shrink-wrap, mattress bags, furniture wrap, and film bubble wrap. **Note**: This type was classified under Film Plastic in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Other Colored Glass Bottles and Containers means colored glass containers and bottles other than green or brown with or without a CRV label. Examples include whole or broken blue or other colored bottles and containers.

Other Ferrous means any iron or steel that is magnetic or any stainless steel item. This type does not include tin/steel cans. Examples include structural steel beams, metal clothes hangers, metal pipes, stainless steel cookware, security bars, and scrap ferrous items.

Other Film means all other plastic film that does not fit into any other type. Examples include other types of plastic bags (sandwich bags, zipper-recloseable bags, newspaper bags, produce bags, frozen vegetable bags, bread bags), food wrappers such as candy bar wrappers, mailing pouches, bank bags, X-ray film, metallized film (wine containers and balloons), and plastic food wrap. **Note**: This type was classified under Film Plastic in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Other Miscellaneous Paper means items made mostly of paper that do not fit into any of the other paper types. Paper may be combined with minor amounts of other materials such as wax or glues. This type includes items made of chipboard, ground wood paper, and deep-toned or fluorescent dyed paper. Examples include cereal and cracker boxes, unused paper plates and cups, goldenrod colored paper, school construction paper, butcher paper, milk cartons, ice cream cartons and other frozen food boxes, pulp paper egg cartons, unused pulp paper plant pots, and hard cover and soft cover books.

Other Non-Ferrous means any metal item, other than aluminum cans, that is not stainless steel and that is not magnetic. These items may be made of aluminum, copper, brass, bronze, lead, zinc, or other metals. Examples include aluminum window frames, aluminum siding, copper wire, shell casings, brass pipe, and aluminum foil.

Other Office Paper means paper used in offices other than ledger and computer paper. Examples include manila folders, manila envelopes, index cards, white envelopes, white window envelopes, notebook paper, ground wood computer paper, junk mail, and carbonless forms. This type does not include white ledger, colored ledger, or computer paper.

Other Small Consumer Electronics means portable non-computer-related electronics with large circuitry. Examples include personal digital assistants (PDA), cell phones, phone systems, phone answering machines, computer games and other electronic toys, portable CD players, camcorders, and digital cameras. **Note**: This type was classified under Remainder/Composite Metal in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Paint means containers with paint in them. Examples include latex paint, oil based paint, and tubes of pigment or fine art paint. This type does not include dried paint, empty paint cans, or empty aerosol containers.

Paper Bags means bags and sheets made from kraft paper. The paper may be brown (unbleached) or white (bleached). Examples include paper grocery bags, fast food bags, department store bags, and heavyweight sheets of kraft packing paper.

PETE Containers means clear or colored PETE (polyethylene terephthalate) containers. When marked for identification, it bears the number 1 in the center of the triangular recycling symbol and may also bear the letters PETE or PET. The color is usually transparent green or clear. A PETE container usually has a small dot left from the manufacturing process, not a seam. It does not turn white when bent. Examples include soft drink and water bottles, some liquor bottles, cooking oil containers, and aspirin bottles.

Phone Books and Directories means thin paper between coated covers. These items are bound along the spine with glue. Examples include whole or damaged telephone books, yellow pages, real estate listings, and some non-glossy mail order catalogs.

Prunings and Trimmings means woody plant material up to 4 inches in diameter from any public or private landscape. Examples include prunings, shrubs, and small branches with branch diameters that do not exceed 4 inches. This type does not include stumps, tree trunks, branches exceeding 4 inches in diameter, or material from agricultural sources.

Remainder/Composite Construction and Demolition means construction and demolition material that cannot be put in any other type. This type may include items from different types combined, which would be very hard to separate. Examples include brick, ceramics, tiles, toilets, sinks, and fiberglass insulation. This type may also include demolition debris that is a mixture of items such as plate glass, wood, tiles, gypsum board, and aluminum scrap.

Remainder/Composite Glass means glass that cannot be put in any other type. It includes items made mostly of glass but combined with other materials. Examples include Pyrex, Corningware, crystal and other glass tableware, mirrors, light bulbs, and auto windshields.

Remainder/Composite Household Hazardous means household hazardous material that cannot be put in any other type. This type also includes household hazardous material that is mixed. Examples include household hazardous waste which if improperly put in the solid waste stream may present handling problems or other hazards, such as pesticides, caustic cleaners, and fluorescent light bulbs.

Remainder/Composite Metal means metal that cannot be put in any other type. This type includes items made mostly of metal but combined with other materials and items made of both ferrous metal and non-ferrous metal combined. Examples include small non-electronic appliances such as toasters and hair dryers, motors, insulated wire, and finished products that contain a mixture of metals, or metals and other materials, whose weight is derived significantly from the metal portion of its construction.

Remainder/Composite Organic means organic material that cannot be put in any other type. This type includes items made mostly of organic materials, but combined with other material types. Examples include leather items, cork, hemp rope, garden hoses, rubber items, hair, carpet padding, cigarette butts, diapers, feminine hygiene products, small wood products (such as Popsicle sticks and tooth picks), sawdust, and animal feces.

Remainder/Composite Paper means items made mostly of paper but combined with large amounts of other materials such as wax, plastic, glues, foil, food, and moisture. Examples include waxed corrugated cardboard, aseptic packages, plastic-coated paper milk cartons, waxed paper, tissue, paper towels, blueprints, sepia, onion skin, fast food wrappers, carbon paper, self adhesive notes, and photographs.

Remainder/Composite Plastic means plastic that cannot be put in any other type. These items are usually recognized by their optical opacity. This type includes items made mostly of plastic but combined with other materials. Examples include auto parts made of plastic attached to metal, plastic drinking straws, foam drinking cups, produce trays, egg cartons, foam packing blocks, packing peanuts, cookie trays found in cookie packages, plastic strapping, foam plates/bowls, and new Formica, vinyl, or linoleum.

Remainder/Composite Special Waste means special waste that cannot be put in any other type. Examples include asbestos-containing materials such as certain types of pipe insulation and floor tiles, auto fluff, auto bodies, trucks, trailers, truck cabs, untreated medical waste/pills/hypodermic needles, and artificial fireplace logs.

Rock, Soil and Fines means rock pieces of any size and soil, dirt, and other matter. Examples include rock, stones, sand, clay, soil and other fines. This type also includes non-hazardous contaminated soil.

Sewage Solids means residual solids and semi-solids from the treatment of domestic waste water or sewage. Examples include biosolids, sludge, grit, screenings, and septage. This type does not include sewage or waste water discharged from the sewage treatment process.

Televisions and Other Items with CRTs. Examples include televisions, computer monitors, and other items containing a cathode ray tube (CRT). **Note**: This type was classified under Remainder/Composite Metal in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Textiles means items made of thread, yarn, fabric, or cloth. Examples include clothes, fabric trimmings, draperies, and all natural and synthetic cloth fibers. This type does not include cloth covered furniture, mattresses, leather shoes, leather bags, or leather belts.

Tin/Steel Cans means rigid containers made mainly of steel. These items will stick to a magnet and may be tin-coated. This type is used to store food, beverages, paint, and a variety of other household and consumer products. Examples include canned food and beverage containers, empty metal paint cans, empty spray paint and other aerosol containers, and bimetal containers with steel sides and aluminum ends.

Tires means vehicle tires. Examples include tires from trucks, automobiles, motorcycles, heavy equipment, and bicycles.

Trash Bags means plastic bags sold for use as trash bags, for both residential and commercial use. This type does not include other plastic bags, like shopping bags, that might have been used to contain trash. **Note**: This type was classified under Film Plastic in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Treated Medical Waste means medical waste that has been processed in order to change its physical, chemical, or biological character or composition, or to remove or reduce its harmful properties or characteristics, as defined in Section 25123.5 of the Health and Safety Code.

Uncoated Corrugated Cardboard usually has three layers. The center wavy layer is sandwiched between the two outer layers. It does not have any wax coating on the inside or outside. Examples include entire cardboard containers, such as shipping and moving boxes, computer packaging cartons, and sheets and pieces of boxes and cartons. This type does not include chipboard boxes such as cereal and tissue boxes.

Used Oil means the same as defined in Health and Safety Code section 25250.1(a). Examples include spent lubricating oil such as crankcase and transmission oil, gear oil, and hydraulic oil.

Used Oil Filters means metal oil filters used in motor vehicles and other engines, which contain a residue of used oil. **Note**: This type was classified under Other Ferrous in the original 57 standard material types used in the 1999 Statewide Study and the solid waste characterization database.

Vehicle and Equipment Fluids means containers with fluids used in vehicles or engines, except used oil. Examples include used antifreeze and brake fluid. This type does not include empty vehicle and equipment fluid containers.

White Ledger Paper means bleached, uncolored bond, rag, or stationery grade paper, without ground wood fibers. It may have colored ink on it. When the paper is torn, the fibers are white. Examples include white paper used in photocopiers and laser printers, and letter paper.

APPENDIX B

Roadmap / Blueprint to Developing a Conversion Technology Project Utilizing Municipal Solid Waste as a Feedstock

Disclaimer

The University of California at Los Angeles Engineering Extension and the United States Navy (Naval Facilities Engineering Command, Engineering Service Center) does not endorse any specific technical approach for any one project. The University of California at Los Angeles Engineering Extension and the United States Navy (Naval Facilities Engineering Command, Southwest) also does not endorse any specific technical supplier / company or technologies or facilities described in this document. The technology and/or facility descriptions are for the purpose of illustrating examples of various types of projects and technologies that are available for the conversion of municipal solid waste into clean renewable energy.

Each project and each location is unique, and will require very detailed understanding of the social, cultural, political, and technical issues specific to that project, in addition to existing infrastructure issues, including existing legal / contract and regulatory issues that have to be addressed. The "roadmap" to developing a conversion technology project utilizing municipal solid waste as a feedstock is meant as a general guideline to some of the steps that should be taken towards the successful development and implementation of a conversion technology project. (Please note that many of the steps can actually be done concurrently.)

Roadmap / Blueprint to Developing an "EcoPark" Project (with a Conversion Technology Utilizing Municipal Solid Waste as a Feedstock)

There are many ways to develop a conversion technology project to recover energy from the municipal solid waste stream. The simplest project concept is a stand alone thermal conversion technology project. Due to the deeply rooted, complex, and intertwined political, social, philosophical, and other infrastructure issues, many industry professionals believe that a thermal conversion can only be successfully implemented as part of a larger integrated waste management, or EcoPark project.

This roadmap / blueprint describe some of the basic tasks for developing a conversion technology project as part of an integrated waste management project or EcoPark project.

An EcoPark or Recycling Park which includes a "conversion technology" which utilizes municipal solid waste project is a very complex facility that requires significant resources to develop into a successful project. The issues that have to be addressed in addition to the selection of an appropriate conversion technology or combination of technologies can potentially dominate the project development efforts.

A listing of some of the major tasks that should be considered as part of the development of a conversion technology project is provided below:

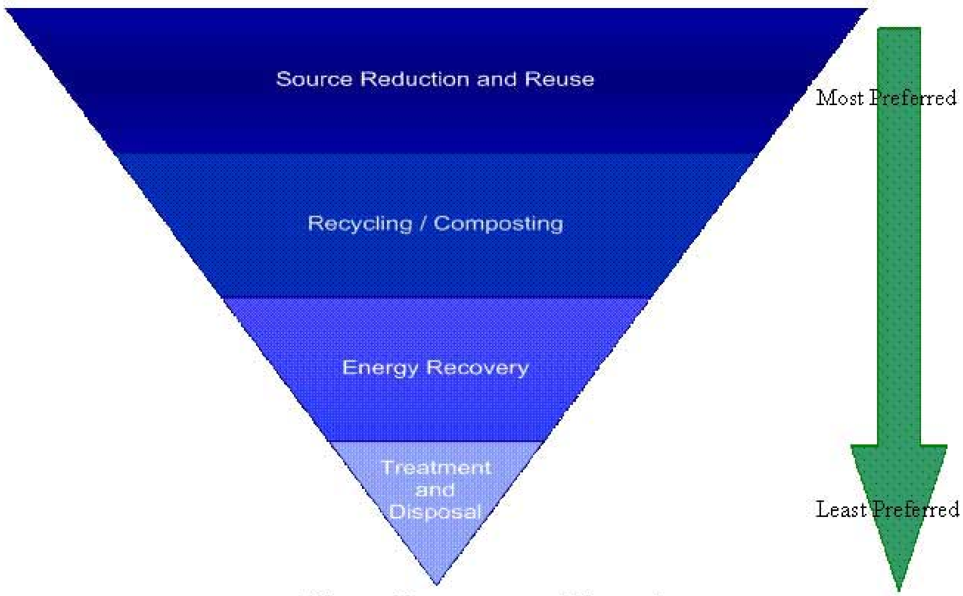
- Develop Project Concept and Scope
- Develop Project Goals and Objectives
- Determine Potential Wasteshed and Participating Entities (Naval Base(s), Jurisdictions, Facilities, Industry, etc.)
- Determine the Waste Composition of Available Wastestream
- Conduct Environmental Justice Analysis
- Develop/Implement Stakeholders and Community Participation Efforts
- Determine Appropriate Conversion Technology / Technologies
- Conduct Conversion Technology Tour of Potential Technologies
- Determine the Legal, Regulatory, and Legislative Issues Impacting the Development and Permitting of the Project
- Finalize Project Concept, Scope, and Goals/Objectives
- Determine the Technical and Economic Feasibility of the Proposed Project/Goals
- Develop and Issue Request for Proposal (EPC and Operations Contract)
- Evaluate Responses and Select Short List of Finalists
- Start Contract Negotiations

Please note that the above tasks are not in any specific order, many of these tasks should be done concurrently, depending upon the type and scope of the envisioned project. Many of the tasks (e.g., stakeholder / community participation tasks, etc.) are essentially ongoing tasks throughout the entire project conceptualization and development process. Brief descriptions of each of the major tasks are provided in the following text:

1. Develop Project Concept and Scope

In developing the project goals for an EcoPark, it is important to take into consideration the hierarchical "integrated waste management approach". Project goals should be consistent with the Department of Defense's solid waste hierarchy; Reduce, Reuse, Recycle, and Disposal (disposal only as a last resort).

The U.S. EPA waste management hierarchy (http://www.epa.gov/wastes/homeland/hierarchy.htm) is shown below:



Waste Management Hierarchy

An integrated waste management project or EcoPark project represents a holistic system approach that encompasses the integrated waste management hierarchy, where there is maximum emphasis put on implementing materials recovery, materials reuse, composting, anaerobic digestion, and other approaches, and where thermal conversion technology be utilized as a "last resort" in order to minimize disposal to land.

An "EcoPark" or "Recycling Park" project is designed to maximize the recovery of recyclables, maximize the value of waste, and recovery energy from non-recyclable materials for the purpose of minimizing disposal at landfills and realizing energy and climate action goals. The project has to be compatible with the existing recycling and solid waste management, and be an integral part of the community.

One of the first tasks to be done in the development of an EcoPark project concept and scope is to conduct a "needs assessment" of the Naval facility that also includes a study of the potential wasteshed. Below is a list of the information to be gathered in the development of the project concept/scope.

- Determine recycling, solid waste needs, and the amount of renewable energy and/or liquid fuels needs of the Navy (and potential participants)
- Determination of what constitutes "renewable energy"
- Determine available in-house resources for development of project
- Determine other outside resources that are needed
- Determine the administrative and organizational to manage the project
- Determine the potential contract vehicle(s) and business structure(s) (e.g., public-private partnership, Enhanced Use Lease (EUL), RFP for EPC and operations, etc.) that would be most beneficial to the Navy
- Determine potential wasteshed, waste volumes, and composition (more details provided in the following sections)
- Select an "owners representative" or technical consultant to assist in the process of project development (if desired) and/or vendor selection

2. <u>Develop Project Goals and Objectives</u>

This task should be done concurrently with the community outreach and stakeholder input efforts. Navy (and other potential participants, e.g., jurisdictions, industry, etc.) expectations should be clarified and defined. For this "roadmap" a selected, preferred Navy site has already been chosen. The areas that need to be discussed and defined include the following:

- Purpose of facility
- Potential additional traditional waste reduction and recycling (materials recovery)
- Processing capacity and size of facility
- Expected products, e.g., energy, chemicals, by-products, compost, secondary manufacturing, etc.
- Environmental impact, e.g., air quality, emissions, waste residue, greenhouse gases,
- Facility/technology reliability
- Potential participants/partners in a "Public Private Partnership"
- Identify potential funding (e.g., grants, loan guarantees, etc.)
- Determining the level of acceptable "risk" to be undertaken by Navy and other potential stakeholders (and participating entities)

3. <u>Determine Potential Wasteshed and Participating Entities (Naval Base(s), Jurisdictions, Facilities, Industry, etc.)</u>

Without a guaranteed waste volume, no project can be technically or economically feasible. There is also opposition to guaranteed "volumes/tonnage", because of the possibility that a guaranteed "tonnage" is detrimental to the recycling and waste reduction approaches where a jurisdiction is constrained to implement more recycling programs because it needs to provide a minimum guaranteed "tonnage" to the conversion technology (waste to clean energy facility).

The recommended approach is to guarantee a "wasteshed" rather than a minimum tonnage over the proposed project life. That way there are no constraints upon the additional development and implementation of waste reduction and recycling programs. The practical limits of current traditional (non-thermal) recycling programs and technologies (e.g., composting, etc.) can be estimated at about 70 percent diversion rate. The remaining 30 percent of a jurisdictions waste generation can be a conservative estimate of the maximum amount of tonnage which is the post-recycling and non-recyclable feedstock available to a thermal conversion waste to clean energy technology.

Using this estimation method, one can determine the overall wasteshed and participating jurisdictions and/or facilities that need to be in your potential wasteshed to make the project feasible. Please note that if 70 percent of the waste is not diverted, more waste will be ending up in the "feedstock" stream to the thermal conversion technology, and/or end up in the landfill. The key is to match the selection of the wasteshed to the selection of the waste reduction recycling programs and the technologies of the integrated EcoPark.

The addition of other potential jurisdictions add a layer of complication as the facility then turns from a single local wasteshed of a "community based" facility to a potential multiple-community or multi-jurisdiction wasteshed "regional facility". These factors must be taken into account in the overall process of developing the concept of the proposed facility.

4. Determine the Waste Composition of the Available Wastestream

After determining the potential wastesheds, the waste composition of the available wastestream should be examined. Existing waste reduction and recycling programs have an impact on a wastestream that is potential feedstock for an integrated waste management technology park. The more successful up-front waste reduction and recycling programs are, the less recyclable materials there are in the wastestream bound for the EcoPark. In the preliminary stages of project development, certain assumptions must be made about the waste composition in order to derive basic mass and energy balance calculations, and to calculate potential output products, e.g., energy, biogas, and residual that need to be disposed. Some changes in waste composition that may occur in the future will not be predictable, for example, legislation that impacts compositions, changes in the number and type of waste generators in the wasteshed, etc.

As part of a detailed characterization study to evaluate the types and amounts of materials that are acceptable for conversion technology feedstock, it is just as important to characterize the materials that are "non-processible" and/or "non-acceptable". This is a critical characterization classification for any conversion technologies waste characterization study because certain types of materials, either because their physical and/or the chemical characteristics can be detrimental to the conversion technology process, and those materials must be removed as part of the "feedstock preprocessing".

The following is a list of waste characterization studies which are conducted as part of an integrated waste management plan and conversion technology feasibility analysis (which includes data for process design and technology evaluation study, and/or for an operating facility:

- Wasteshed Analysis (Volume / Composition)
- Waste Characterization by Materials Type
- Conversion Technology (Process Specific) Characterization for Non-Acceptable and for Non-Processible Wastes)
- Regulatory/Legislative Impacts on Waste Characterization and Conversion Technology Feedstock Processing
- Waste Composition by Material Type and Functional Categories
- Waste Characterization for Biogenic and Non-Biogenic Materials
- Proximate / Ultimate Analysis
- Conversion Technology Processed Fuel (from Solid Waste) Physical Storage Characteristics Study
- Moisture Content and Heating Value (BTU Analysis)
- Biological Methane Potential (BMP) Waste Characterization (for biological processes that generate methane as a product)
- Cumulative Size Distribution of Overall Feedstock Stream
- Cumulative Size Distribution Analysis by Materials Category
- Transfer Station / Materials Recovery Facility Recovery Efficiency and Process Optimization Characterization Study
- Transfer Station / Materials Recovery Facility Residual Waste Characterization for Determining the Conversion Technology Feedstock Potential of the Residue
- Waste Characterization for Conversion Technology Unit Process Optimization
- Hazardous Waste Characterization (including Hazardous Waste Radioactive Waste, and Infectious Waste Characterization)
- Load Check Programs (for Hazardous Waste)
- Waste Characterization for Determination of Permitting Classification (e.g., CIWMB Three Part Test) for Solid Waste Facilities Permit

Each study above is related to each other in some way, so that it is important to understand the full spectrum of requirements needed from project conception to project completion and operations. This way the characterization data is coordinated (e.g., consistent classifications and definitions, etc.), and the previous studies can be utilized as a technical reference for the future studies. Definitions from study to study must be consistent, and changes in definitions and classifications from study to study should be tracked.

Each type of waste characterization study listed above has a proper time for completion within the overall framework of developing, designing, building, and operating a conversion technology project.

The fundamental rule when designing a study is that you have to know what you are going to use the data for. Sometimes the sampling protocol is much more complex than the "characterization" analysis. For example, to determine the fuel value of a waste sample, the actual size of the sample needed is very small,(less than one pound). But trying to assure a "representative sample", you many need to take many samples, combine them, and conduct the analysis on many samples, and/or you can develop a sampling protocol in which you take a multiple samples (e.g., over a period of a week so as to account for the variability of different wastesheds collected during the week, etc.) which have been aggregated, and conduct a sample size reduction protocol, e.g., "Cone and Quarter" to reduce the sample to size required for the fuel value characterization. .

The general rule for the level of detailed needed in a waste characterization study is that the more detailed the data, the more information you can utilize, you can always combine the more detailed data into broader classifications, for example, a more detailed classification of "office paper" can be broken down into "white ledger", "colored ledger", computer paper", "mixed paper", etc. The more detailed classification is useful for recycling because each of the different materials types brings different amounts of revenue on a per ton basis. However, for a thermal conversion process, the fuel values for those papers are similar, so there is no need for separating them into a more detailed classification.

For the initial integrated waste management plan and conversion technology feasibility study phase for the Navy, we recommend conducting the following characterization studies/analysis:

- Wasteshed Analysis (Volume / Composition)
- Waste Characterization by Materials Type
- Conversion Technology (Process Specific) Characterization for Non-Acceptable and for Non-Processible Wastes)
- Waste Characterization for Biogenic and Non-Biogenic Materials
- Regulatory/Legislative Impacts on Waste Characterization and Conversion Technology Feedstock Processing
- Proximate / Ultimate Analysis
- Moisture Content and Heating Value (BTU Analysis)

A proper sampling protocol to get statistically representative samples that truly represents a widely varying non-homogeneous and seasonal waste stream is also a challenge. Given restricted budgets, understanding how to interpret the available data is collected and its "limitations and implications" for a conversion technology becomes critical.

Besides waste composition, an understanding of the wasteshed, and the control of the various wastestreams materials are part of a waste characterization study if detailed targeted programmatic plans are to be developed and implemented.

Certain wastestreams such as "construction and demolition waste" (C & D waste) are typically not directly utilized as feedstock for conversion technology projects because of the "size" and materials handling characteristics and unit process feed characterization implications (e.g., large pieces of concrete, re-bars, etc.). Characterization needs for C & D waste is relatively simple, for thermal conversion technologies, the materials typically recovered from the C & D wastestream will be wood and paper.

Depending upon the type of conversion technology, only certain types of wood may be used as feedstock (e.g., clean dimensional lumber and not chemically treated lumber which may be harmful to the process) for the conversion process. The broad category of “wood” in a waste characterization study would require a further separation to have an accurate estimate of the amount of processible wood in the conversion technology feedstock. A proper waste characterization study takes these issues into account.

Many legal / regulatory and technical engineering requirements drive the need for various types of characterization data. For example, recently upon final clarification, under the EPA rules published in the Federal Register (Feb 4, 2010, RFS2), the biogenic portion of post-recycled MSW qualify as "renewable biomass" for the purpose of meeting the federal mandate for the production of advanced biofuels. This federal rule necessitates a characterization of the feedstock stream to determine the portion of the solid waste which is biogenic (derived from natural sources, paper, wood, greenwaste, foodwaste, etc.) and which is non-biogenic (e.g., plastic, tires, etc.). This characterization is needed because the income stream derived from the energy sales is dependent upon how much of the waste stream is deemed “renewable biomass”.

Below is the traditional materials classification that has been the standard for the development of jurisdiction integrated waste management plans.

CalRecycle (CIWMB) Uniform Waste Characterization Method and Protocols (Developed by UCLA Engineering Extension (E. Tseng)	
PAPER	
A	Uncoated Cardboard
B	Kraft Paper
C	Newspaper
D	White Paper
E	Phone Books / Directories
F	Low Grade Mixed Paper
G	Remainder Composite Paper
GLASS	
A	Clear Glass
B	Green Glass
C	Brown Glass
D	Other Colored Glass
E	Flat Glass
F	Remainder Composite Glass
METAL	
A	Tin and Steel Cans
B	Aluminum Cans
C	Other Ferrous
D	Other Nonferrous
E	Metal Appliances (White Goods)
F	Remainder Composite Metals

PLASTIC	
A	Plastic PETE Containers
B	Plastic HDPE Containers
C	Plastic Miscellaneous Containers Number 3 - 7
D	Plastic Film
E	Durable Plastic Items
F	Remainder Composite Plastics
OTHER ORGANICS	
A	Food Waste
B	Leaves and Grass
C	Branches, Prunings, and Trimmings
D	Large Stumps
E	Crop Residue
F	Manure
G	Textiles
H	Other Organic Remainder Composite
CONSTRUCTION AND DEMOLITION WASTE	
A	C & D Concrete
B	C & D Asphalt
C	C & D Asphalt Roofing and Shingles
D	Clean Lumber
E	Treated Wood and Lumber
F	Drywall
G	Rocks, Soil & Fines
H	C & D Remainder Composite
HOUSEHOLD HAZARDOUS WASTE	
A	HHW Paint and Primers
B	HHW Vehicle and Equipment Fluids
C	HHW Motor Oil
D	HHW Batteries
E	HHW E-Waste
F	HHW Remainder Composite
SPECIAL WASTE	
A	Special Waste Ash
B	Special Waste Sewage Sludge
C	Special Waste Industrial Sludge
D	Treated Medical Waste
E	Special Waste Bulky Items
F	Special Waste (Tires, and Other Waste)
G	Mixed Residue / Remainder Composite Special Waste

The above classification scheme was originally designed back in 1993 for the primary purpose of identifying materials for “recycling” programs. Since then the classification scheme has been revised for the purpose of obtaining additional data for a wider variety of waste diversion activities.

The following page is the newest waste characterization classification scheme used for Integrated Solid Waste Management Planning, used by the City of Los Angeles in their 2009 Commercial Waste Characterization Study. The characterization protocols were jointly developed by UCLA Engineering Extension (Professor E. Tseng) and with EcoTelesis (a non-profit environmental organization developed by the U.S EPA). Field studies were conducted by EcoTelesis staff, and with students from various universities.

WASTESTREAM CHARACTERIZATION STUDY:
MATERIALS AND PRODUCT/FUNCTION CLASSIFICATION

(Developed by City of Los Angeles, UCLA Engineering Extension and EcoTelesis International)

1. CONTAINERS AND PACKAGING				
A	Steel		M	Plastic #6 PS
B	Aluminum		N	Plastic #7 Other
C	Glass		O	Plastic Film
D	Ceramic / Glass-Ceramic		P	Plastic Trash Bags
E	Paperboard		Q	Plastic Grocery / Merchandise Bags
F	Cardboard		R	Wood
G	Other Paper		S	Metal Composite / Combination
H	Plastic #1 PETE		T	Paper Composite / Combination
I	Plastic #2 HDPE		U	Plastic Composite / Combination
J	Plastic #3 PVC		V	Glass Composite / Combination
K	Plastic #4 LDPE		W	Other Materials / Composite Packaging
L	Plastic #5 PP			
2. DURABLE GOODS				
A	Steel		J	Textiles
B	Aluminum		K	Carpet
C	Other Non-Ferrous Metals		L	Bulky Items (Furniture)
D	Glass		M	Metal Composite / Combination
E	Ceramic / Glass-Ceramic		N	Paper Composite / Combination
F	Plastic (Durable Plastic Items)		O	Plastic Composite / Combination
G	Wood		P	Glass Composite / Combination
H	Wood Pallets		Q	Other Materials / Composite
I	Rubber and Leather		R	Tires
3. NON-DURABLE GOODS				
A	Newspaper		I	Food Waste
B	White Paper		J	Clothing / Textiles
C	Colored Ledger		K	Non-Durable Plastic Goods
D	Computer Paper		L	Metal Composite / Combination
E	Other Office Paper		M	Paper Composite / Combination
F	Mixed Paper		N	Plastic Composite / Combination
G	Magazines / Directories		O	Glass Composite / Combination
H	Other / Composite Paper		P	Other Materials
4. OTHER WASTES				
A	Ash / Sludge		K	C & D Wood
B	Yard Waste		L	Misc./Remainder Composite Inorganic
C	Manure		M	HHW Paint
D	Agricultural Waste		N	HHW Vehicle/Equipment Fluids
E	Misc./Remainder Composite Organic		O	HHW Used Oil / Use Oil Filters
F	C & D Concrete		P	HHW E-Waste
G	C & D Asphalt Paving		Q	HHW Batteries
H	C & D Asphalt Roofing		R	Other HHW
I	C & D Soil / Fines		S	Mixed Residue
J	C & D Drywall / Gypsum			

The new methodology is designed to provide additional information beyond the limited "materials" classification. The proposed characterization is a two-tiered approach which combines a traditional "CIWMB materials type classification" characterization study with a more extensive version of the "functional aspect" ("product type") characterization utilized the U.S. EPA characterization methodology. The broad EPA function/product classifications (containers/packaging, durable goods, non-durable goods, and other waste will be used, but the more detailed CIWMB materials types will be utilized. This will provide the most amount of information used for waste reduction and recycling planning.

The original CIWMB classification was designed for to focus on "recycling markets". With the emphasis on extended manufacturer responsibility, implementation of waste reduction / source reduction, additional types of data/information beyond just "materials classification" is needed to address these programmatic options focused on source reduction, and other generator-based operational practices. The data will also enable an assessment of the potential for substituting materials that are "more recyclable" (a source reduction practice).

The materials type and function/product classifications can be recombined to create a more traditional CIWMB waste composition characterization classifications, for example, aluminum in the durable goods classification (e.g., folding Al chair can be combined with the aluminum cans to obtain the total amount of "aluminum".

Waste characterization studies can provide a lot of useful information when they are carefully designed with specific objectives to meet specific long term goals. Characterization studies can be very expensive, and can take a long time to do, especially if "seasonal" data is required, and/or if "representative sampling" is required. Some scientific tests may take over a month to complete, e.g., 30-day "Biological Methane Potential" for the organic fraction of the wastestream (for determining the amount of potential biogas that can be generated).

Project-specific waste characterization data collected for a specific project (from waste characterization studies designed and conducted for that study) is always the best, but can be very costly and resource extensive. Existing data can be used as a proxy to estimate of waste composition in many cases in the project feasibility phases. However, as a technology and project scenario gets finalized along with the waste diversion and recycling programs to be implemented, it is critical that project specific data be developed.

A waste characterization study that is being conducted for the purpose of both an "integrated waste management plan" and also a potential "conversion technology" project, it is important to be able to estimate the change in the overall waste composition as existing waste diversion programs are improved and as new programs are implemented. As an example, with the recovery of recyclable materials such as paper, the fuel value of the remaining waste stream is decreased; also the percent of food will increase (as will the overall moisture content). It is important to recognize that "integrated waste management" means that the wasteshed is an interdependent system, and the waste composition is very dependent upon the planned and implemented diversion programs, and thus will have an impact on the feedstock composition for the potential conversion technology and/or combination of technologies. When designing a waste characterization study, the study must obtain the kind of data that can provide as much useful information to estimate the impact of the various diversion programs upon the potential composition of the conversion technology feedstock.

5. Conduct Environmental Justice Analysis

The United States Environmental Protection Agency defines environmental justice as: "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including a racial, ethnic, or a socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies. Meaningful involvement means that: (1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns of all participants involved will be considered in the decision making process; and (4) the decision makers seek out and facilitate the involvement of those potentially affected".

An extensive "environmental justice" analysis of the potentially impacted communities should be conducted to identify groups of people that may be unfairly impacted. Representation should be provided as part of the community outreach and stakeholder engagement process.

6. Develop/Implement Stakeholders and Community Participation Efforts

Community participation and stakeholder input is an integral part of planning an Eco Town or Recycling Park project from the very beginning. Environmental justice also requires that the impacted communities be given an opportunity for meaningful involvement in the development and permitting of the projects. This effort should begin as early as possible in the project development process.

Key participants that should be contacted are local political and community leaders, local environmental groups, and other non-governmental organizations (NGOs). Effort should be spent working with the local appropriate regulatory agencies in the early stages of project development and getting assigned a lead project contact person to be part of the community participation and stakeholder input effort is also an essential part of this task.

Identify and address stakeholder and community key issues of concern related to the proposed project. Provide a transparent and open communication process to allow for ongoing continuing dialog. The project proponent should be prepared to affirmative steps to recruit as much public participation as possible. A dedicated project website should be maintained.

Organize subcommittees to address various issues, including providing technical specialists and other resources as needed. Impacted communities will require extensive mitigation measures and monitoring programs to minimize the environmental impacts of the proposed project. Environmental justice considerations require that the project proponent provide clear, concise, and easy to understand materials describing the proposed project, its impacts, and costs/benefits.

The stakeholder and community participation input is a long process and will continue even after the proposed facility is constructed and in operation. Ongoing community outreach and involvement with the facility will firmly establish community connection with the facility, especially if the facility is designed as a "community based facility" whose primary role is to serve the local community waste management and energy needs.

7. Determine Appropriate Conversion Technology / Technologies

Determining the appropriate conversion technologies that are part of the EcoPark's integrated waste management approach is one of the most critical steps. The selection of the "appropriate" conversion technology or mix of technologies must match the diversion process goals/objective of the stakeholders. The technologies must also be operationally relatable and an overall systems operational performance must be provided by the potential vendors. Listed below are some of the tasks that are typically conducted as part of determining the appropriate technology/technologies:

- Developing a list of potential technology providers
- Developing weighted evaluation factors
- Obtain basic information from potential vendors
- Feedstock composition / parameters
- Level of Technology (Stage of Development / Maturity of Technology)
- Mass and Energy Balance (including calculation methods and assumptions)
- Appropriate Size / Throughput of Technologies
- Product Output (e.g., energy, biogas, liquid fuels, secondary manufacturing potential)
- Emissions and Process Residues
- Equipment and Systems Operations Guarantees / Warranties
- Develop Shortlist of Potential Vendors (for site visit of Reference Facilities)

The selection and weighting of the evaluation factors will create a process which will document the evaluation reasoning behind the selection of the technologies. This process should be fair and transparent, and the evaluation factors should be included in the questionnaires to the potential technology vendors.

8. Conduct Conversion Technology Tour of Potential Technologies

Due to the lack of full commercial scale integrated materials recovery facilities (EcoPark / Recycling Park) projects in the United States, it is important for the stakeholders and Navy project development team to conduct a hands-on ("see it for yourself") facility visit. Conducting site visits is sometimes referred to as "kicking the tires" to see what you are getting. Conducting site visits to actual reference facilities is considered part of the “verification” process for the information submitted by the potential vendors during the process of developing a “short list”.

The main purpose and objectives of the conversion technology best management practices tour include the following:

- Determine applicability of technologies to proposed Navy project requirements
- Identify / Evaluate “Best Management Practices” (BMPs)
- Provide a context to the overall scope of the proposed project
- See the reference benchmark projects to understand what the various approaches/projects would look like (and identify what could be improved)
- Understand the various “Integrated Management Approaches” to determine the most appropriate approach to use to match the stakeholders’ expectations
- Identify the “Lessons Learned” by existing BMPs
- Verify the facility / technology performance and operating history
- Understand the impact of sociological and cultural factors on technology selection and facility design / operations
- Understand the impact of legal/regulatory driven design and operational requirements in the various countries / cities
- Learn successful approaches to community participation and environmental/social justice issues related to the proposed project
- Verify submitted mass and energy balance
- Verify the economic feasibility of the project and financial strength of potential technology provider(s)
- Verify capital and operational costs for technologies/facilities
- Determine the facility / technology’s regulatory compliance history and environmental performance
- Interface with local community and stakeholders of the reference project
- Develop preliminary list of potential vendors/contractors to receive a RFP

It is important to have an experienced tour facilitator/guide that is familiar with the various conversion technologies and can provide technical pre-briefings of the various technologies/facilities, and can provide a debriefing of each visit so that the important issues can be discussed. The technologies and facilities selected should be similar in scope and type of technology for what is initially being contemplated. It is also important to understand the overall context in terms of the legal/regulatory, technical, social, and other supporting infrastructure that made the “reference facility” operations successful.

Photographs and/or video documentation should be requested of each facility well in advance of the actual visit. Photography/video reminders are invaluable for refreshing memories of what is visited. A conversion technology evaluation tour which includes a lot of various facilities will seem like a blur, and facilities will tend to all look the same unless the debriefing discussions and photographs point out the differences between the facilities. The experience and lessons learned from the conversion technology tour(s) should be used in helping finalize the project concept, scope, and goals/objectives.

9. Determine the Legal, Regulatory, and Legislative Issues Impacting the Development and Permitting of the Project

An EcoPark integrated waste management project that has a thermal conversion technology component will face many Federal, State, and local siting and permitting issues. One of the keys to successful permitting is to have a clear understanding of the legal, regulatory, legislative, and environmental documentation (e.g., NEPA/CEQA compliance) and legislative issues that can impact the design, development and permitting of the proposed project. An extensive and exhaustive "defensible" NEPA/CEQA document will need to be prepared as part of the overall permitting process.

There must be sufficient time set aside in the project development schedule to adequately address the permitting process. There must also be sufficient project development capitalization in the budget to allow for the permitting of controversial waste management project. In California, the permitting path for a thermal conversion technology is unclear, and there is debate on how these types of facilities should be classified, so there will be actual "unknowns" that must be dealt with.

10. Finalize Project Concept, Scope, and Goals/Objectives

This step provides a clear definition and understanding of the stakeholder's and Navy's overall project requirements once the previous tasks have been completed and the technical /economic feasibility analysis indicates that the project is a "go". The information that needs to be generated in this step should to be coordinated with the Navy's Purchasing/Contracting arm so that a Request for Proposal (RFP) will accurately reflect the desired project concept and goals/objectives.

- Finalize technical and economic feasibility analysis (go / no-go)
- Finalize "commitment" by Navy (and other participants) for project site, wasteshed, tip/operations fee, grants, etc.
- Assign responsibilities for each component of the project development
- Determine optimal "business arrangements"
- Determine the project contracting strategy (e.g, Enhanced Use Lease (EUL), Energy Savings Performance Contract (ESPC), turnkey contract to Engineer, Procure, Construct (EPC), permit, finance, and operate, etc.).
- Determine desired facility standards (e.g., LEED or equivalent, etc.)
- Finalize technical parameters (e.g., wasteshed, tonnage, composition, technologies, reliability requirements, performance requirements, etc.)
- Finalize "systems performance guarantee" requirements over the project life
- Finalize funding mechanism(s)
- Finalize project "partner(s)" (if public-private partnership, e.g., other jurisdictions, other Navy basis, other participating entities, etc.)
- Finalize long term roles for stakeholders and community

- Develop a long term Navy public relations / communications program for the project (which is to be coordinated with the community outreach/education program)
- Develop a sample contract with the Navy Legal Dept. (sample contract to be included with the RFP)
- Prepare list of potential pre-qualified vendors to receive RFP

The finalized project concept, scope, goals/objects should accurately reflect the cumulative consensus input from an informed stakeholder, community, and Navy project development team, and will represent a reasonable feasible project that can be competitively bid and constructed/operated successfully.

11. Develop and Issue Request for Proposal/Qualifications

When all of the above tasks have been completed, the Navy's will develop a Request for Proposal / Qualifications based on the selected contracting strategy. The RFP/RFQ must describe the finalized project concept, scope, technical requirements, goals/objectives (including the expected products/output, e.g., energy, synfuel, etc.) and the roles. The RFP/RFQ should provide a clear description of the evaluation factors for the selection of the preferred vendor(s). The RFP/RFQ should require potential responders to the RFP/RFQ to designate "business sensitive" or "technical/trade secret" materials in the RFP/RFQ. The Navy may consider using an independent technical consultant to help prepare the RFP/RFQ. The Navy should conduct a RFP/RFQ workshop (firms can participate by internet) to describe the overall project and take written questions related to the RFP/RFQ.

Note that it takes a tremendous amount of effort and expense for a potential vendor to respond to this type of an RFP/RFQ, this is why it is key that the Navy establish its commitment to see the project to completion once the RFP/RFQ is issued.

12. Evaluate Responses and Select Short List of Finalists

This task involves organizing a "selection committee" to determine a ranked/prioritized short list of finalists so the Navy can start negotiations with the highest ranked proposer(s). The selection committee should include various stakeholders (Navy, participating jurisdictions, industry, etc.), including project development team members with technical and financial/business expertise (and/or have access to experts if needed), and include representative(s) of the impacted public/community.

The evaluation process may require additional informational requests and data verification. Additional facility tours may be required for verification of performance claims. This will also allow some members of the selection committee who had not previously gone on the reference facility technology tours se see the reference facilities. It is important to keep the weighted matrix evaluation forms from each person, so that in the event of a challenge to the selection process, the decision making process can be readily be explained and defended.

13. Start Contract Negotiations

Start contract negotiations with the vendor with the highest ranked proposal.

APPENDIX C

Environmental Justice Analysis for San Diego County Area

DEFINITION OF EVIRONMENTAL JUSTICE

- The **<u>United States Environmental Protection Agency</u>** defines environmental justice as: **"**the <u>fair treatment</u> and <u>meaningful involvement</u> of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

- **Fair treatment** means that no group of people, including a racial, ethnic, or a socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies.

- **Meaningful involvement** means that: (1) potentially affected community residents have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision; (3) the concerns of all participants involved will be considered in the decision making process; and (4) the decision makers seek out and facilitate the involvement of those potentially affected**"**.

QUANTITATIVE MEASUREMENT ISSUES

- Although the United States Environmental Protection Agency (USEPA) defines what environmental justice means, they do not define exact tests that decide whether something is environmentally just or not environmentally just.

- If exact and objective numerical tests are not defined, decisions on the environmental justice of an issue are open to the decision maker's arbitrary judgments and whims.

- Additionally, the USEPA definition for environmental justice does not specifically tell exactly what races, ethnic groups, cultures, income classes, and socioeconomic groups should be considered when measuring environmental justice. Besides the usually mentioned groups of minorities or those with low income, environmental issues may also affect such groups as children, elderly, or women

- A distinction should be made between measuring an **<u>environmental impact</u>**, and measuring an **<u>environmental justice impact</u>**. There could be an adverse environmental impact, but it may not affect minority or low income areas. Nevertheless, any harmful environmental impact would have to be addressed, even if it did <u>not</u> affect minority or low income areas.

WHAT DATA DO WE CURRENTLY HAVE TO MEASURE ENVIRONMENTAL JUSTICE ISSUES?

An important resource for data that can currently be used to analyze environmental justice issues is the Decennial Census:

- The 2000 Decennial Census conducted by the U. S. Census Bureau obtained a wide variety of demographic and economic information about the U. S. population at a number of geographic levels such as state, county, jurisdiction, zip code, and smaller areas. This information is available free-of-charge on the Census Bureau's web site.

- The next Decennial Census will be conducted in 2010, but detailed data for analyzing Environmental Justice issues will not be available until at least 2012.

WHAT TYPES OF DATA ARE AVAILABLE FROM THE 2000 DECENNIAL CENSUS?

Types of data available include information on:

- Race or Hispanic ethnicity of the population (<u>Hispanics are considered an ethnic group and not a race in the 2000 Decennial Census</u>)
- Sex and age of the population
- Owner-occupied vs. renter-occupied housing units
- Family/Children status of households
- Size of households
- Linguistic isolation of households (i.e. no one in the household can understand English well)
- School enrollment and educational attainment of the population
- Type of industry and occupation for employed workers
- Income and poverty status of households
- Number of units and type of heating fuel in the housing structure
- Number of vehicles available, means of transport and travel time to work
- Value of the housing unit or monthly rent paid

WHAT LEVELS OF GEOGRAPHIC DETAIL ARE AVAILABLE FROM THE 2000 DECENNIAL CENSUS?

It is important to keep in mind that the Decennial Census records people at their place of residence, and is not a workplace survey. Some of the geographic levels available for people's place of residence include:

- <u>State</u>

- <u>County</u>

- Jurisdiction

- Census Tract (a Census Bureau geographic designation that includes from 1,500 to 8,000 people but is optimally about 4,000 people – there are 605 Census Tracts that are in San Diego County)

- Census Block Group (a Census Bureau geographic designation that includes from 600 to 3,000 people but is optimally about 1,500 people – there are 1,762 Census Block Groups in the County). It is a part of a Census Tract.

USING MAPS TO UNDERSTAND THE DATA

Maps are a good way to get an overview of the Environmental Justice issues affecting the surroundings of a facility.

The following fifteen maps give an example of this for the County of San Diego. The first map shows the incorporated cities in San Diego County and the second map shows military facilities in the County.

The next thirteen maps examine several 2000 Decennial Census indicators for minority groups, income status, age, education level, labor force status, and location of rental units, at the Census Block Group Level.

A Census Block Group is defined as a geographic unit of 600 to 3,000 people but is optimally about 1,500 people – there are 1,762 Census Block Groups that are in San Diego County.

SPECIFIC INDICATORS MAPPED

The indicators mapped are:

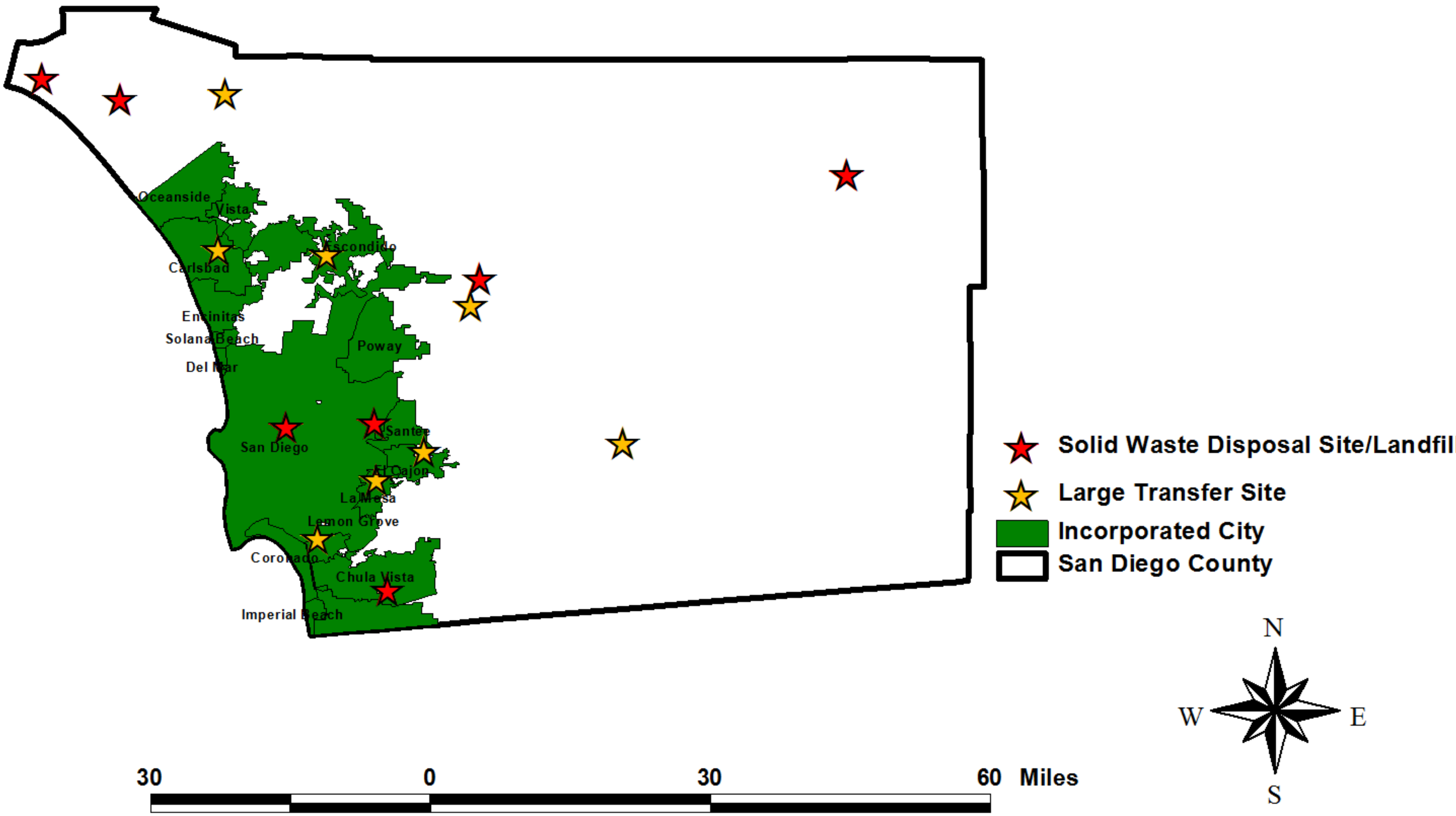
1. Percent of Population with White Only Race
2. Percent of Population Minority (Non-White race and/or Hispanic ethnicity)
3. Percent of Population with Black Only Race
4. Percent of Population with Asian Only Race
5. Percent of Population with Hispanic Ethnicity
6. Percent of Population That Speak Spanish and Are Linguistically Isolated (no one understands English well)
7. Percent of Population Less Than 18 Years of Age
8. Percent of Population 25 and Over with No High School Diploma

9. Median (middle value of) Household Income in 1999
10. Percent of Households with Income <u>Below Poverty Level</u>
11. Percent of Housing Units Occupied by <u>Renters</u>
12. Percent of Population 16 and Over in the <u>Armed Forces</u>
13. Percent of Population 16 and Over in the <u>Civilian Labor Force</u>

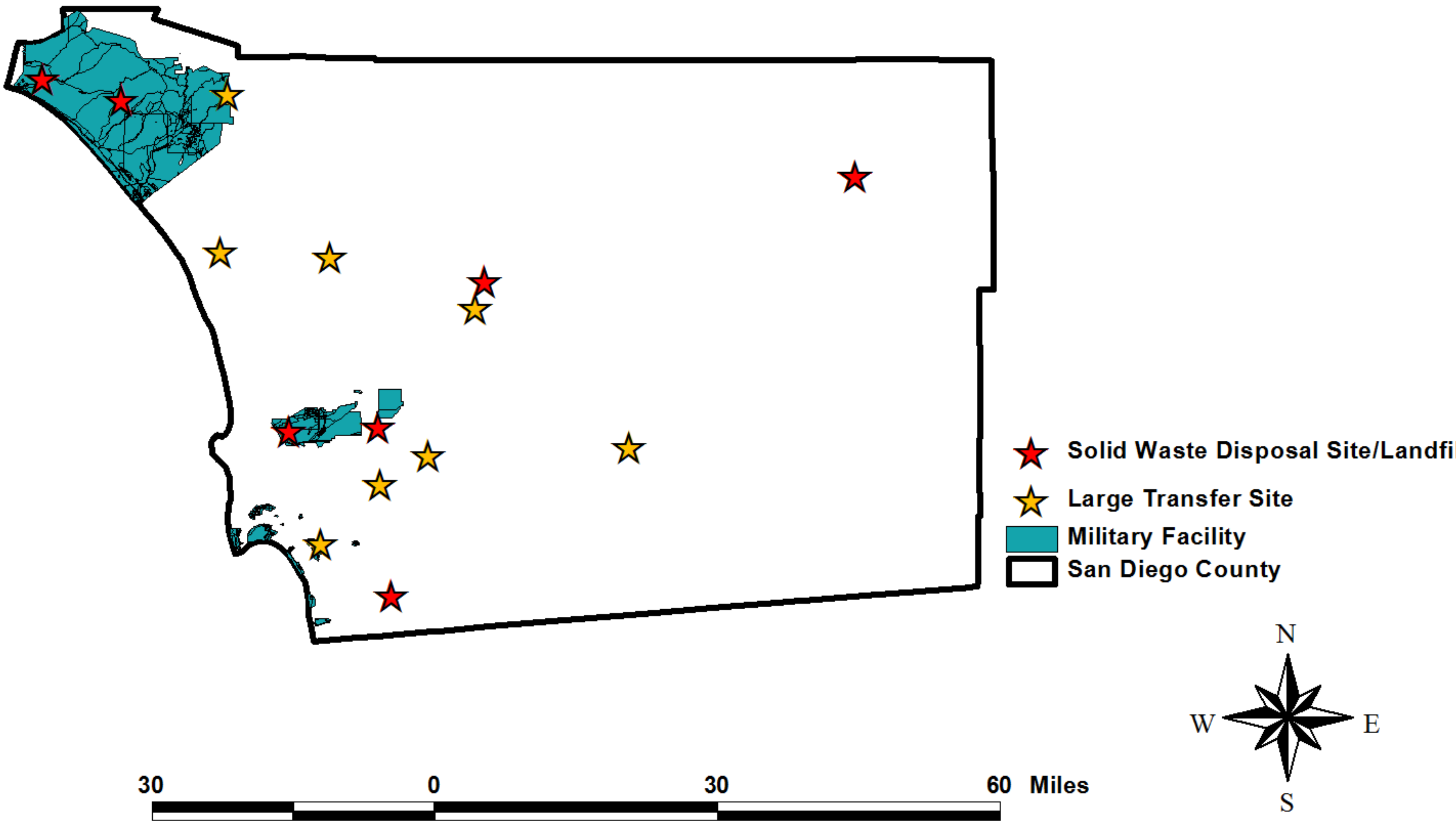
For each of the thirteen indicators, the values for the Census Block Groups are divided into 3 groups, which may be considered low, medium and high values. The groups differ for each indicator.

The maps can be enlarged by using the menu items VIEW and ZOOM.

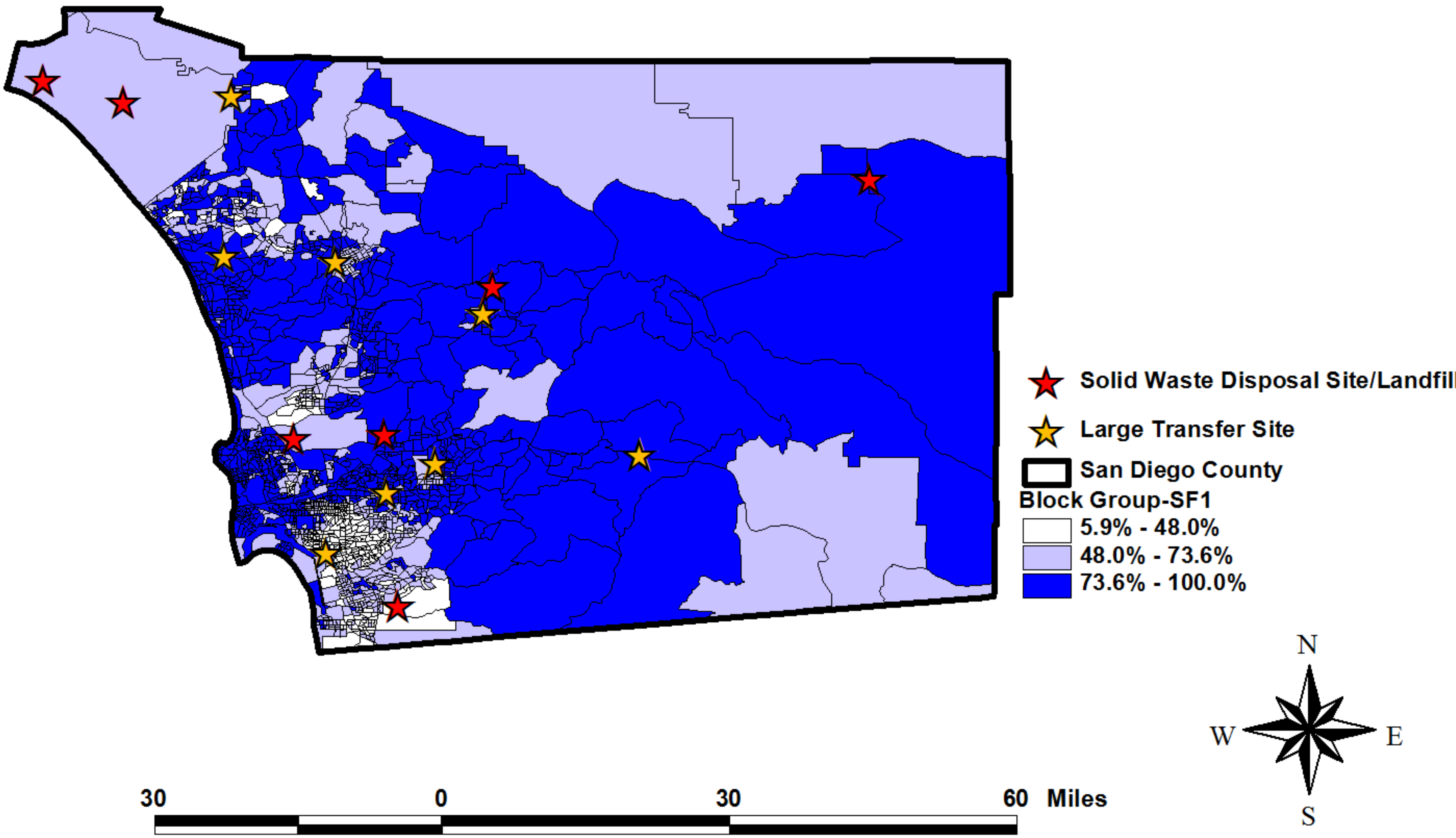
San DiegoCounty - Active Landfills/Large Transfer Sites and Incorporated Cities
Based on CIWMB SWIS Database and 2000 Decennial Census Summary Files

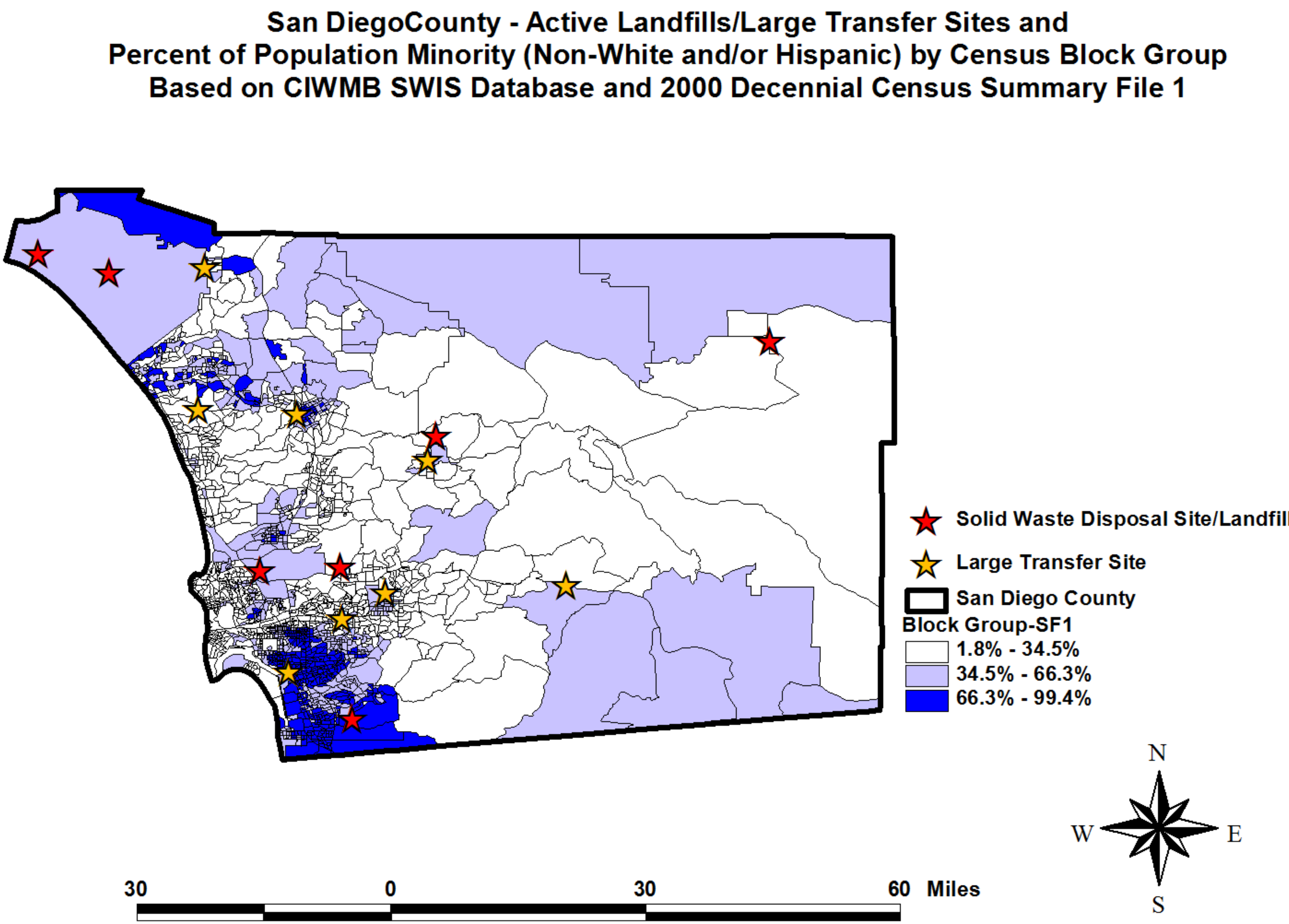


San DiegoCounty - Active Landfills/Large Transfer Sites and Military Facilities
Based on CIWMB SWIS Database and 2000 Decennial Census Summary Files

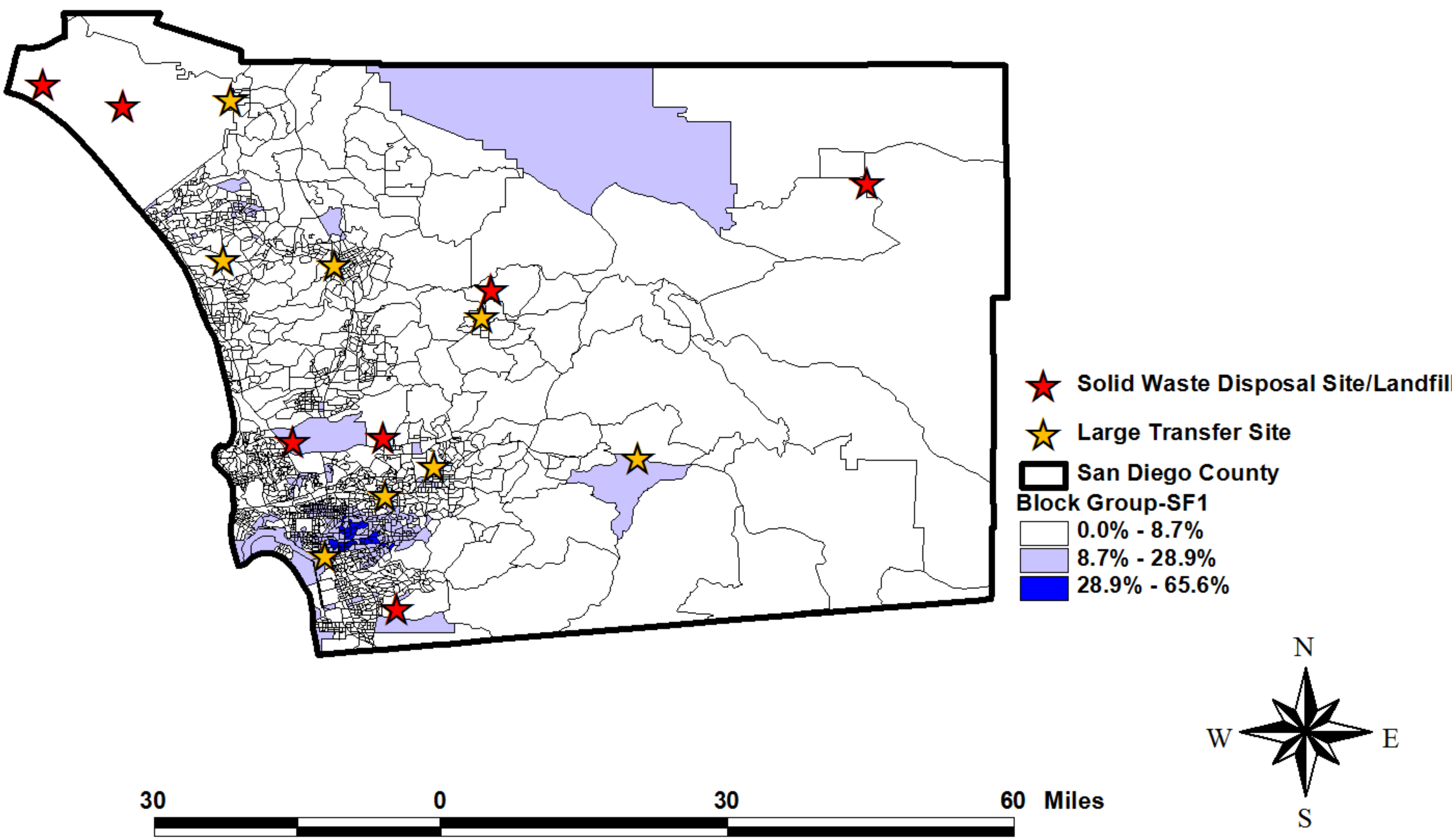


San DiegoCounty - Active Landfills/Large Transfer Sites and
Percent of Population with White Only Race by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1

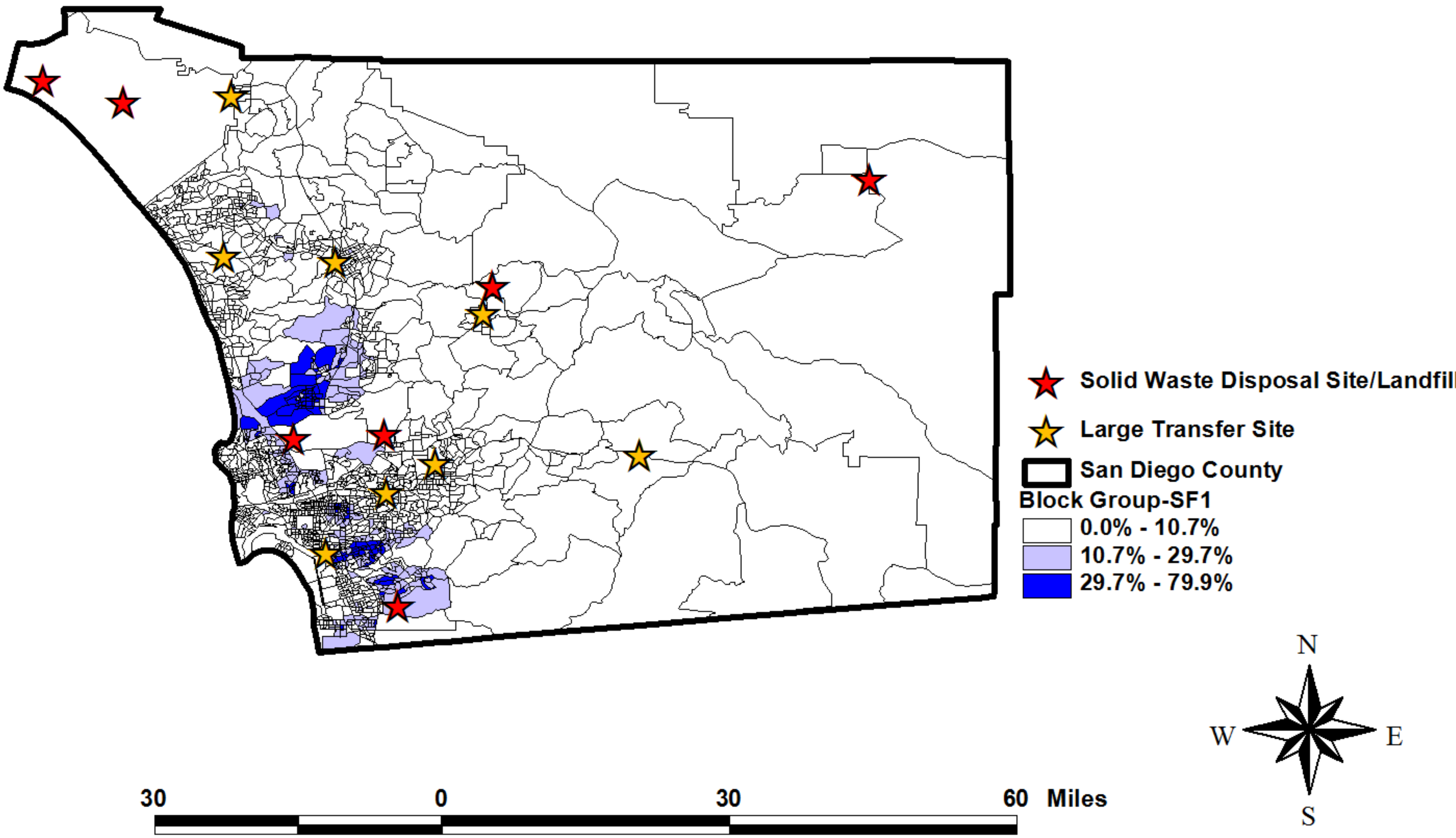



San DiegoCounty - Active Landfills/Large Transfer Sites and
Percent of Population Minority (Non-White and/or Hispanic) by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1
Solid Waste Disposal Site/Landfill
Large Transfer Site
San Diego County
Block Group-SF1
1.8% - 34.5%
34.5% - 66.3%
66.3% - 99.4%
N
W
E
S
30
0
30
60
Miles

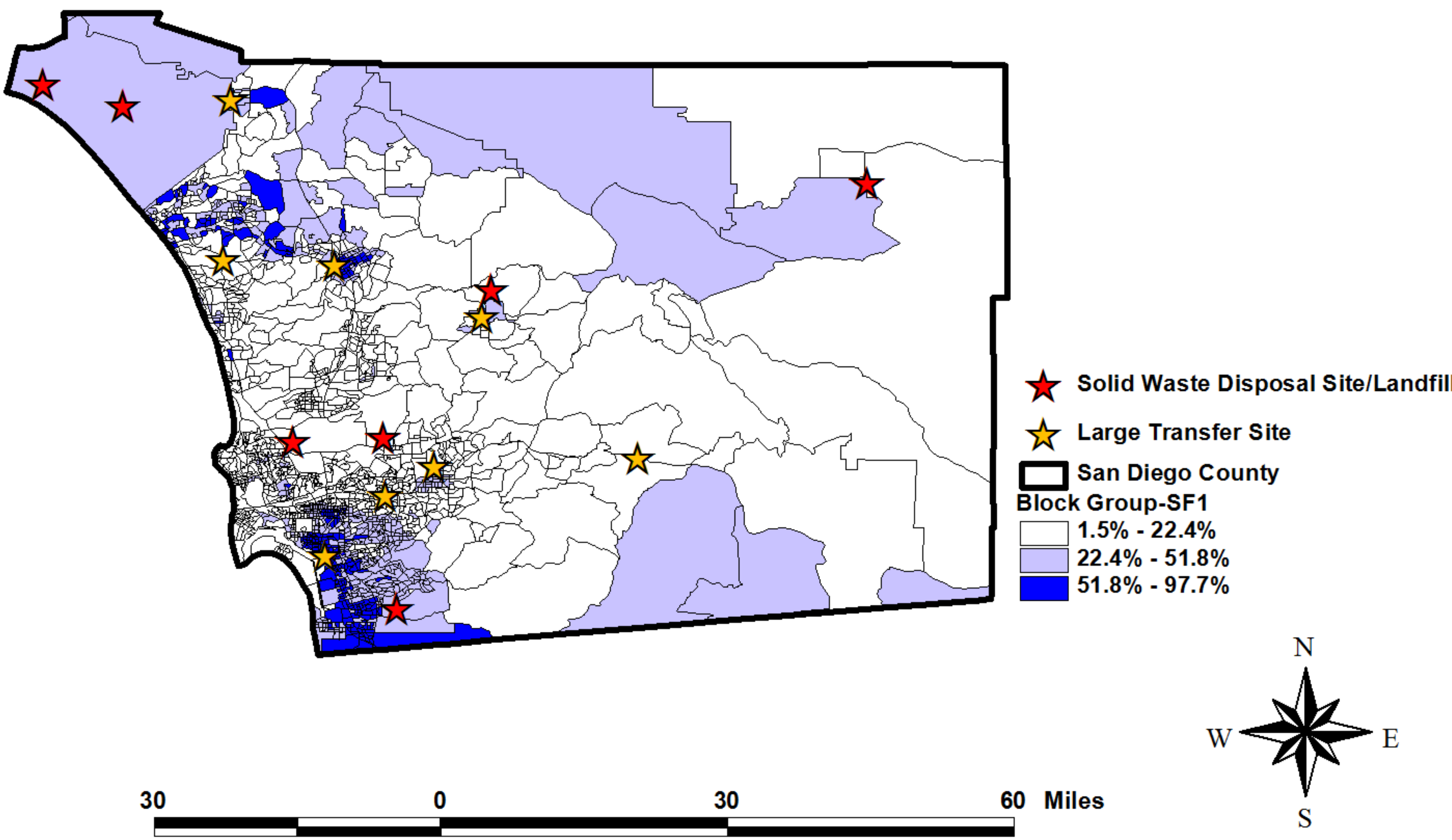
San DiegoCounty - Active Landfills/Large Transfer Sites and
Percent of Population with Black Only Race by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



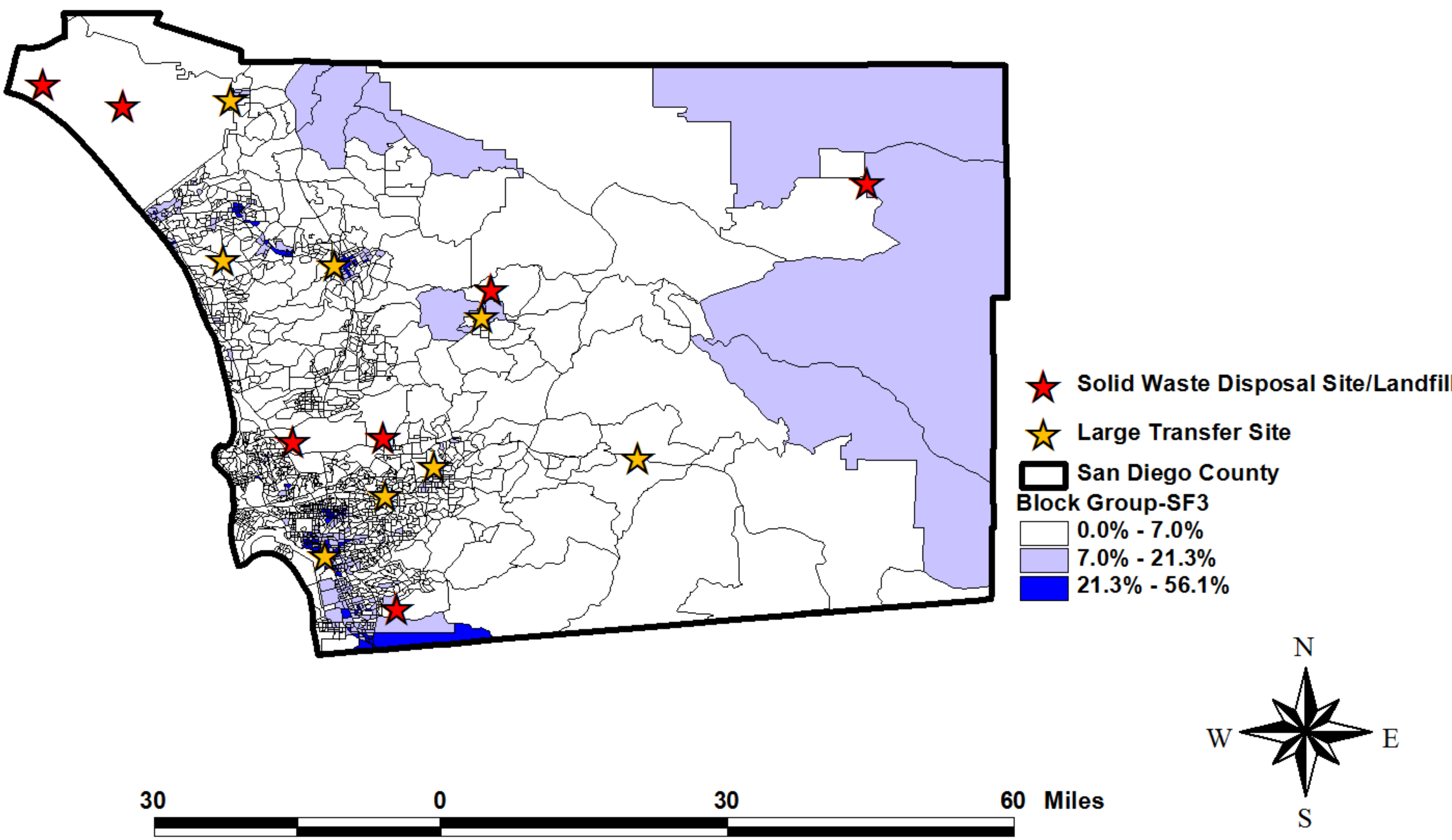
San DiegoCounty - Active Landfills/Large Transfer Sites and Percent of Population with Asian Only Race by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



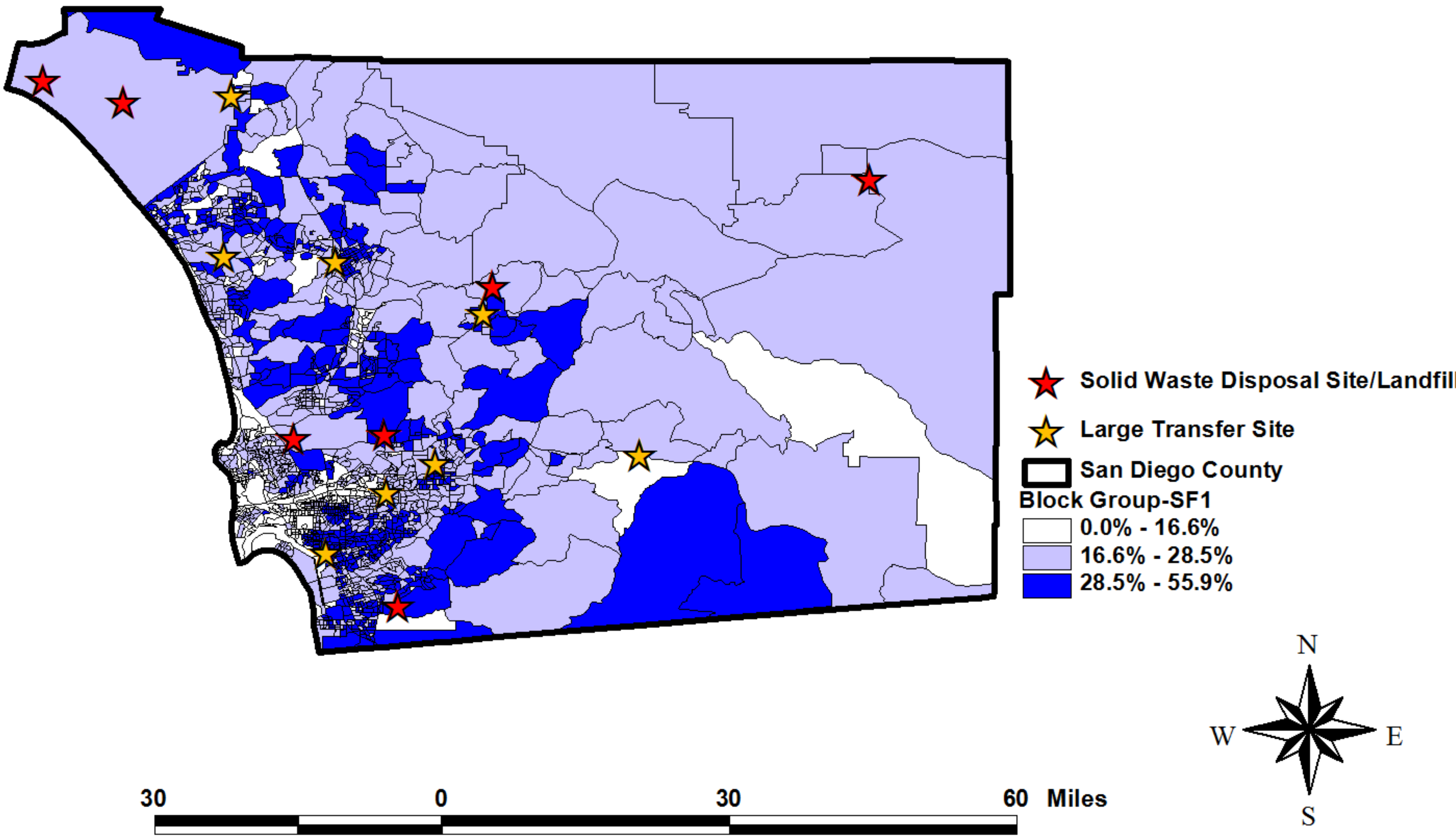
San DiegoCounty - Active Landfills/Large Transfer Sites and Percent of Population with Hispanic Ethnicity by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



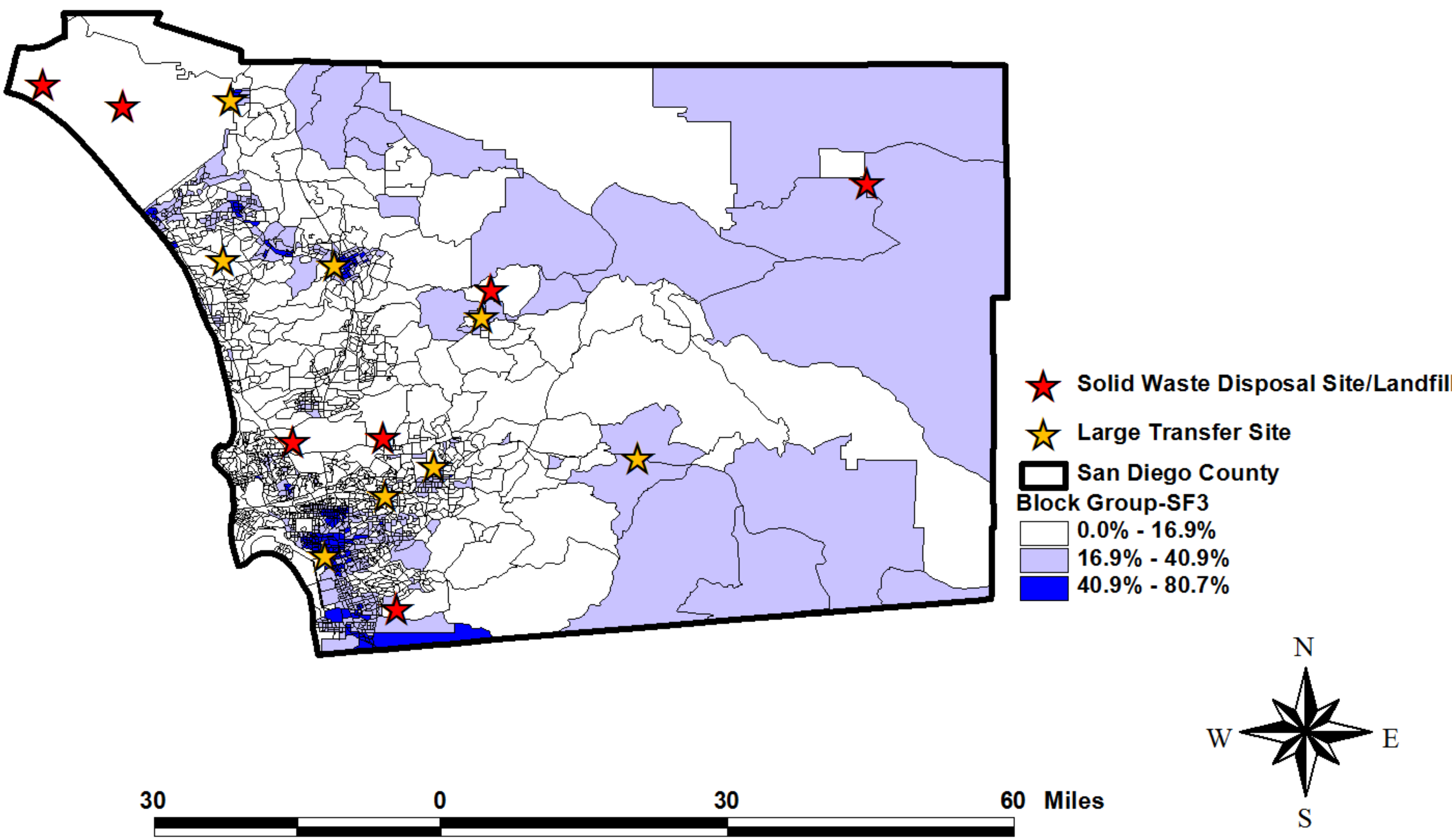
San DiegoCounty - Active Landfills/Large Transfer Sites and
Percent of Households That Speak Spanish and Are Linguistically Isolated by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



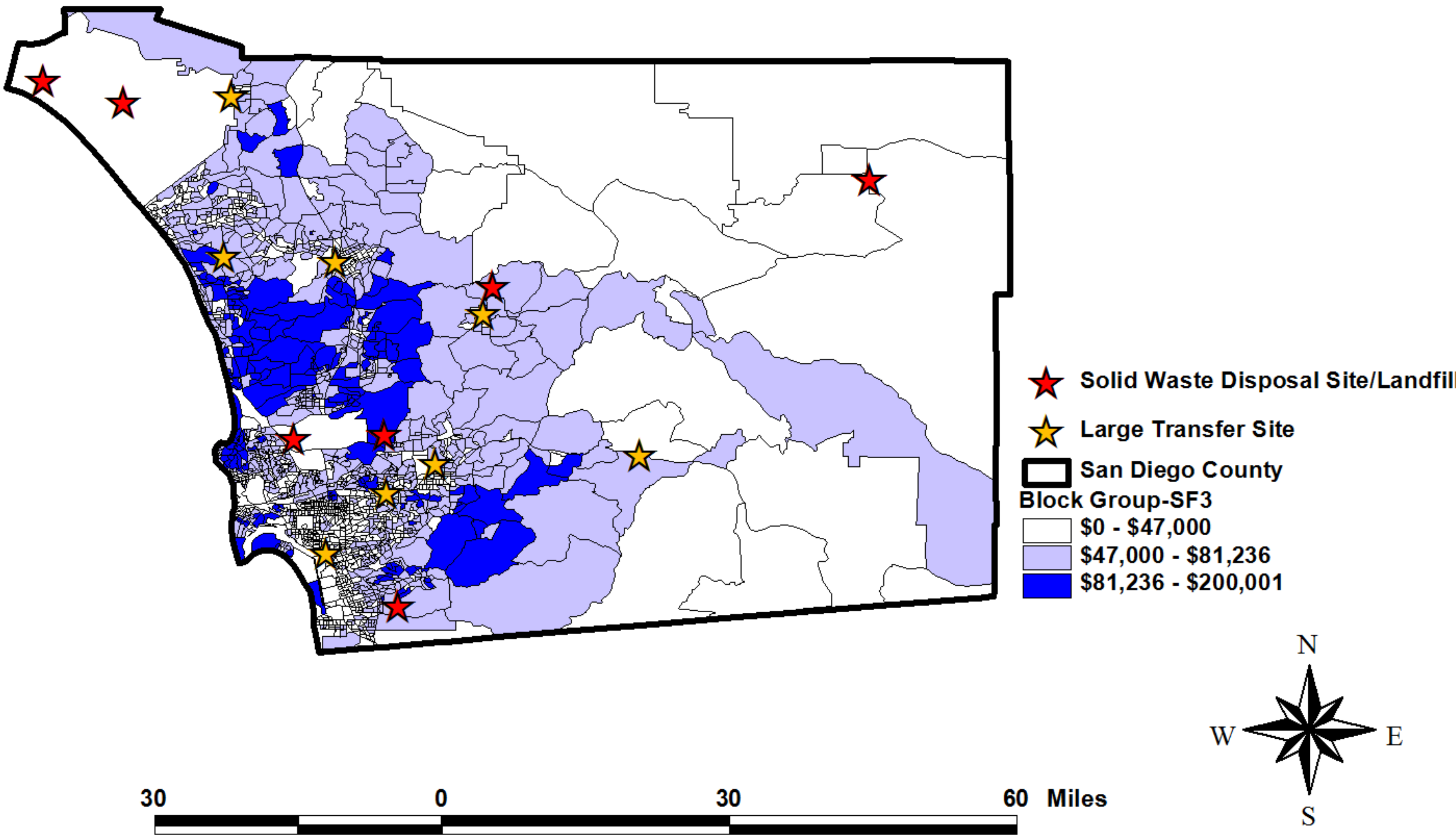
San DiegoCounty - Active Landfills/Large Transfer Sites and Percent of Population Less Than 18 Years of Age by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



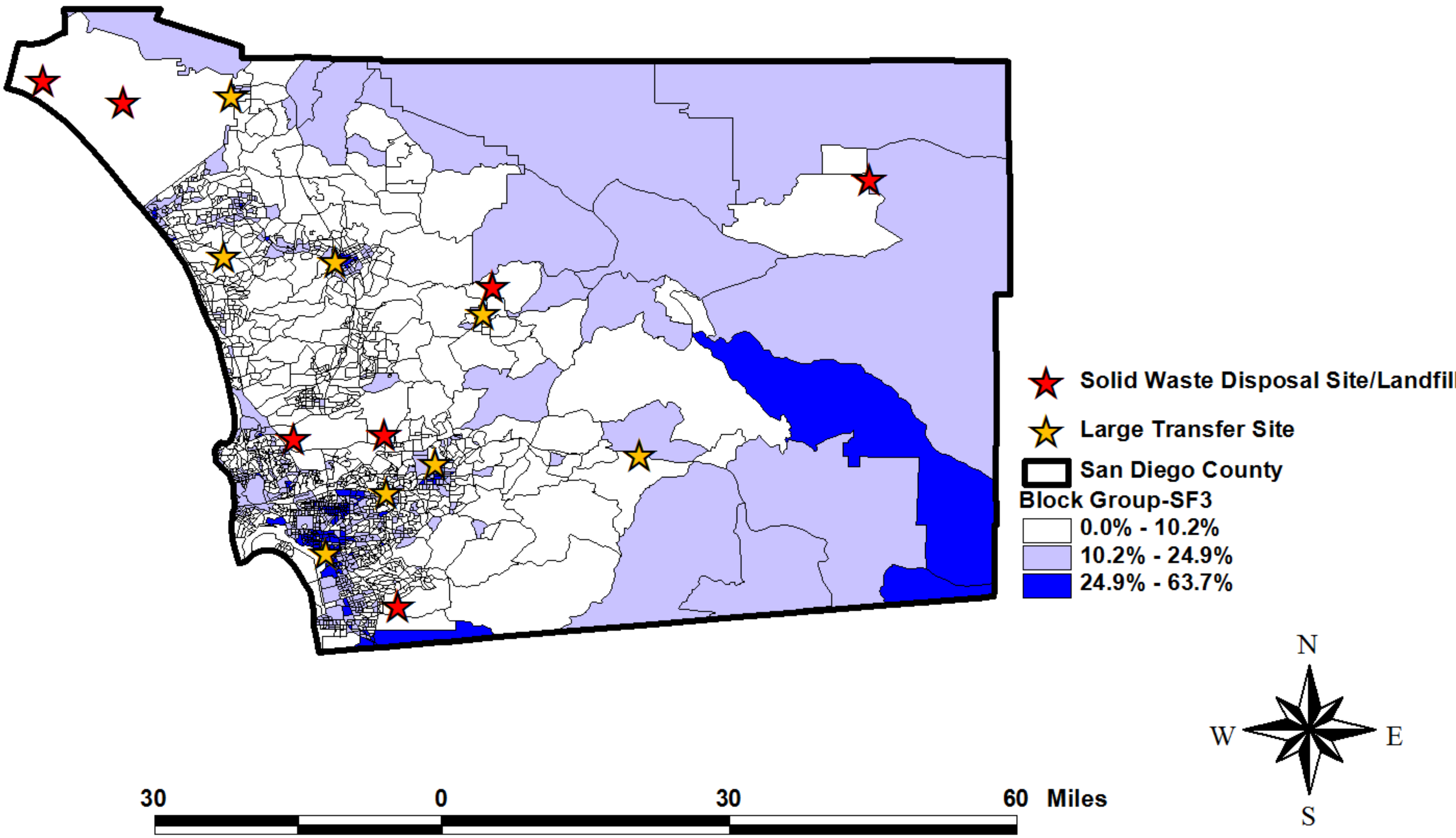
San DiegoCounty - Active Landfills/Large Transfer Sites and Percent of Population 25 and Over with No High School Diploma by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



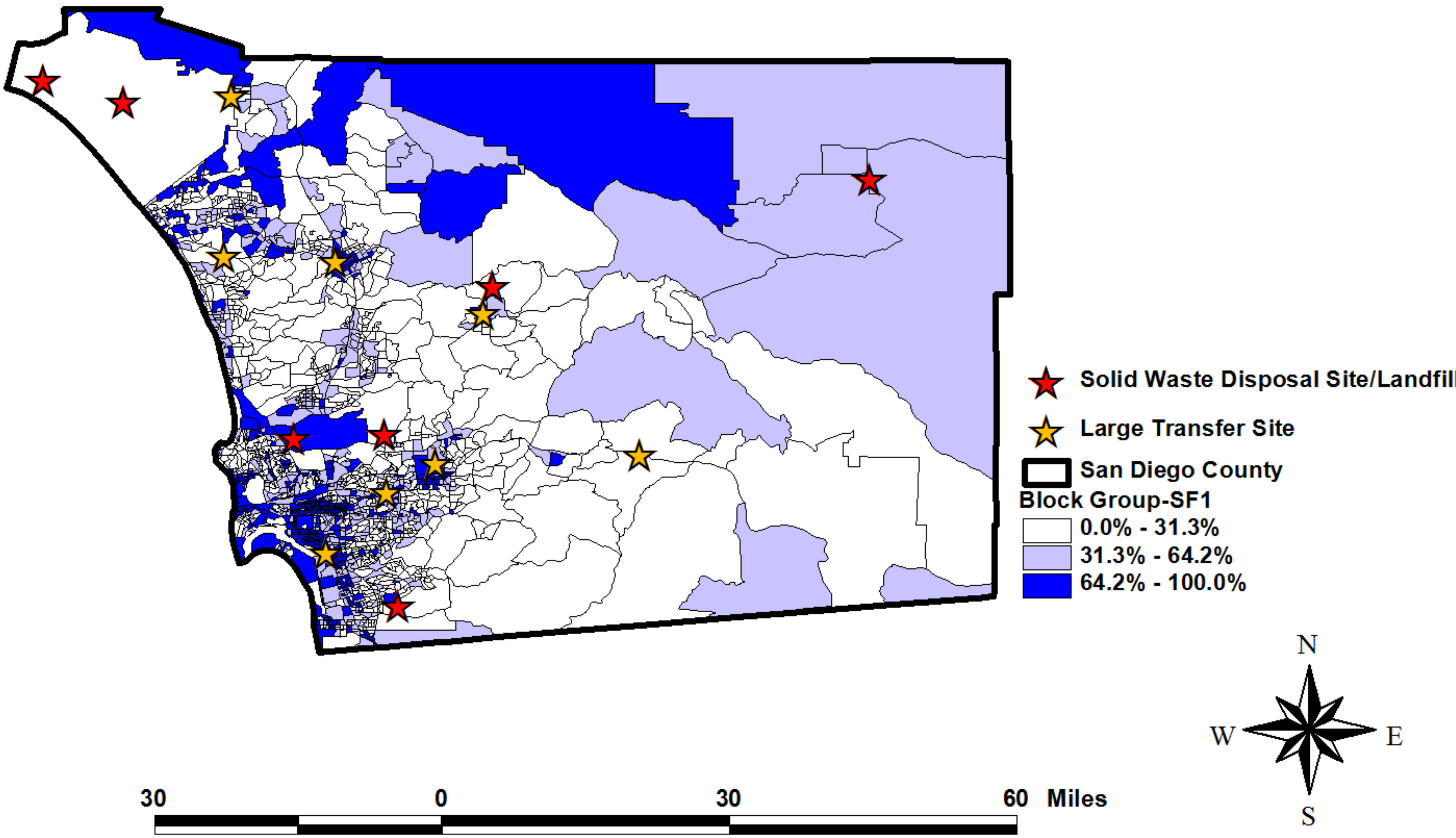
San DiegoCounty - Active Landfills/Large Transfer Sites and Median Household Income in 1999 by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



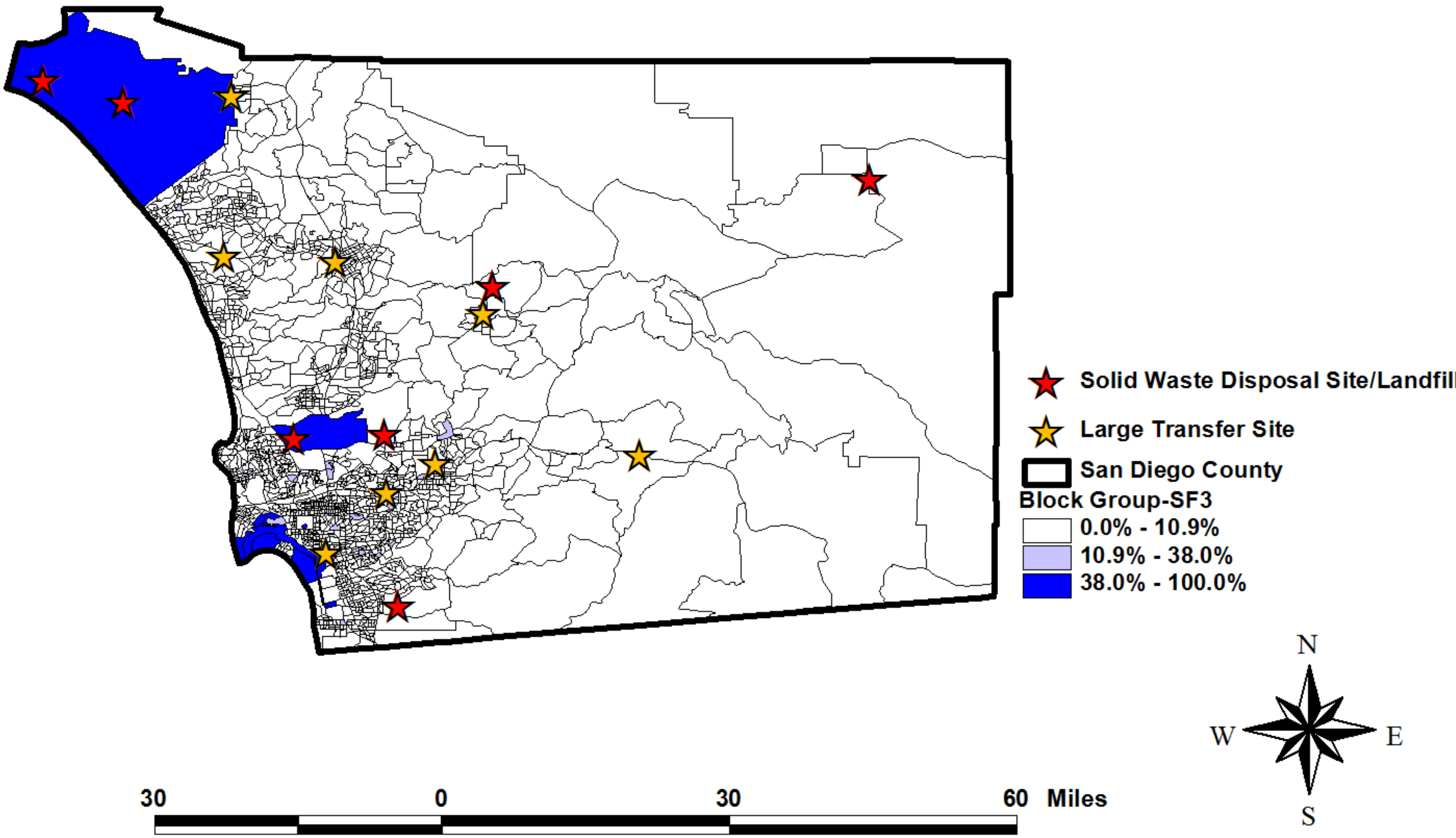
San DiegoCounty - Active Landfills/Large Transfer Sites and
Percent of Households with 1999 Income Below Poverty Level by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



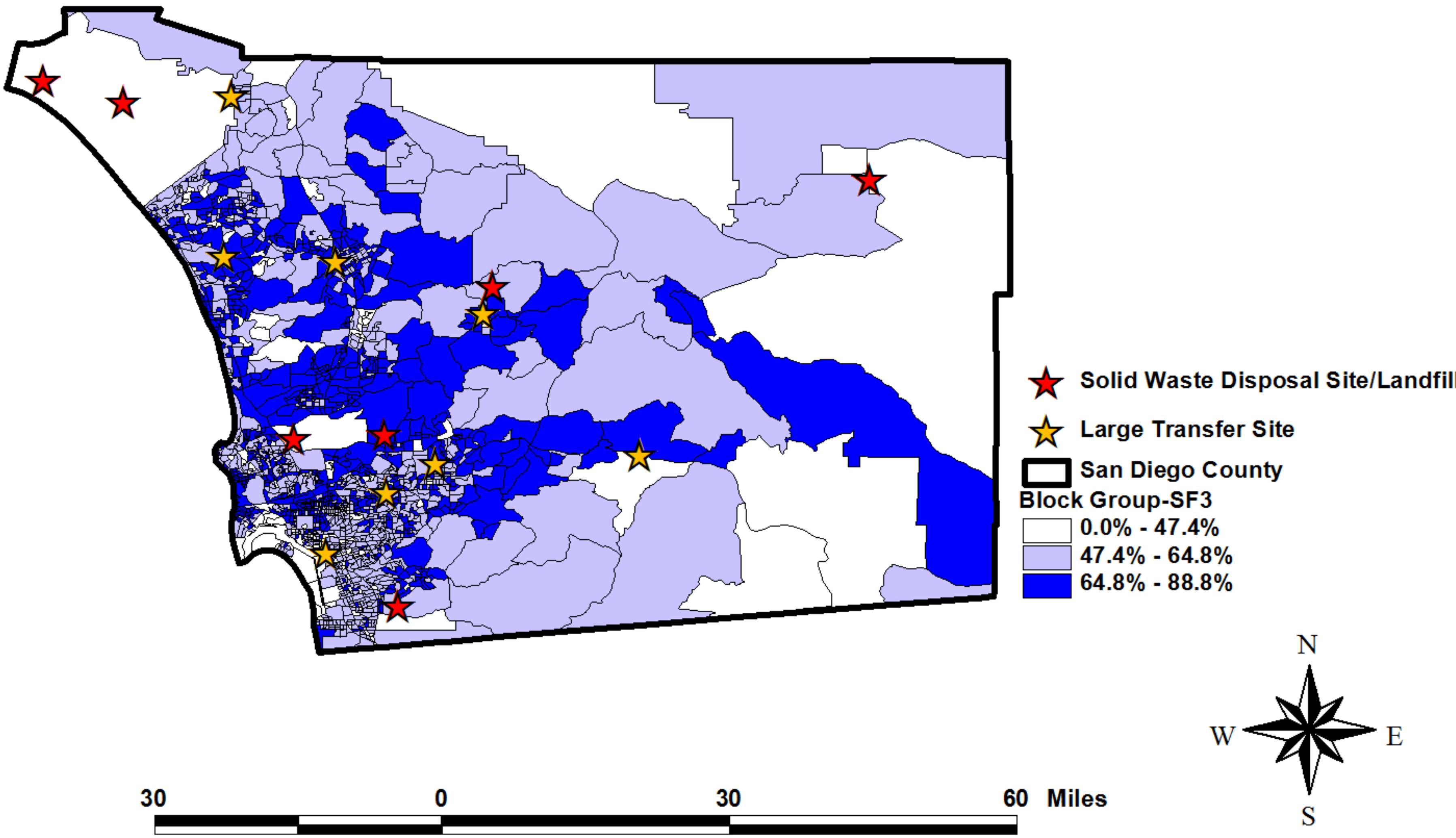
San DiegoCounty - Active Landfills/Large Transfer Sites and Percent of Housing Units That Are Renter-Occupied by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



San DiegoCounty - Active Landfills/Large Transfer Sites and Percent of Population 16 and Over in the Armed Forces by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



San DiegoCounty - Active Landfills/Large Transfer Sites and
Percent of Population 16 and Over in the Civilian Labor Force by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



SOME OBSERVATIONS ON THE MAPS

The maps show that:

- **<u>Whites</u> are concentrated in Oceanside/Carlsbad/Encinitas, north San Diego City, La Jolla area and eastern portions of the County.**
- **<u>Minorities</u> (primarily Hispanics) are generally concentrated in the southwest portion of the County and areas around Camp Pendleton.**
- **<u>Blacks</u> are concentrated in the Lemon Grove and San Diego City areas.**
- **<u>Asians</u> are concentrated in the National City/Chula Vista and Poway areas.**
- **<u>Hispanics</u> are generally concentrated in the extreme southwest portion of the County and areas around Camp Pendleton.**
- **<u>Hispanics That Do Not Understand English Well</u> are again in the extreme southwest portion and Camp Pendleton portions of the County.**

SOME OBSERVATIONS ON THE MAPS

- **Percent of Persons Less Than 18 Years of Age are generally concentrated in Hispanic areas and selected areas in the western portion of the County.**

- **Adults with No High School Diploma are again generally concentrated in Hispanic areas listed above.**

- **Median Household Income tends to be highest in selected areas in the western portion of the County.**

- **Poverty Levels are generally concentrated in the Hispanic areas and rural areas in the eastern portion of the County.**

- **Landfills are generally located in the western portion of the County and on military bases.**

- **Many of the indicators seem to be saying the same thing. For example, areas with high concentrations of Hispanics also have high percents of the adult population with no high school diploma and households below poverty level.**

MAKING SENSE OF THE MAPS

Although the maps are useful, they are limited because:

- **They do not present a definite way to measure whether environmental injustice exists.**

- **There is no quantitative measure of the relationship between the large numbers of indicators available. (Over 400 indicators have been assembled to evaluate environmental justice.)**

- **There is no way to condense the large number of indicators to a few that are really important when measuring environmental justice.**

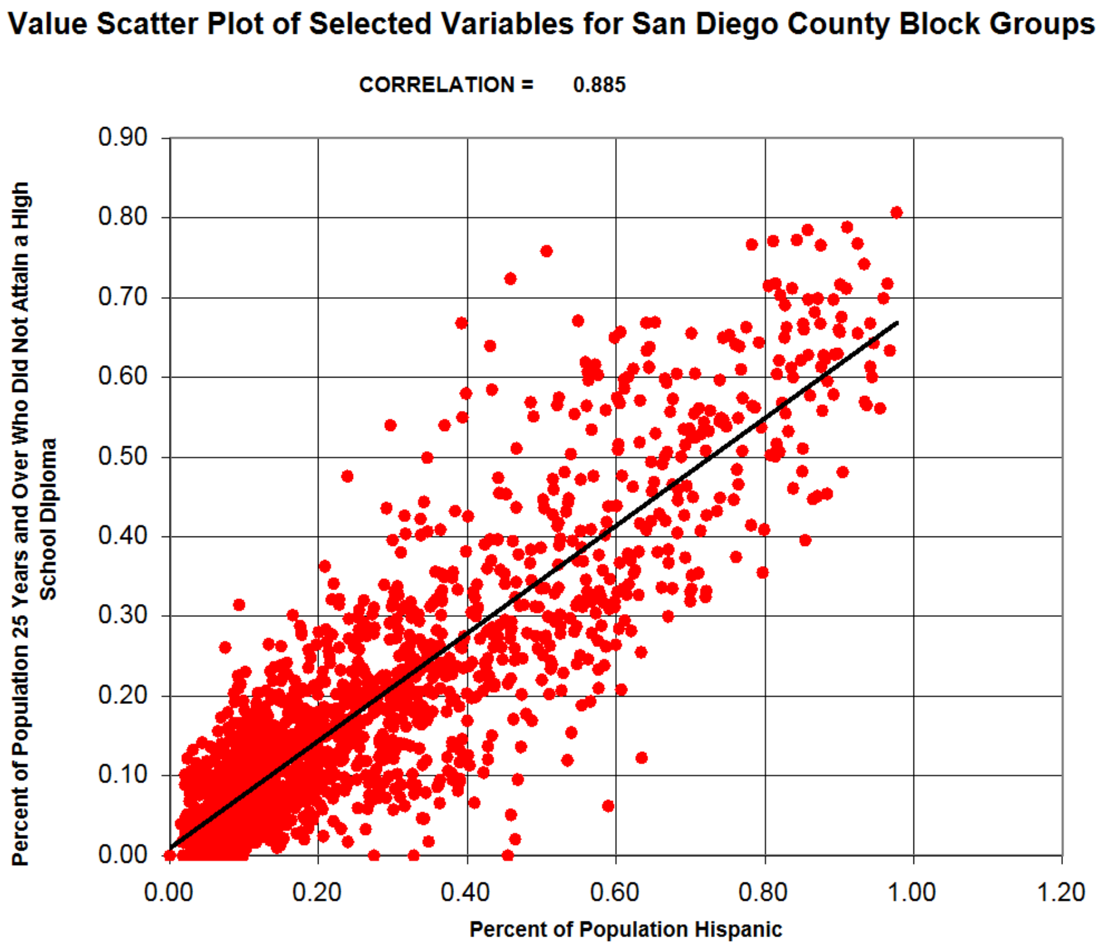
To help resolve these issues, two statistical procedures are very helpful:

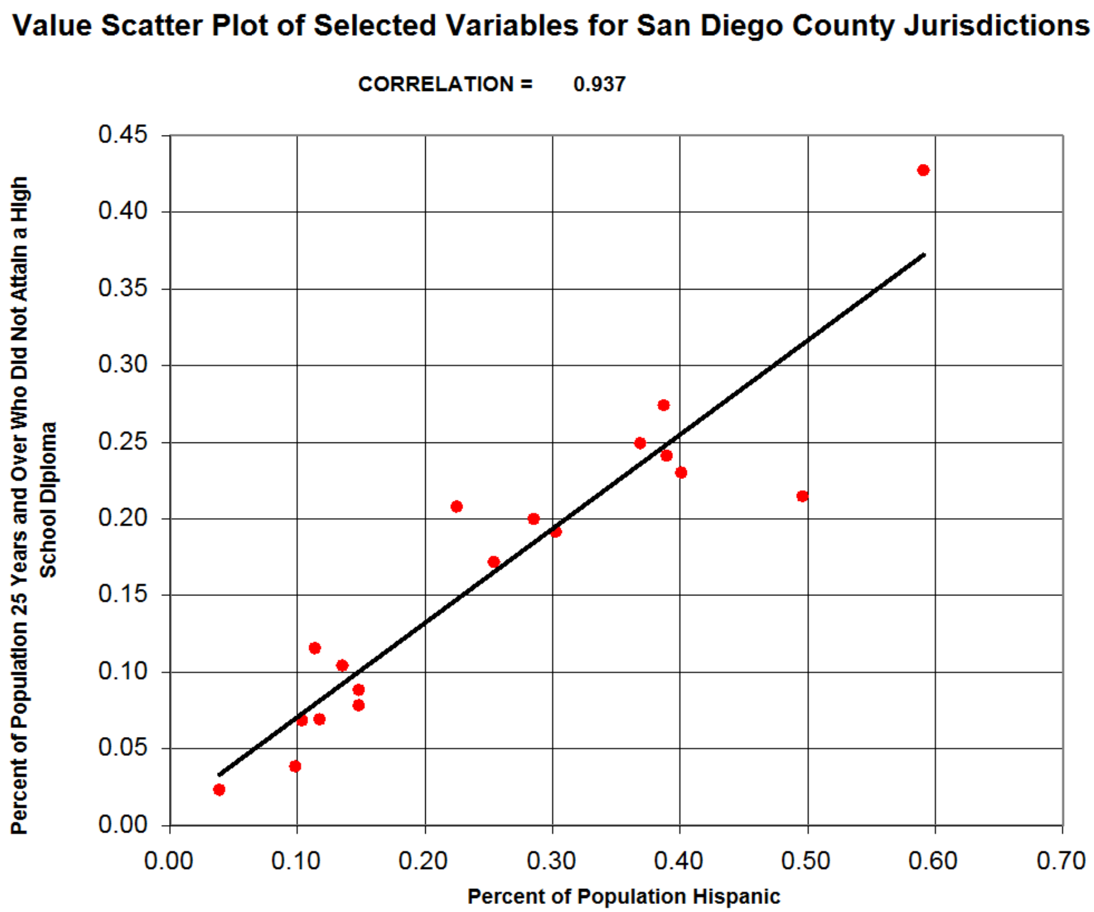
- **Correlation Analysis**
- **Factor Analysis**

CORRELATION ANALYSIS

- Correlation is a means of obtaining a specific number that measures the relationship between 2 indicators. For example, the graph on the next page shows the relationship between ***Percent of Population Hispanic*** and ***Percent of Population 25 and Over Who Did Not Attain a High School Diploma*** for the 1,762 Census Block Groups in San Diego County. On the next page are the same 2 indicators for the 18 Incorporated Cities in San Diego County.

- In each case, the ***Percent of Population Hispanic*** for each Block Group is measured on the horizontal axis (x-axis) with values from 0.00 (0 percent) to 1.00 (100 percent). The ***Percent of Population 25 and Over Who Did Not Attain a High School Diploma*** is measured on the vertical axis (y-axis) with values from 0.00 (0 percent) to 1.00 (100 percent). Each dot on the graph represents 1 Blcok Group in the first graph and 1 Incorporated City in the second graph.


Value Scatter Plot of Selected Variables for San Diego County Block Groups
CORRELATION = 0.885
Percent of Population 25 Years and Over Who Did Not Attain a High School Diploma
Percent of Population Hispanic
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0.00
0.20
0.40
0.60
0.80
1.00
1.20


Value Scatter Plot of Selected Variables for San Diego County Jurisdictions
CORRELATION = 0.937
Percent of Population 25 Years and Over Who Did Not Attain a High School Diploma
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Percent of Population Hispanic

CORRELATION ANALYSIS

- **The general trend of the dots is to rise from left to right on the graph. This means that as the *Percent of Population Hispanic* in a Block Group increases, the *Percent of Population 25 and Over Who Did Not Attain a High School Diploma* also increases.**

- **You should look at two things: (1) the slant of the straight line drawn through the points, and (2) how close the points are to the straight line drawn through the points. Graphs below demonstrate these concepts.**

- **If the line slants upward from left to right, it indicates that one indicator increases as the other indicator increases. This is termed a <u>direct</u> relationship.**

- **If the line slants downward from left to right, it indicates that one indicator decreases as the other indicator increases. This is termed an <u>inverse</u> relationship.**

- **If the line is horizontal from left to right, it indicates that there is no relationship between the two fields.**

CORRELATION ANALYSIS

- **Regardless of the slant of the line, the closer the points are to the line, the definiteness of whatever relationship is shown is more pronounced.**

- **A numerical measure of this relationship between the two fields is termed the <u>correlation</u>. Correlations have values ranging from +1.000 to –1.000.**

- **A correlation value of +1.000 indicates it is a direct relationship (line slants upward from left to right) with all points right on the line.**

- **A correlation value of -1.000 indicates it is an inverse relationship (line slants downward from left to right) with all points right on the line.**

- **A correlation value of 0.000 indicates no relationship between the two fields (line is horizontal) with all points right on the line.**

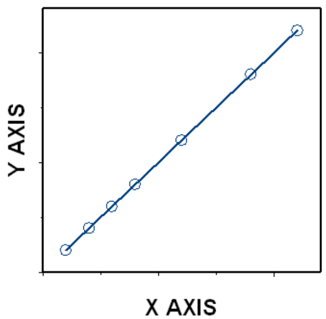
- **Values between 0.000 and +1.000 indicate a direct relationship. As the values get closer to +1.000, the direct relationship is stronger (the points are closer to the line).**

CORRELATION ANALYSIS

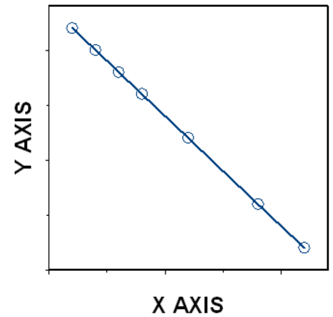
- **Values between 0.000 and -1.000 indicate an inverse relationship. As the values get closer to -1.000, the inverse relationship is stronger (the points are closer to the line).**

- **The following graphs give examples of various correlations:**

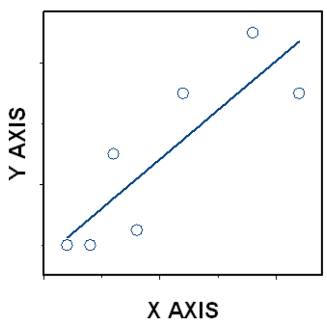
CORRELATION = +1.000



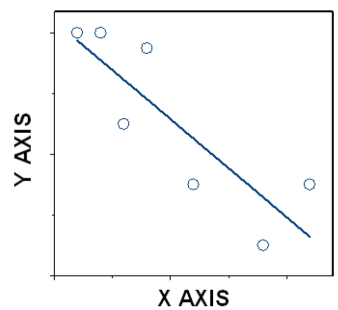
CORRELATION = -1.000



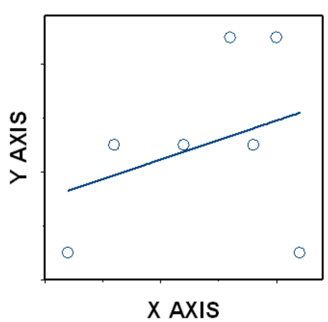
CORRELATION = +0.848



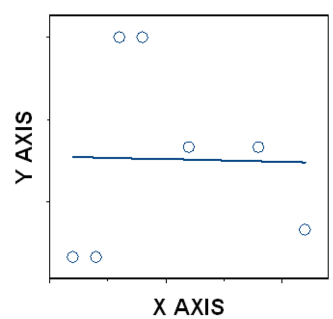
CORRELATION = -0.848



CORRELATION = +0.333



CORRELATION = -0.020



CORRELATION ANALYSIS

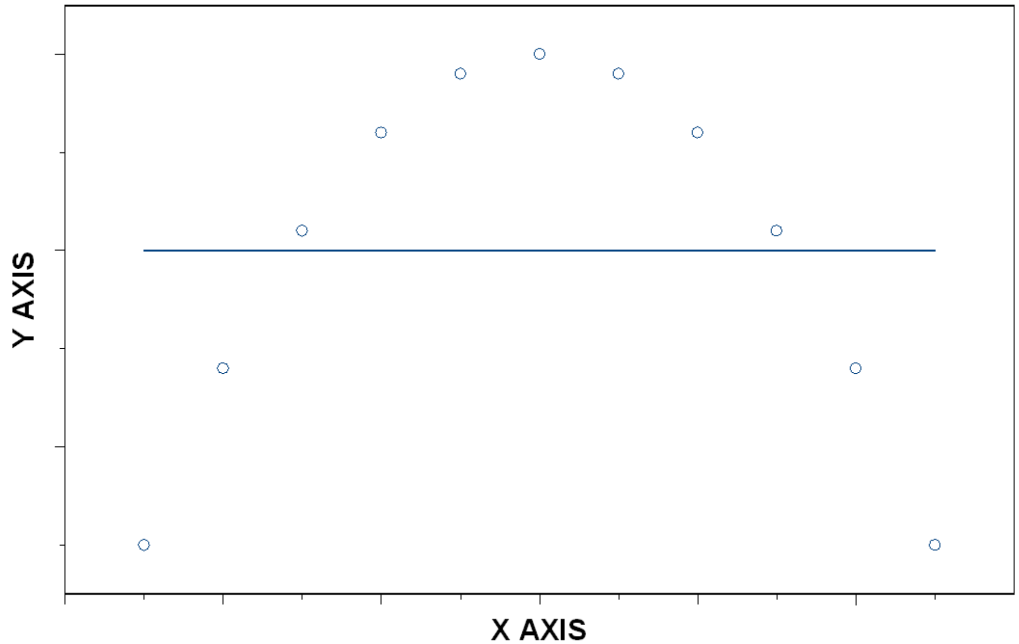
Two points on correlations need to be noted. Examples are shown on the next page.

- **First, the correlation measures the relationship with a straight line. If the relationship is really a curved line, the correlation may not be accurate.**

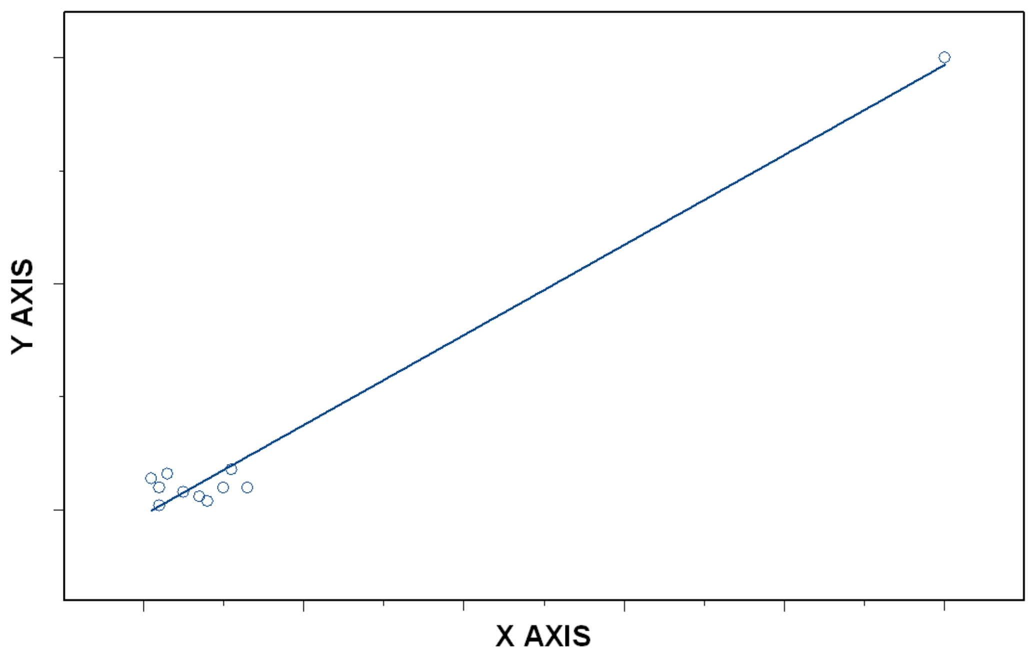
- **Second, you can get erroneously high positive or negative correlations, if all points except one or two are clustered at one end of the graph, and there are only one or two points at the other end of the graph with very high or low values. The point(s) at the far end of the graph may not show the same relationship as the other points.**

It is important to look at the graph of the correlation, and not just use the correlation number.

MISLEADING CORRELATION = +0.00



MISLEADING CORRELATION = +0.988



CORRELATION ANALYSIS

- **Excel files are provided for Census Block Group, Census Tract and incorporated jurisdictions correlations for the County of San Diego.**
- **Each of these files also has a table that allow you to see at a glance, for a particular indicator, what the correlation is with each other indicator.**
- **Additionally, Excel files are provided that shows all of the relevant data for a selected Block Group, Census Tract and incorporated city in the County of San Diego. Rankings are also shown.**

FACTOR ANALYSIS

- **Even though correlation gives a numerical value for the relationship between 2 indicators, there are still a very large number of indicators, and there is no way to tell which of them are important.**

- **It would be very helpful to have a technique that reduced the large number of indicators to a few key ones that explained most of the variation in all the original fields. Then it could be determined which factors are majorly affecting demographic indicators in The County of San Diego.**

- **A statistical technique called Factor Analysis has been very useful for this. Details of the calculations are not important at this time.**

- **Factor Analysis reduces all the original indicators to a very few key new factors that explain the as much of the variation in all the original indicators as possible.**

FACTOR ANALYSIS

- **It is important to understand that the new Factor Analysis factors are not named like the original indicators. The new Factor Analysis indicators are extracted from the information in the original indicators. This will be clarified with an example.**

- **The first new Factor Analysis factor explains the most variation in all the original indicators. The second Factor Analysis factor explains the second highest amount of variation in all the original indicators after removal of the first factor's effect. The third Factor Analysis factor explains the third highest amount of variation in all the original indicators after removal of the first and second factors' effect, etc.**

- **Furthermore, each of the new Factor Analysis factors are independent and has no correlation with each other Factor.**

- **You have to look at the results to determine what each new Factor Analysis factor represents.**

FACTOR ANALYSIS

- The following pages show the results of Factor Analysis on all of the Census Block Groups for the County of San Diego.
- The first page shows the results for Factor 1, which explains the highest amount of variation in all the original indicators.
- Correlations of the original indicators with the new Factor 1 are shown in descending order. Only indicators that show high positive correlations (+0.60 or more) or high negative correlations (-0.60 or less) are shown.
- You have to examine the indicators shown to determine what the first factor represents. For this factor, all of the high positive correlations are for original indicators that are highly correlated with ***Percent of Population Hispanic***, and all the high negative correlations are for original indicators that have high correlations with the White population.
- Consequently, the most important factor in the County of San Diego is <u>Hispanics in contrast with Whites</u>.

FACTOR 1 INDICATOR	FACTOR 1
Percent of Population 25 Years and Over Who Did Not Attain a High School Diploma	0.93009
Percent of Population Some Other Race Only	0.89901
Percent of Population Hispanic	0.89738
Percent of Population Minority	0.89719
Percent of Householders Some Other Race Only	0.89606
Percent of Householders Hispanic	0.89058
Percent of Occupied Housing Units With Greater Than 1 and Up to 2 Occupants Per Room	0.88254
Percent of Population 25 Years and Over Who Had Attained a Nursery School to an 8th Grade Education	0.87153
Percent of Households That Are 2 Or More Persons And an Other Family	0.84097
Percent of Population Foreign Born and Not a Citizen	0.84064
Percent of Households That Are 2 Or More Persons And an Other Family With Own Children Under 18	0.82232
Percent of Households That Are Linguistically Isolated and the Household Language is Spanish	0.82174
Percent of Population 25 Years and Over Who Had Attained a 9th-12th Grade Education But Did Not Graduate High School	0.80919
Percent of Occupied Housing Units With Greater Than 2 Occupants Per Room	0.79359
Percent of Population 25 Years and Over Who Had No Schooling completed	0.75132
Percent of Population Less Than 18 Years of Age	0.72959
Average Household Size for Occupied Housing Units	0.72169
Percent of Employed Civilian Population 16 Years and Over With Building/Ground Cleaning/Maintenance Occupations	0.71905
Percent of Households with 1999 Income Below the Poverty Level	0.68699
Percent of Population 3 Years and Over Who Were Enrolled in Nursery School Through Grade 12	0.66519
Percent of Employed Civilian Population 16 Years and Over With Production Occupations	0.64941
Percent of Population 3 Years and Over Who Were Enrolled in Grades 1-8	0.64420
Percent of Householders Two Or More Races	0.60749
Percent of Households That Are 2 Or More Persons And an Other Family With No Own Children Under 18	0.60697
Percent of Employed Civilian Population 16 Years and Over With Mgmt/Business/Financial Operations Occupations	-0.65435
Percent of Population 25 Years and Over Who Attained a Higher than Bachelor's Degree	-0.65686
Median Age for Population	-0.65991
Per Capita Income in 1999	-0.70593
Percent of Employed Civilian Population 16 Years and Over With Professional/Related Occupations	-0.71848
Percent of Population 25 Years and Over Who Attained a Bachelor's Degree Only	-0.73350
Percent of Population Native and Born in the United States	-0.77326
Percent of Householders White Only	-0.80405
Percent of Population White Only	-0.81464
Percent of Occupied Housing Units With 1 or Less Occupants Per Room	-0.86268

FACTOR ANALYSIS

Results for Factors 2, 3, 4, 5 and 6 are presented on the next pages. Examine the correlations shown to see if you agree with this analysis.

- **<u>Factor 2</u>, which can be interpreted as the second most important factor in the County of San Diego, represents <u>Owner-Occupied Housing Units in contrast with Renter-Occupied Housing Units</u>.**

- **<u>Factor 3</u>, which can be interpreted as the third most important factor in the County of San Diego, represents <u>Those in the Labor Force in contrast with Retirees</u>.**

- **<u>Factor 4</u>, which can be interpreted as the fourth most important factor in the County of San Diego, represents <u>College Graduates in contrast with High School Only Graduates</u>.**

- **<u>Factor 5</u>, which can be interpreted as the fifth most important factor in the County of San Diego, represents <u>Those in the Armed Forces</u>.**

FACTOR ANALYSIS

- **<u>Factor 6</u>, which can be interpreted as the sixth most important factor in the County of San Diego, appears to be <u>Rural Areas in contrast with more urban areas with Asian Population</u>.**

- **High correlations decrease with each factor because once Factor 1 has been determined, any remaining Factors can only explain the variation not explained by Factor 1. Similarly Factor 6 can only explain the variation not explained by Factors 1, 2, 3, 4 and 5.**

- **For the County of San Diego, any thorough environmental justice analysis should definitely look at: (1) Hispanics, (2) Renters and Home Owners, (3) Those in the Armed Forces, (4) Retirees, and (5) Those in the Civilian Labor Force.**

- **The same Factor Analysis was done for all Census Tracts in San Diego County. Results were similar.**

FACTOR 2 INDICATOR	FACTOR 2
Percent of Households That Are 1 Person	0.81620
Percent of Occupied Housing Units That Are Renter-Occupied	0.80535
Percent of Occupied Housing Units With 1 Vehicle Available	0.79765
Percent of Population in Renter-Occupied Housing Units	0.78628
Percent of Households That Are 2 Or More Persons And a Nonfamily Household	0.68764
Percent of Housing Units Where the Number of Units in the Structure is 10 to 19	0.64892
Percent of Population in Occupied Housing Units Where the Number of Units in the Structure is 10 to 19	0.62208
Percent of Occupied Housing Units Where House Heating Fuel Is Electricity	0.60376
Median Household Income in 1999	-0.60196
Median Number of Rooms in Renter-Occupied Housing Units	-0.60737
Percent of Households That Are 2 Or More Persons And a Married Couple Family With No Own Children Under 18	-0.69407
Percent of Households That Are 2 Or More Persons And a Married Couple Family With Own Children Under 18	-0.70195
Percent of Occupied Housing Units With 3 Vehicles Available	-0.71639
Percent of Population in Owner-Occupied Housing Units	-0.80192
Percent of Households That Are 2 Or More Persons	-0.80529
Median Number of Rooms in Housing Units	-0.80934
Percent of Occupied Housing Units That Are Owner-Occupied	-0.81039
Percent of Population in Occupied Housing Units Where the Number of Units in the Structure is 1 Detached	-0.83521
Percent of Housing Units Where the Number of Units in the Structure is 1 Detached	-0.84695
Percent of Households That Are 2 Or More Persons And a Family	-0.86330
Percent of Households That Are 2 Or More Persons And a Married Couple Family	-0.93385

FACTOR 3 INDICATOR	FACTOR 3
Percent of Population 16 Years and Over Who Were in the Labor Force	0.847171
Percent of Population 16 Years and Over Who Were in the Civilian Labor Force	0.737885
Percent of Population 16 Years and Over Who Were in the Civilian Labor Force and Employed	0.711837
Percent of Population 18-64 Years of Age	0.650606
Percent of Population Greater Than 64 Years of Age	-0.815254
Percent of Population 16 Years and Over Who Were Not in the Labor Force	-0.826626

FACTOR 4 INDICATOR	FACTOR 4
Median Value for Owner-Occupied Housing Units	0.598799
Percent of Population 25 Years and Over Who Attained a Higher than Bachelor's Degree	0.577068
Per Capita Income in 1999	0.500563
Percent of Employed Civilian Population 16 Years and Over With Office/Administrative Support Occupations	-0.575729
Percent of Population 25 Years and Over Who Attained a High School Diploma Only	-0.630675
Percent of Population 25 Years and Over Who Attained a College Education But Did Not Receive a Bachelor's Degree	-0.647626

FACTOR 5 INDICATOR	FACTOR 5
Percent of Population Female	0.731055
Percent of Workers 16 Years and Over Who Travel to Work by Car, Truck, or Van	0.604170
Median Year Housing Unit Structure Was Built	0.582429
Percent of Population Male	-0.588363
Percent of Workers 16 Years and Over Who Travel to Work by Walking	-0.652667
Percent of Population 16 Years and Over Who Were in the Armed Forces	-0.768359
Percent of Population in Group Quarters	-0.782671

FACTOR 6 INDICATOR	FACTOR 6
Percent of Occupied Housing Units Where House Heating Fuel Is Bottled/Tank/LP Gas	0.604365
Percent of Occupied Housing Units Where House Heating Fuel Is Wood	0.544502
Percent of Employed Civilian Population 16 Years and Over Who Worked in the Construction Industry	0.515745
Percent of Workers 16 Years and Over Whose Travel Time to Work Was 15-29 Minutes	-0.505100
Percent of Population Foreign Born and a Naturalized Citizen	-0.571634
Percent of Householders Asian Only	-0.651999
Percent of Population Asian Only	-0.667199

OUTLINE OF TESTING

After determining which indicators are important, testing can be done by:

1. **Calculating the mean and median demographic indicator for Census Block Groups that contain either Landfills or Large Transfer Stations, and the mean and median demographic indicator for all Block Groups in the County and State.**

2. **Comparing the mean and median for Block Groups that either have Landfills or Large Transfer Stations, and the mean and median for all Block Groups in the County and State.**

The following graphs examine the indicators of:

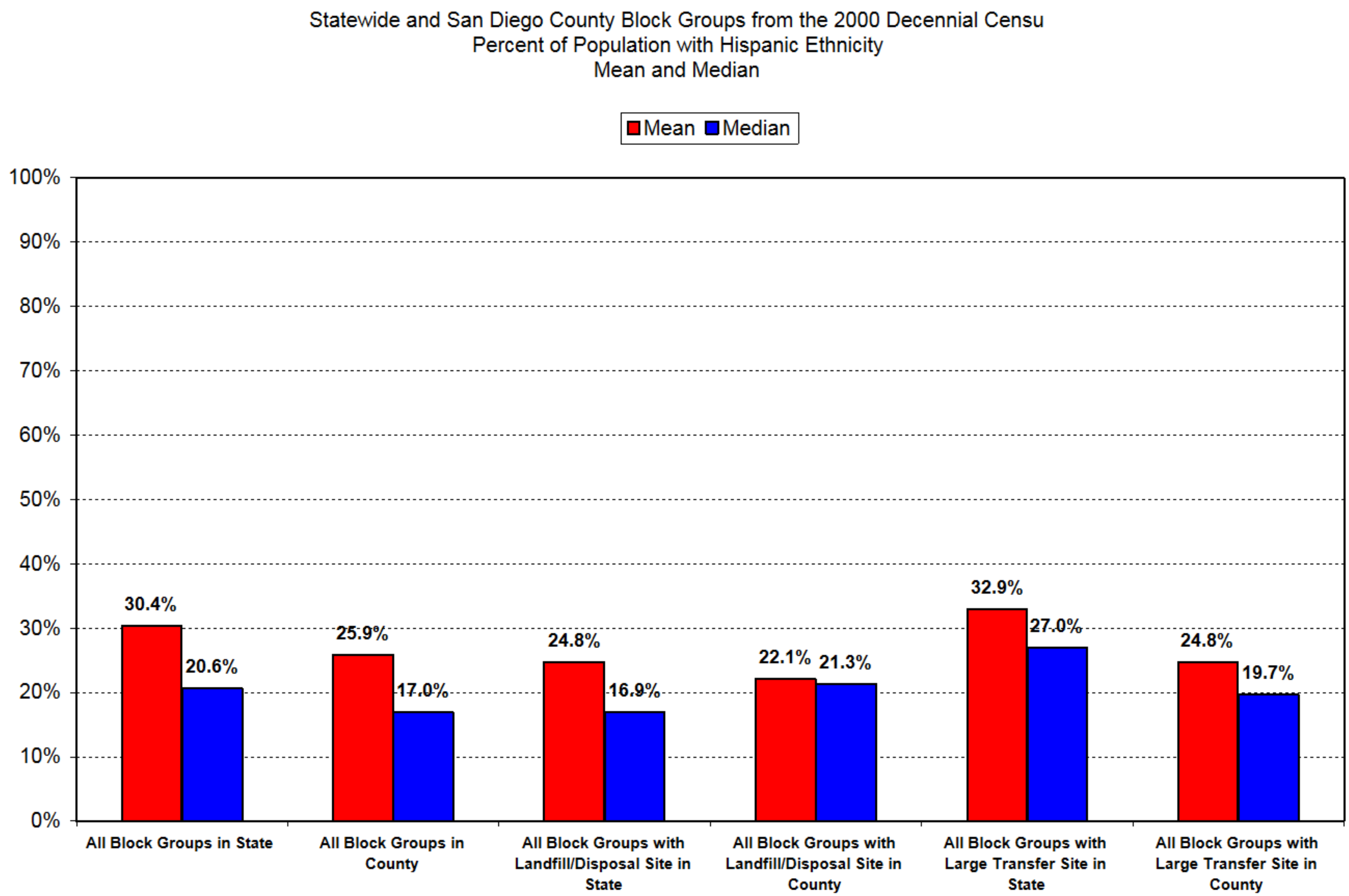
1. **Percent of Hispanic Ethnicity**
2. **Percent of Renter-Occupied Housing Units**
3. **Percent of Asian Only Race**
4. **Median Household Income**
5. **Percent of Households Below Poverty Level.**

OUTLINE OF TESTING

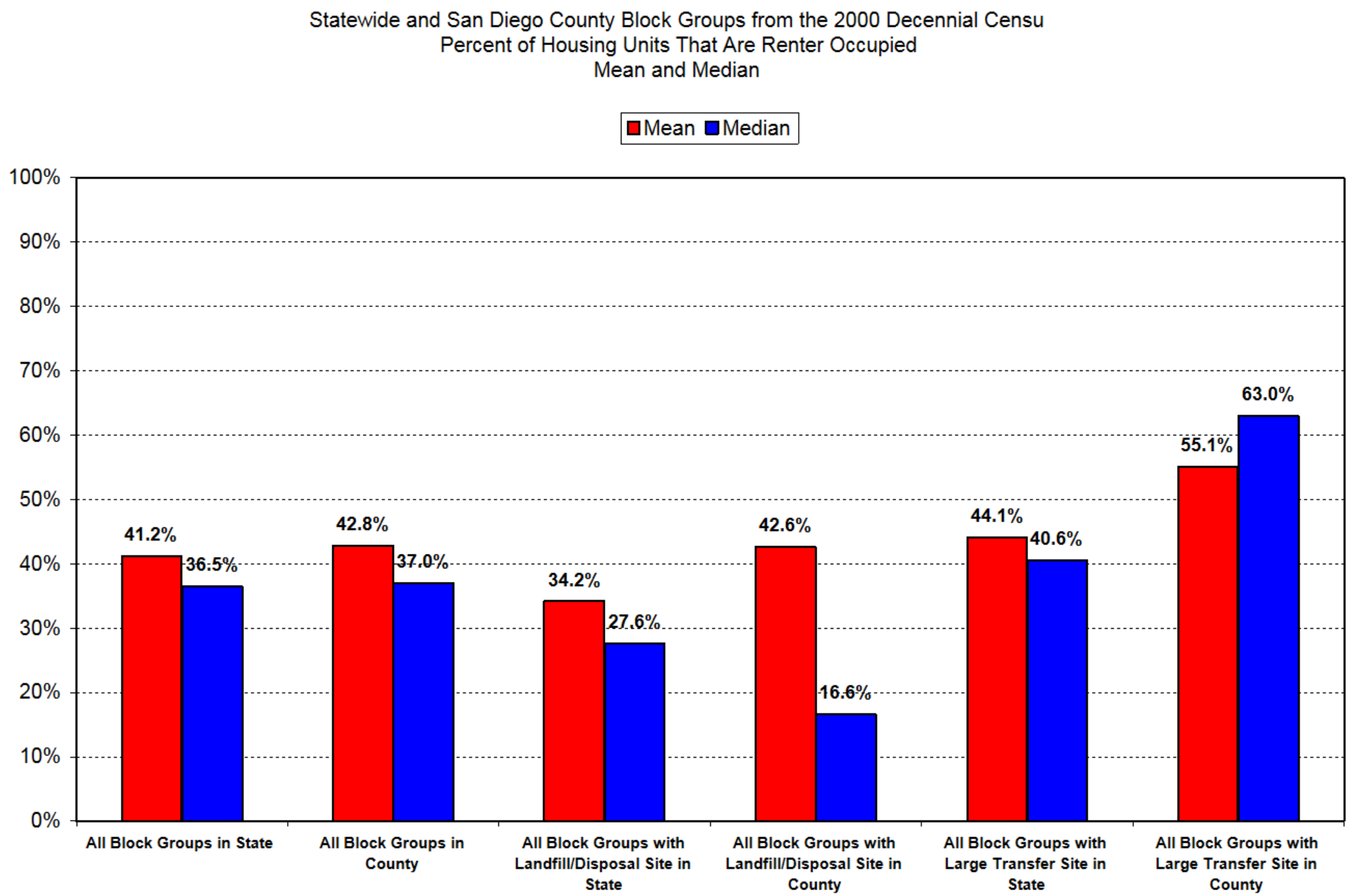
The following graphs compare these numbers for Census Block Groups in the County of San Diego to the entire State. Please keep in mind that there are only 6 Block Groups that have Landfills in The County of San Diego and 8 Block Groups that have Large Transfer Stations in The County of San Diego.

Some observations are:

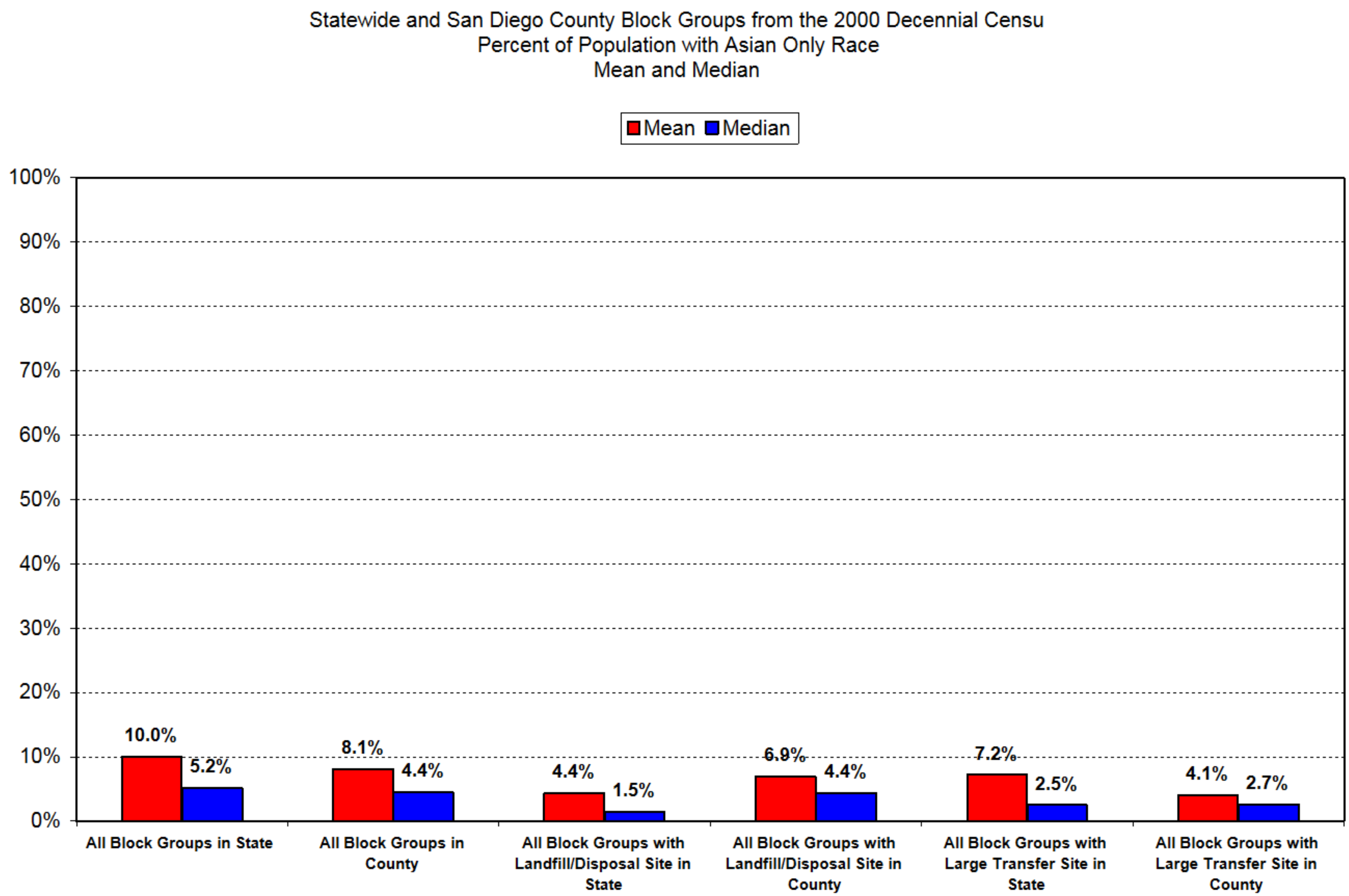
1. **Block Groups where Landfills and Large Transfer Stations are located in San Diego County do not have high concentrations of Hispanics, as compared to the entire State.**
2. **Large Transfer Stations tend to be located in areas with concentrations of renter-occupied units in San Diego County.**
3. **Landfills tend to be located in higher income areas in San Diego County.**

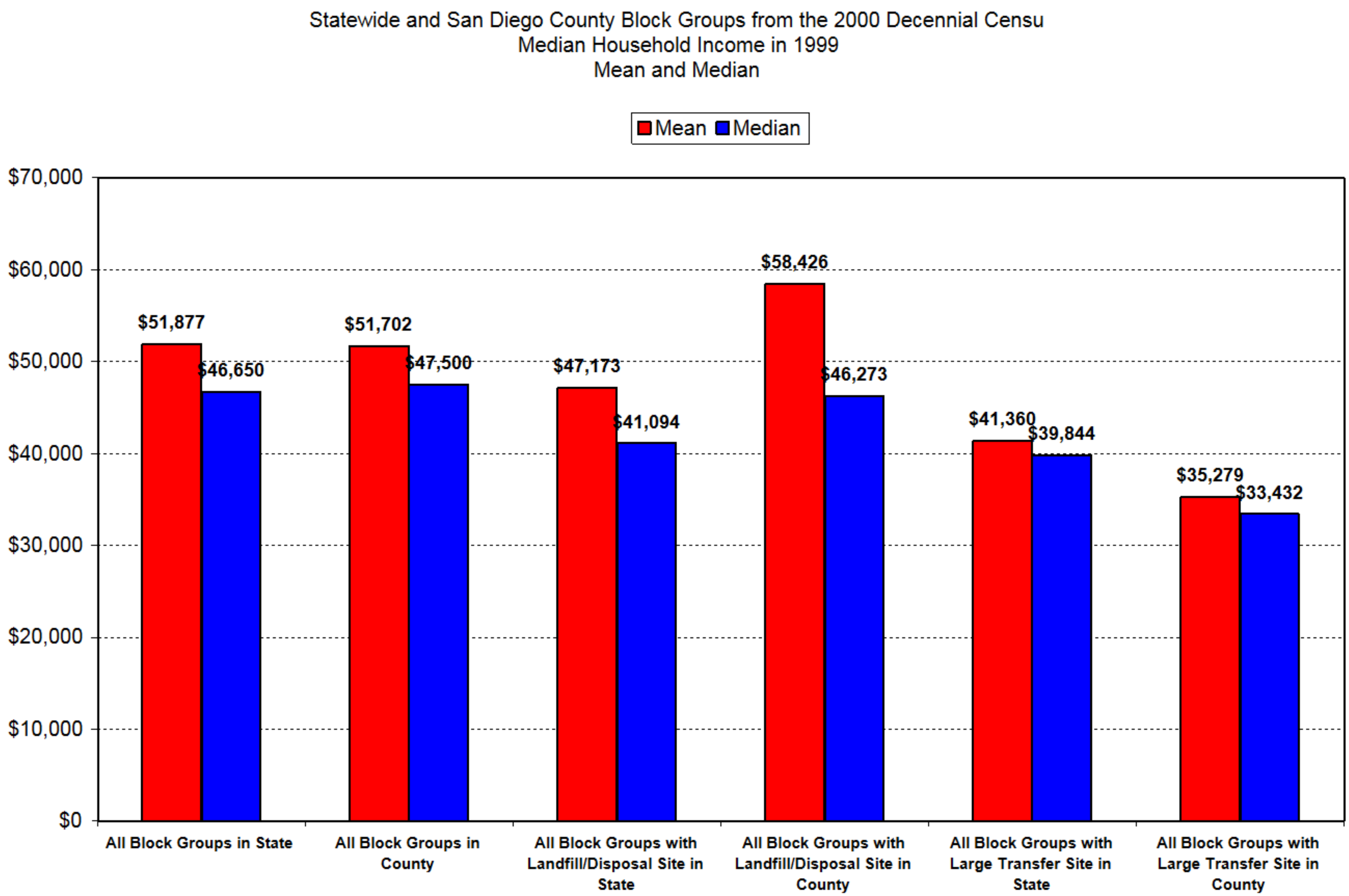


Statewide and San Diego County Block Groups from the 2000 Decennial Censu
Percent of Population with Hispanic Ethnicity
Mean and Median
Mean
Median
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
30.4%
20.6%
25.9%
17.0%
24.8%
16.9%
22.1%
21.3%
32.9%
27.0%
24.8%
19.7%
All Block Groups in State
All Block Groups in County
All Block Groups with Landfill/Disposal Site in State
All Block Groups with Landfill/Disposal Site in County
All Block Groups with Large Transfer Site in State
All Block Groups with Large Transfer Site in County

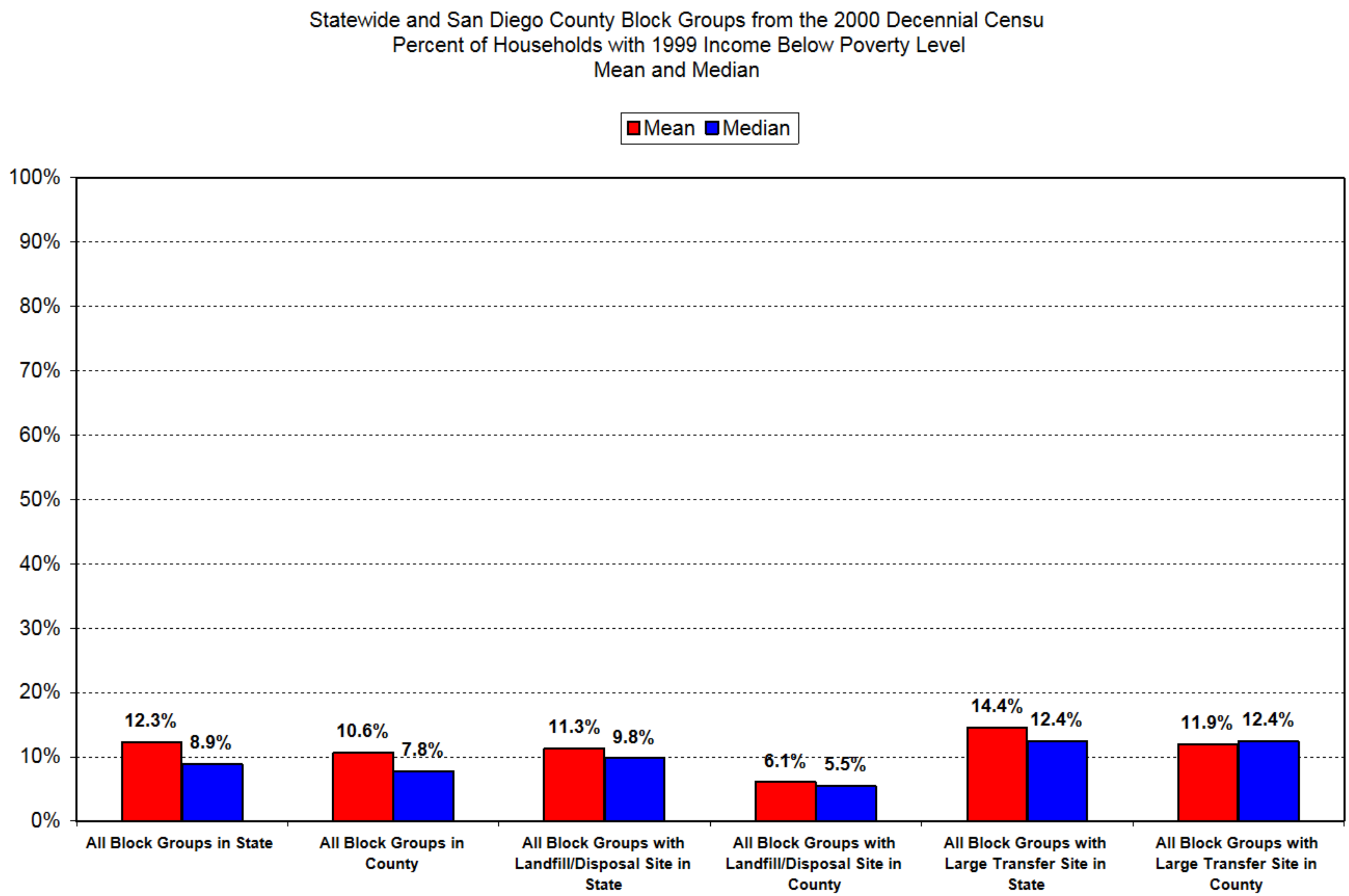


Statewide and San Diego County Block Groups from the 2000 Decennial Censu
Percent of Housing Units That Are Renter Occupied
Mean and Median
Mean
Median
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
41.2%
36.5%
42.8%
37.0%
34.2%
27.6%
42.6%
16.6%
44.1%
40.6%
55.1%
63.0%
All Block Groups in State
All Block Groups in County
All Block Groups with Landfill/Disposal Site in State
All Block Groups with Landfill/Disposal Site in County
All Block Groups with Large Transfer Site in State
All Block Groups with Large Transfer Site in County


Statewide and San Diego County Block Groups from the 2000 Decennial Censu
Percent of Population with Asian Only Race
Mean and Median
Mean
Median
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
10.0%
5.2%
8.1%
4.4%
4.4%
1.5%
6.9%
4.4%
7.2%
2.5%
4.1%
2.7%
All Block Groups in State
All Block Groups in County
All Block Groups with Landfill/Disposal Site in State
All Block Groups with Landfill/Disposal Site in County
All Block Groups with Large Transfer Site in State
All Block Groups with Large Transfer Site in County

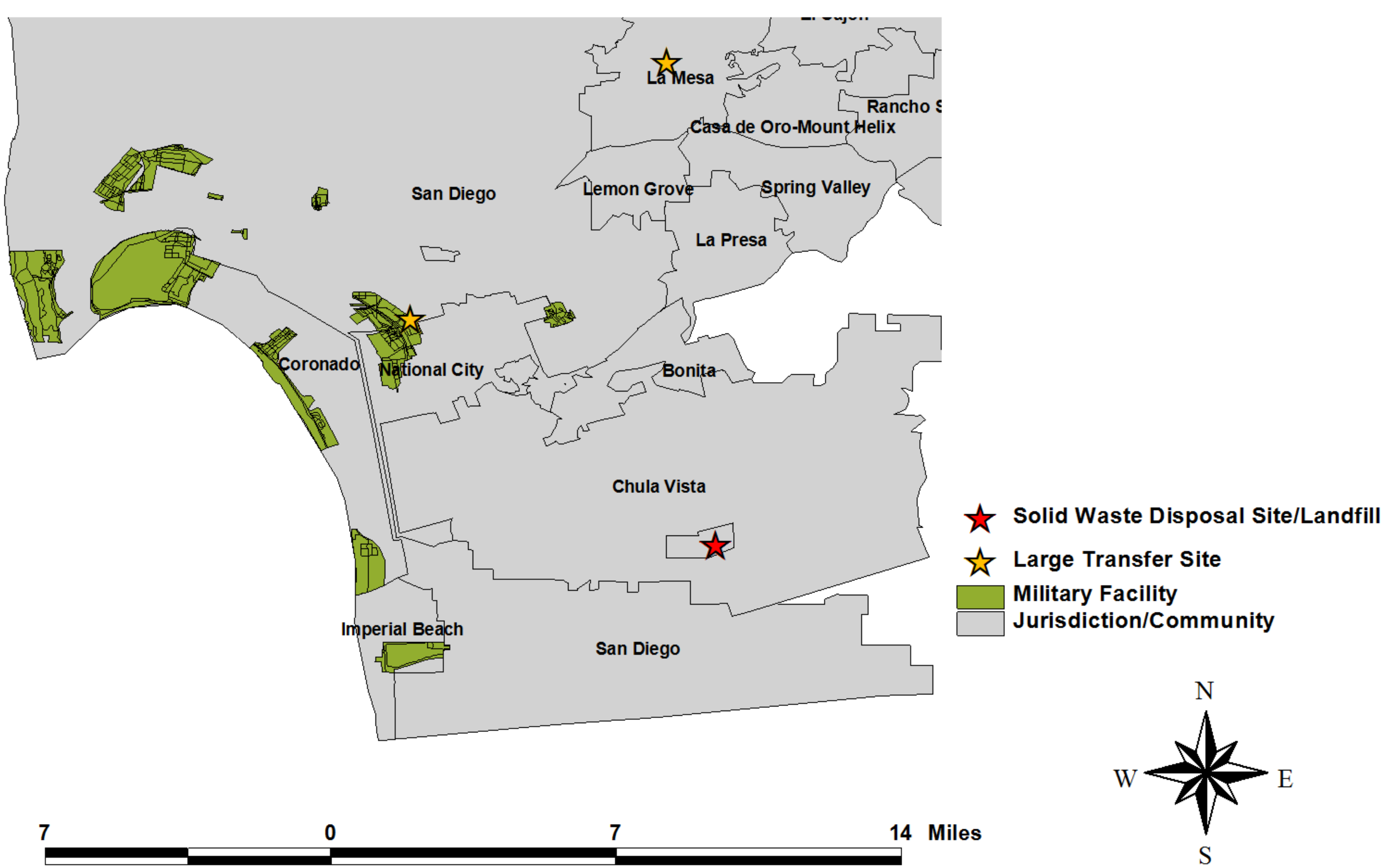


Statewide and San Diego County Block Groups from the 2000 Decennial Censu
Median Household Income in 1999
Mean and Median
Mean
Median
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
$51,877
$46,650
$51,702
$47,500
$47,173
$41,094
$58,426
$46,273
$41,360
$39,844
$35,279
$33,432
All Block Groups in State
All Block Groups in County
All Block Groups with Landfill/Disposal Site in State
All Block Groups with Landfill/Disposal Site in County
All Block Groups with Large Transfer Site in State
All Block Groups with Large Transfer Site in County

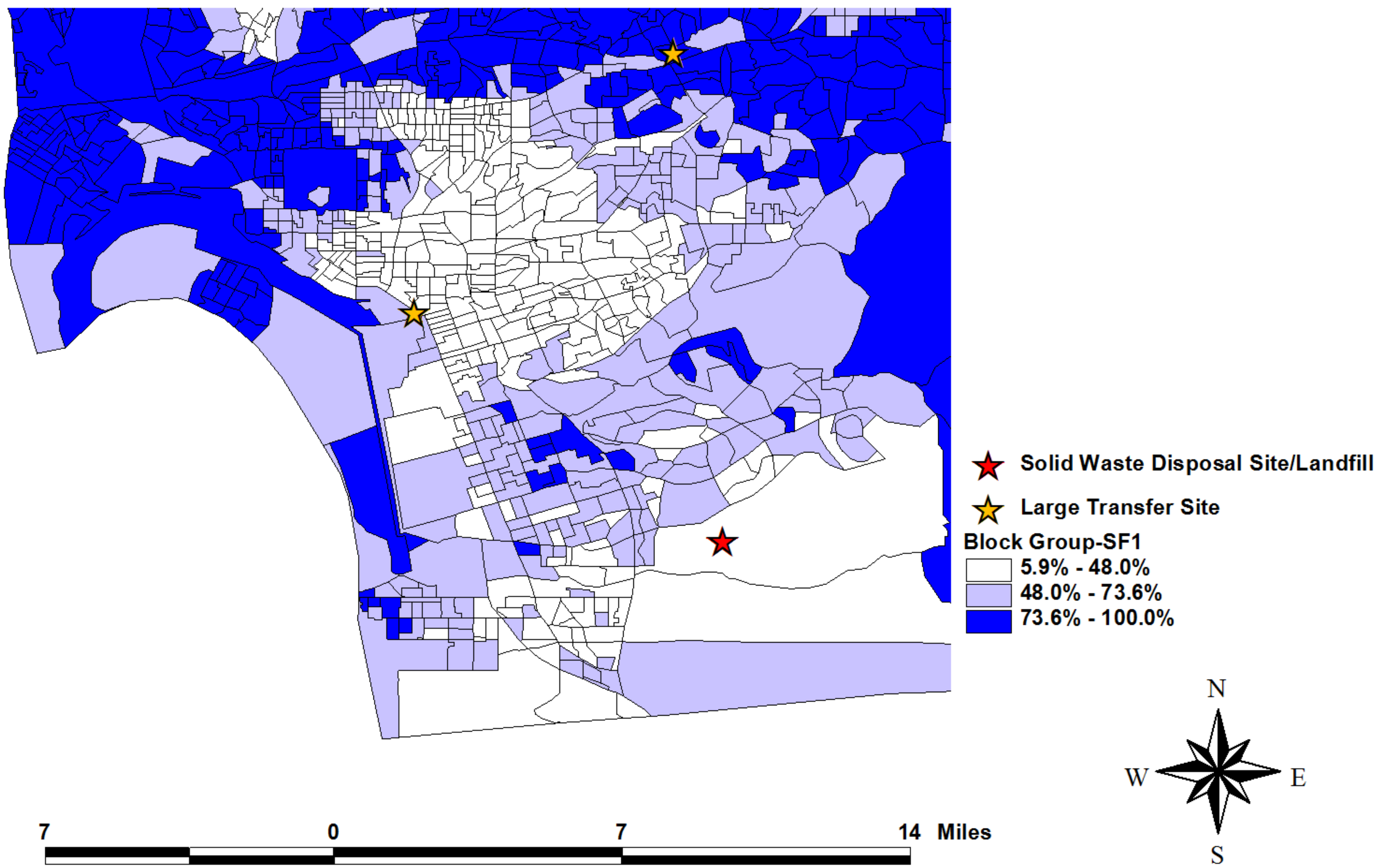


Statewide and San Diego County Block Groups from the 2000 Decennial Censu
Percent of Households with 1999 Income Below Poverty Level
Mean and Median
Mean
Median
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
12.3%
8.9%
10.6%
7.8%
11.3%
9.8%
6.1%
5.5%
14.4%
12.4%
11.9%
12.4%
All Block Groups in State
All Block Groups in County
All Block Groups with Landfill/Disposal Site in State
All Block Groups with Landfill/Disposal Site in County
All Block Groups with Large Transfer Site in State
All Block Groups with Large Transfer Site in County

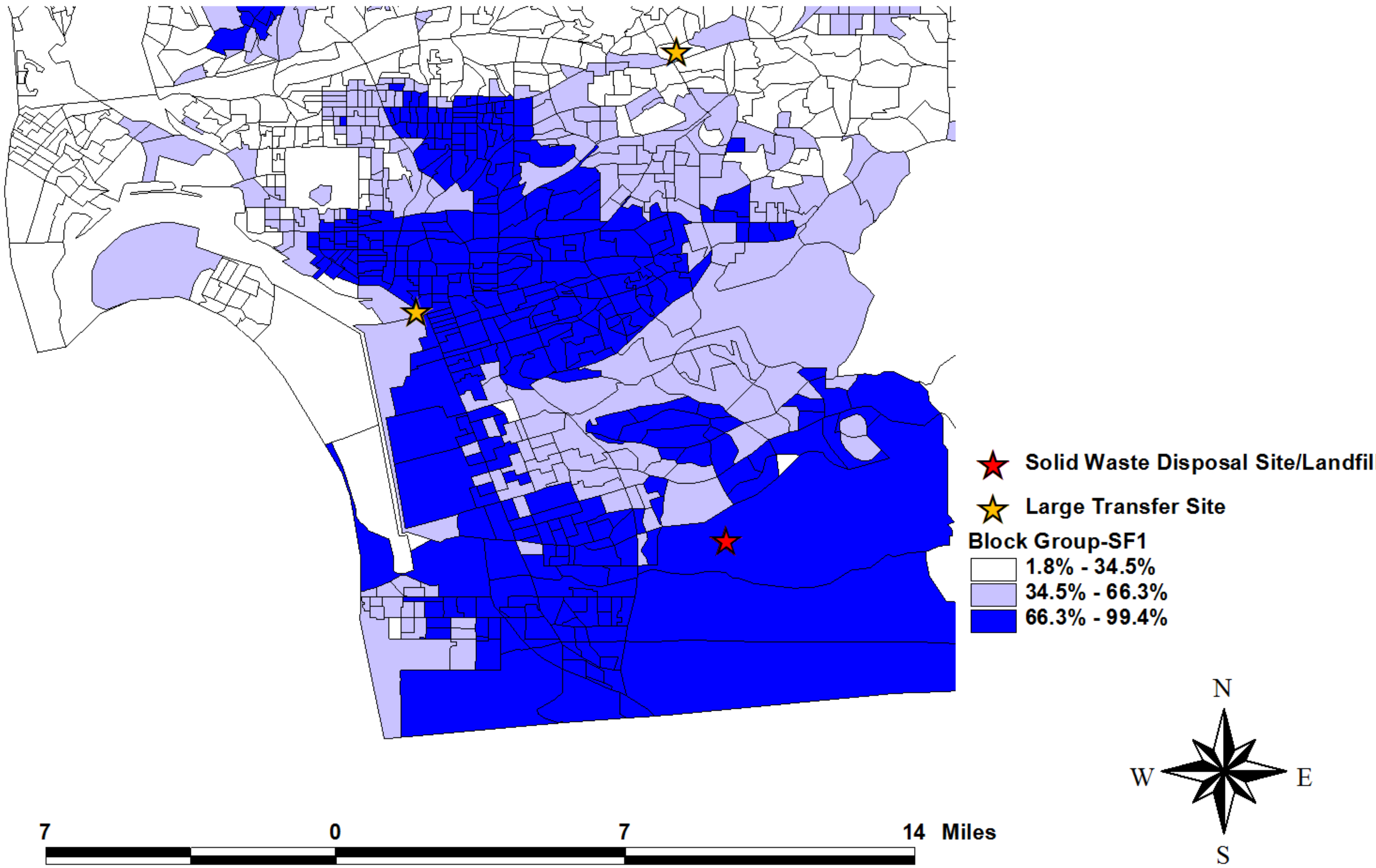
Coronado-National City Area-Active Landfills/Large Transfer Sites and Military Facilities and Jurisdictions/Community Names Based on CIWMB SWIS Database and 2000 Decennial Census Summary Files



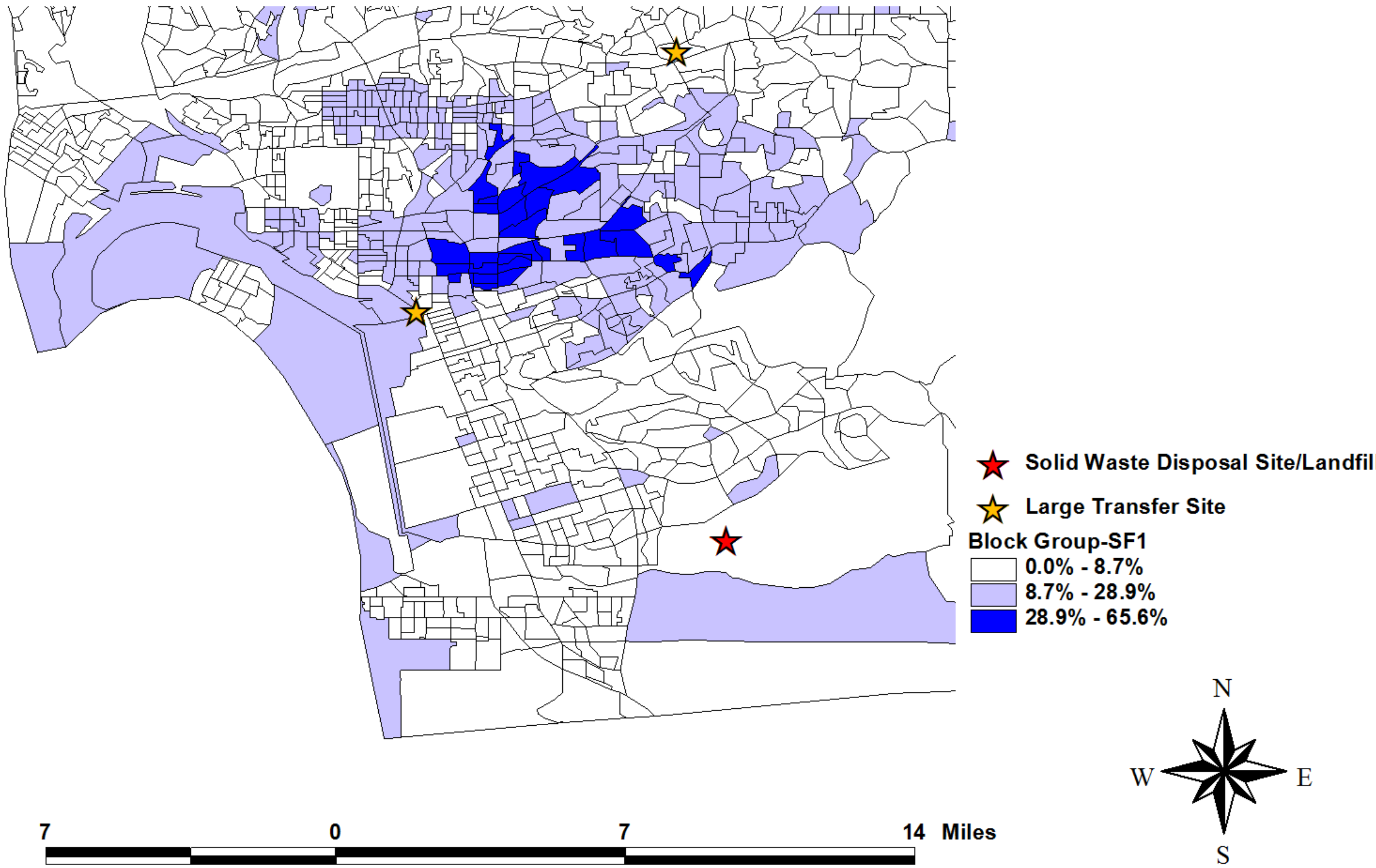
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population with White Only Race by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



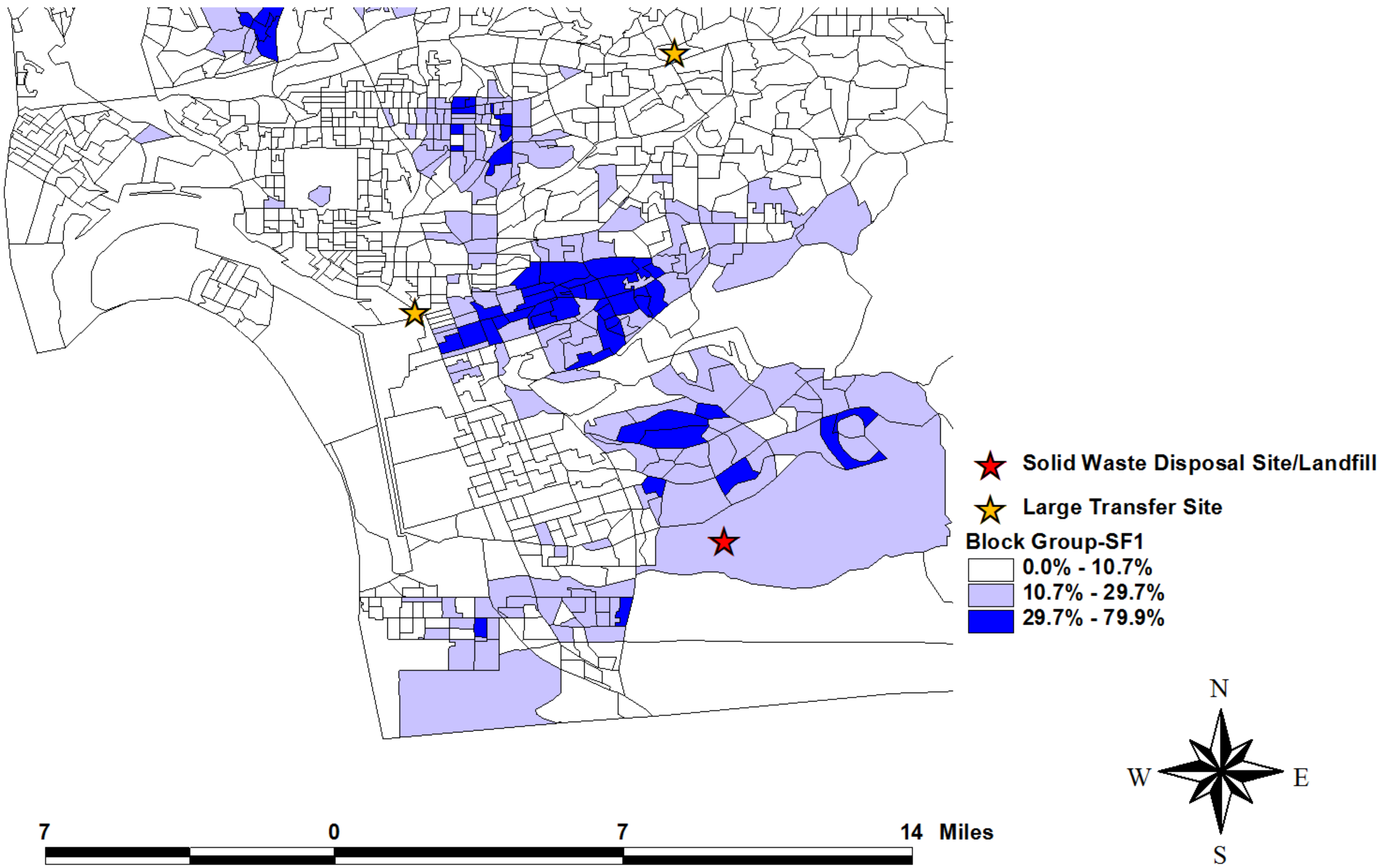
Coronado-National City Area-Active Landfills/Large Transfer Sites and
Percent of Population Minority (Non-White and/or Hispanic) by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



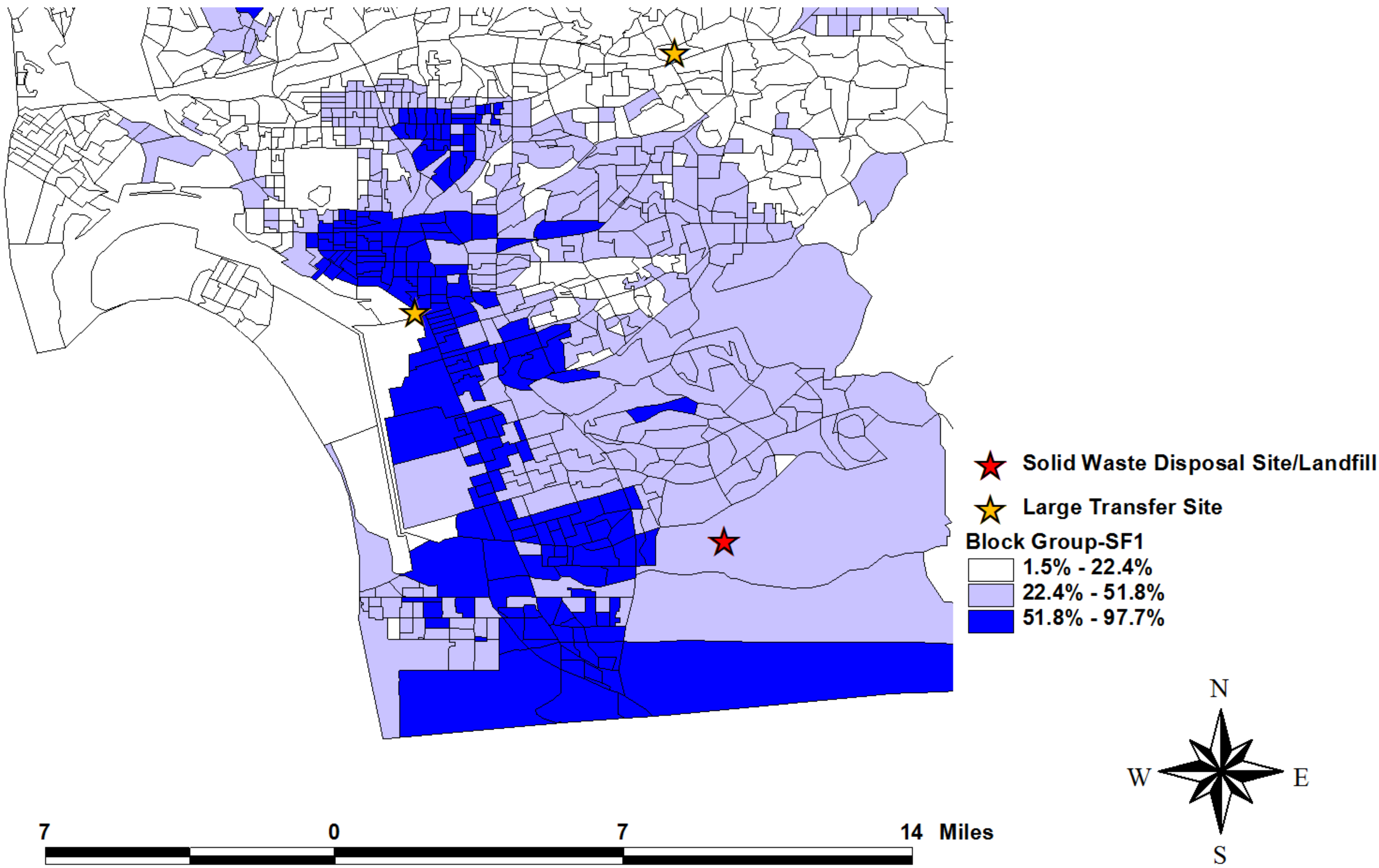
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population with Black Only Race by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



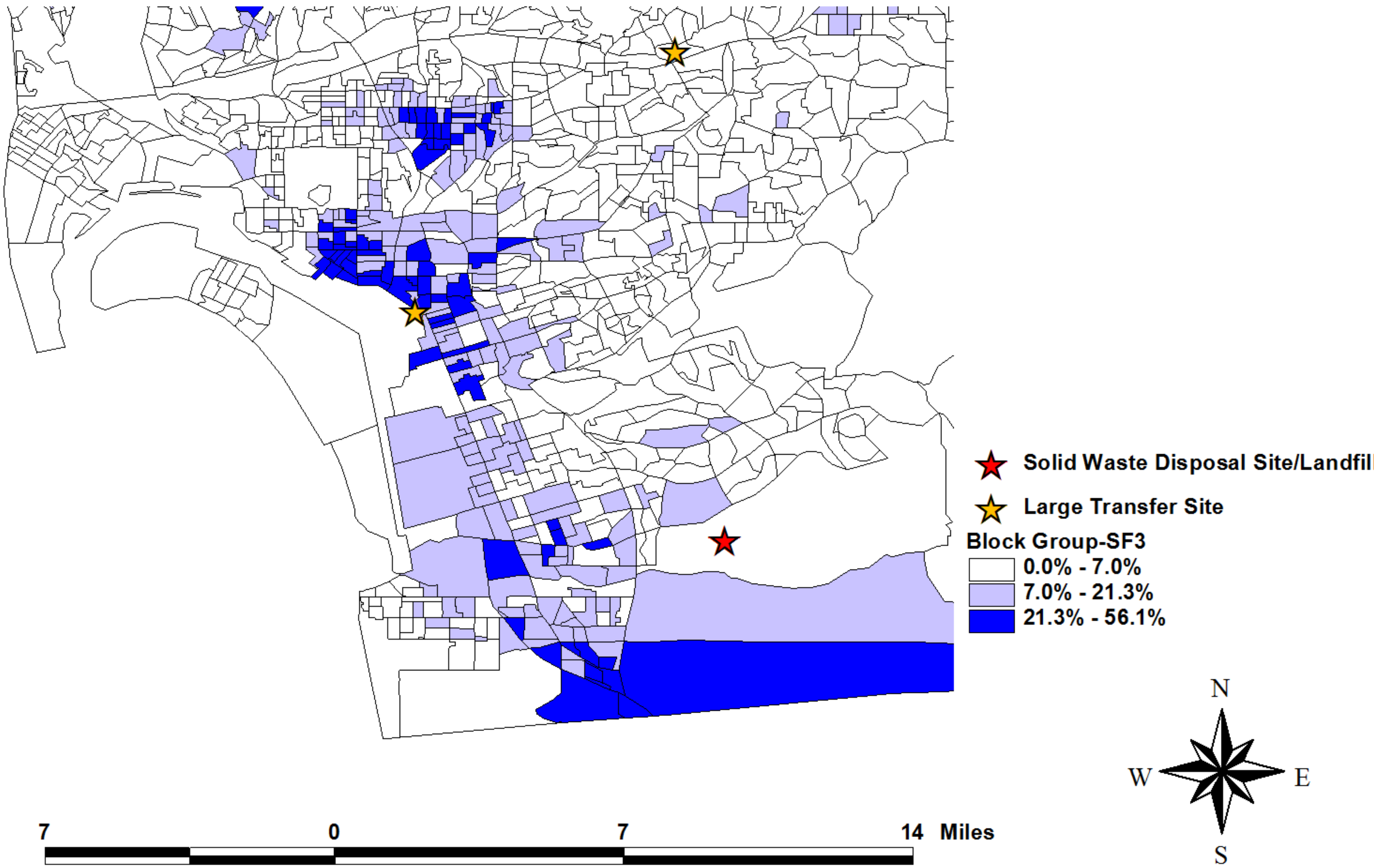
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population with Asian Only Race by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



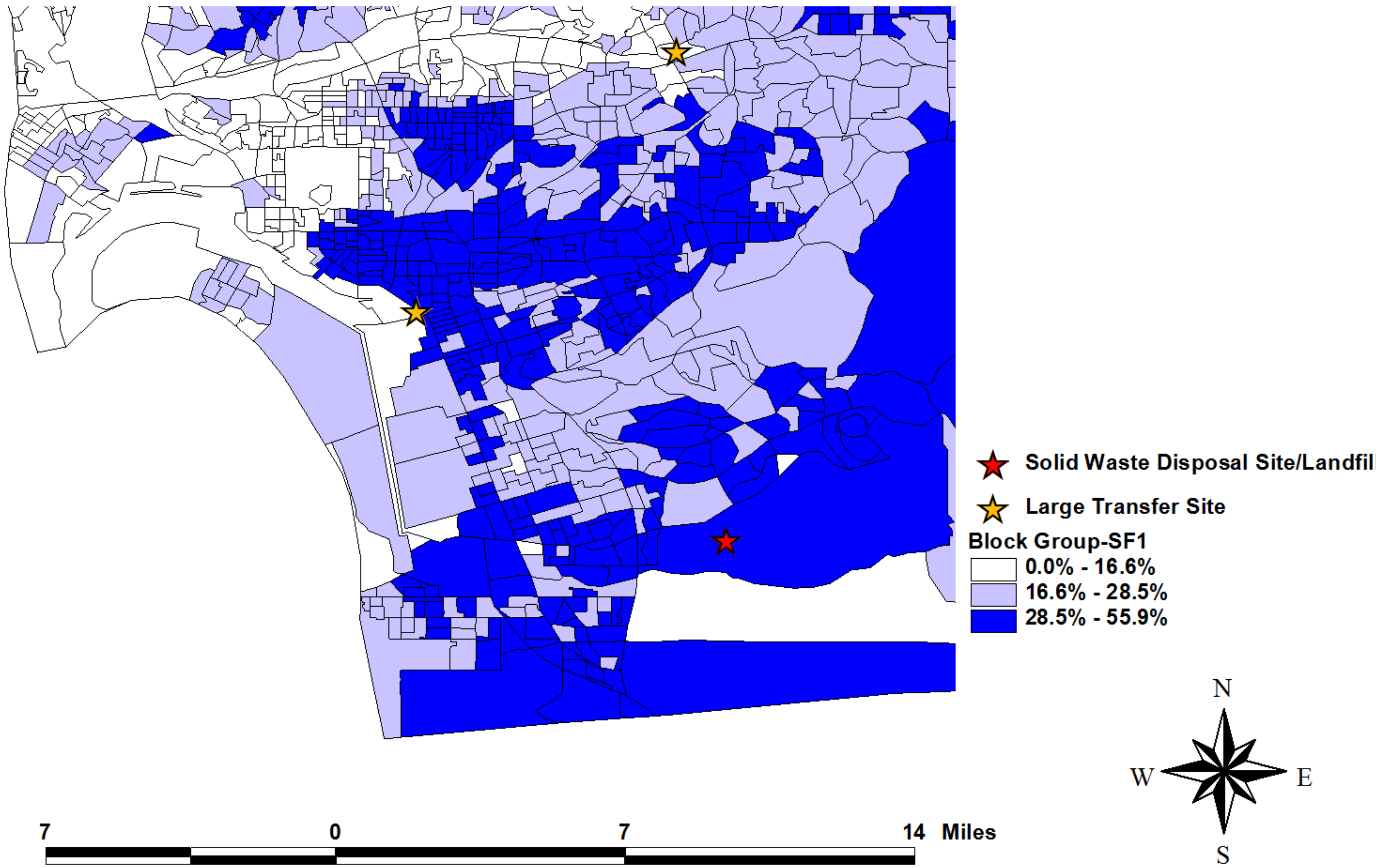
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population with Hispanic Ethnicity by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



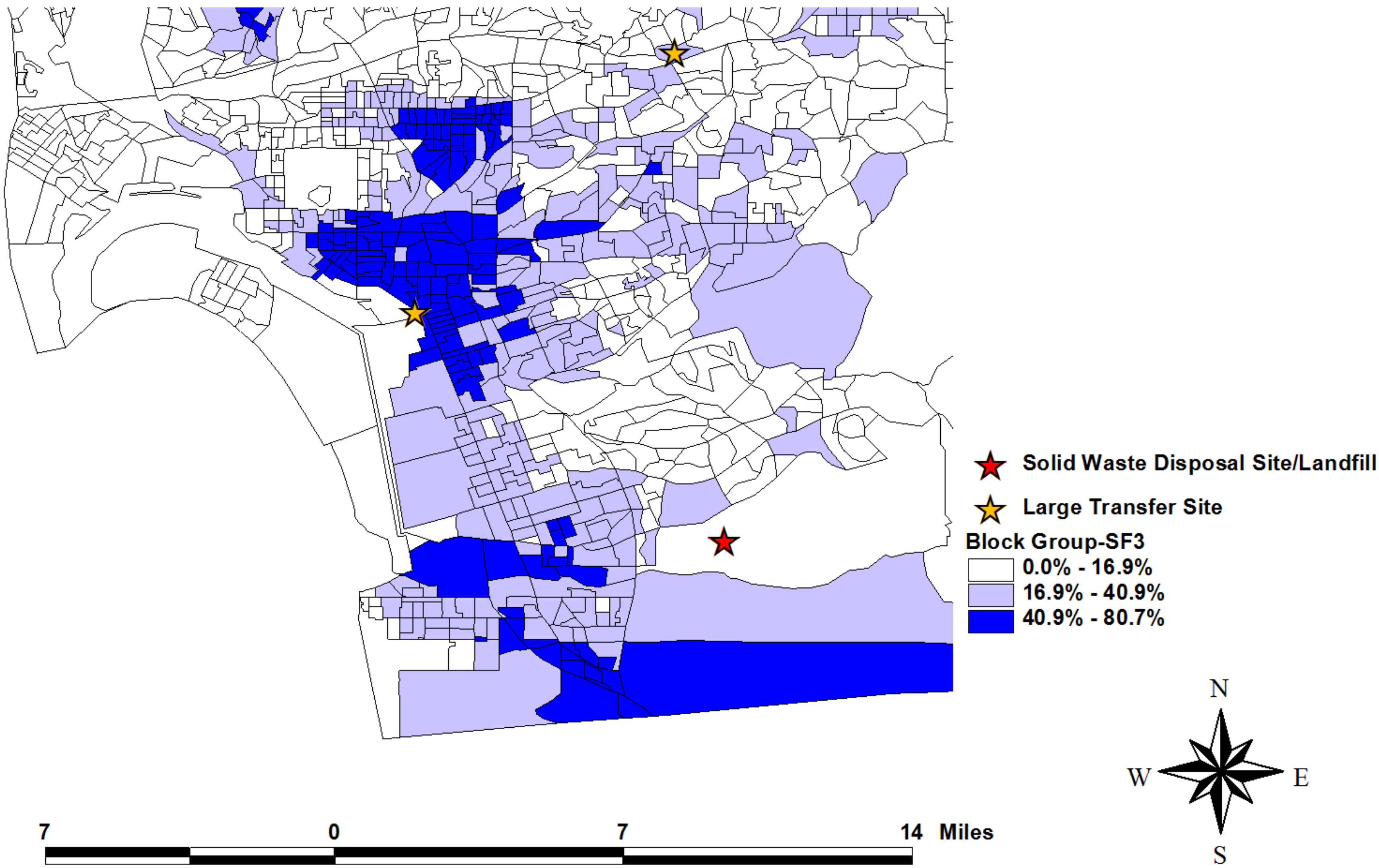
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Households That Speak Spanish and Are Linguistically Isolated by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



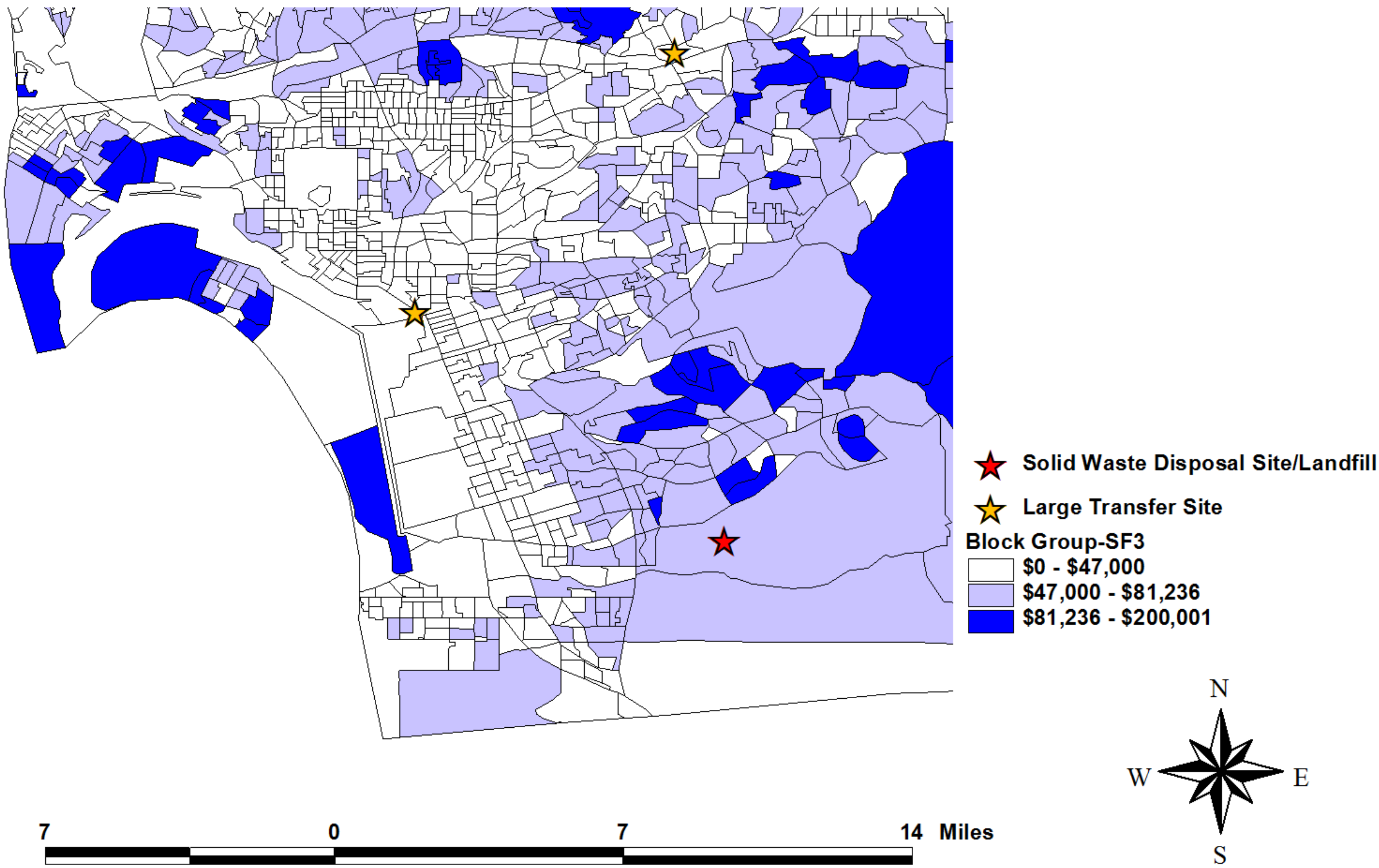
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population Less Than 18 Years of Age by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



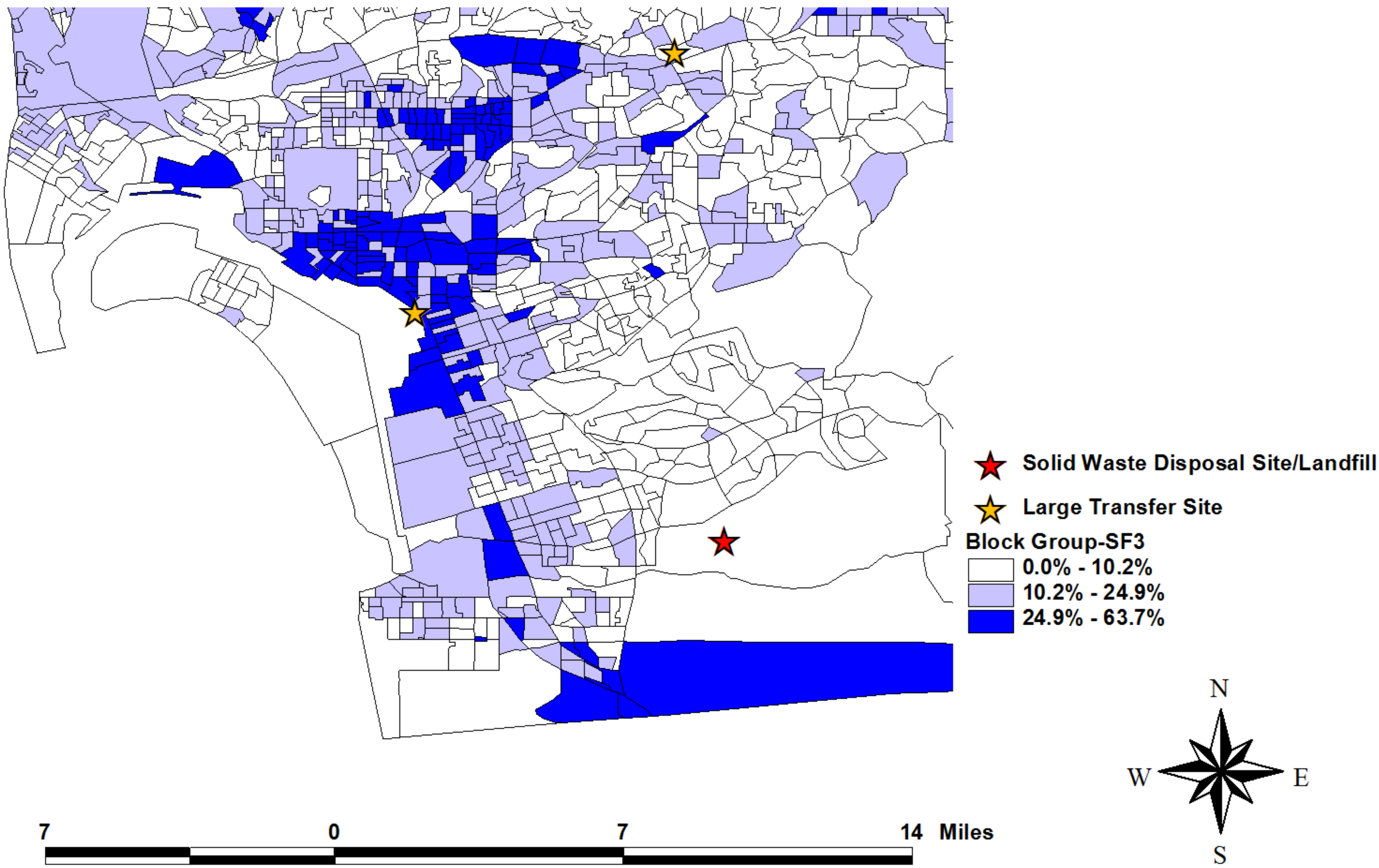
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population 25 and Over with No High School Diploma by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



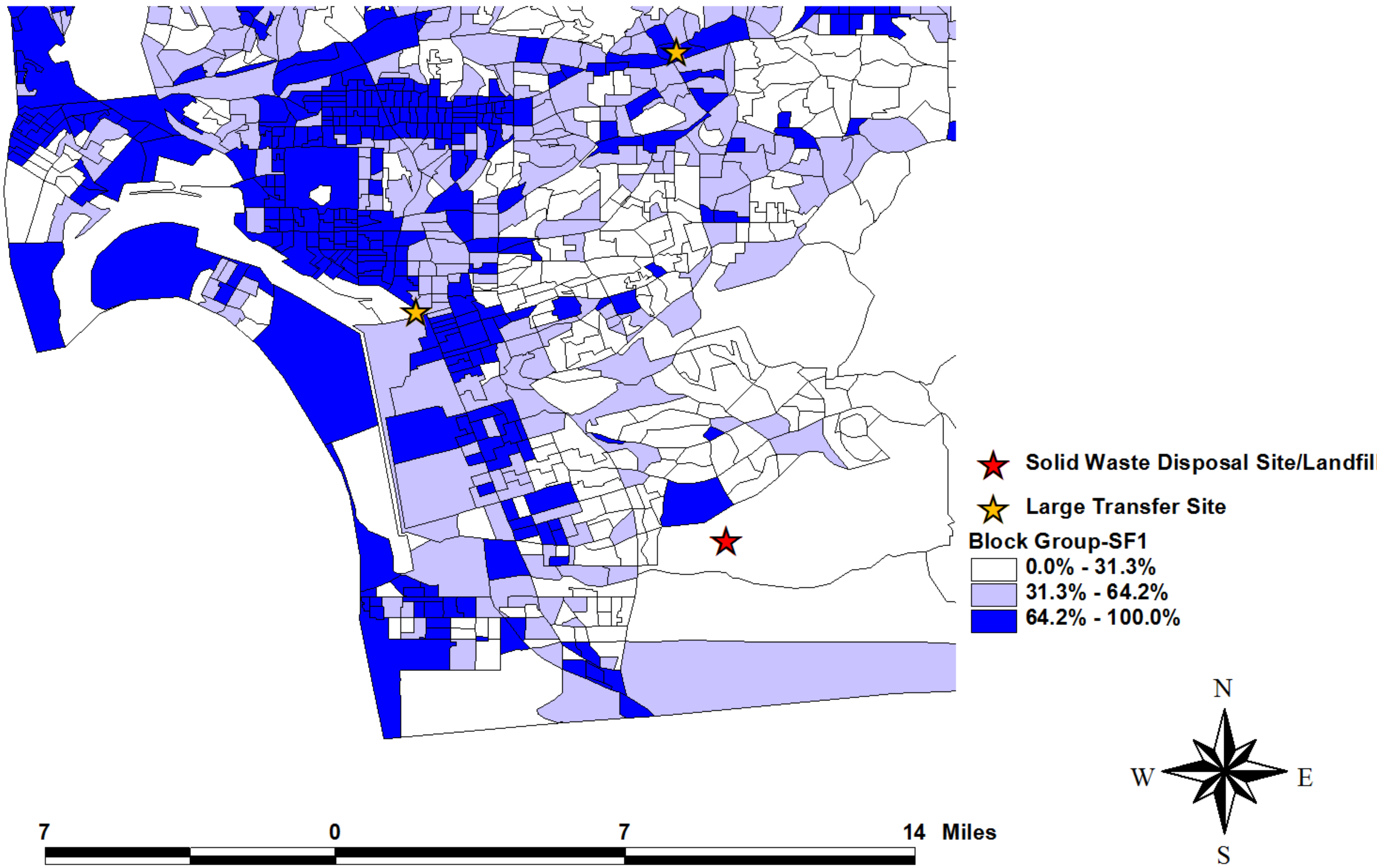
Coronado-National City Area-Active Landfills/Large Transfer Sites and Median Household Income in 1999 by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



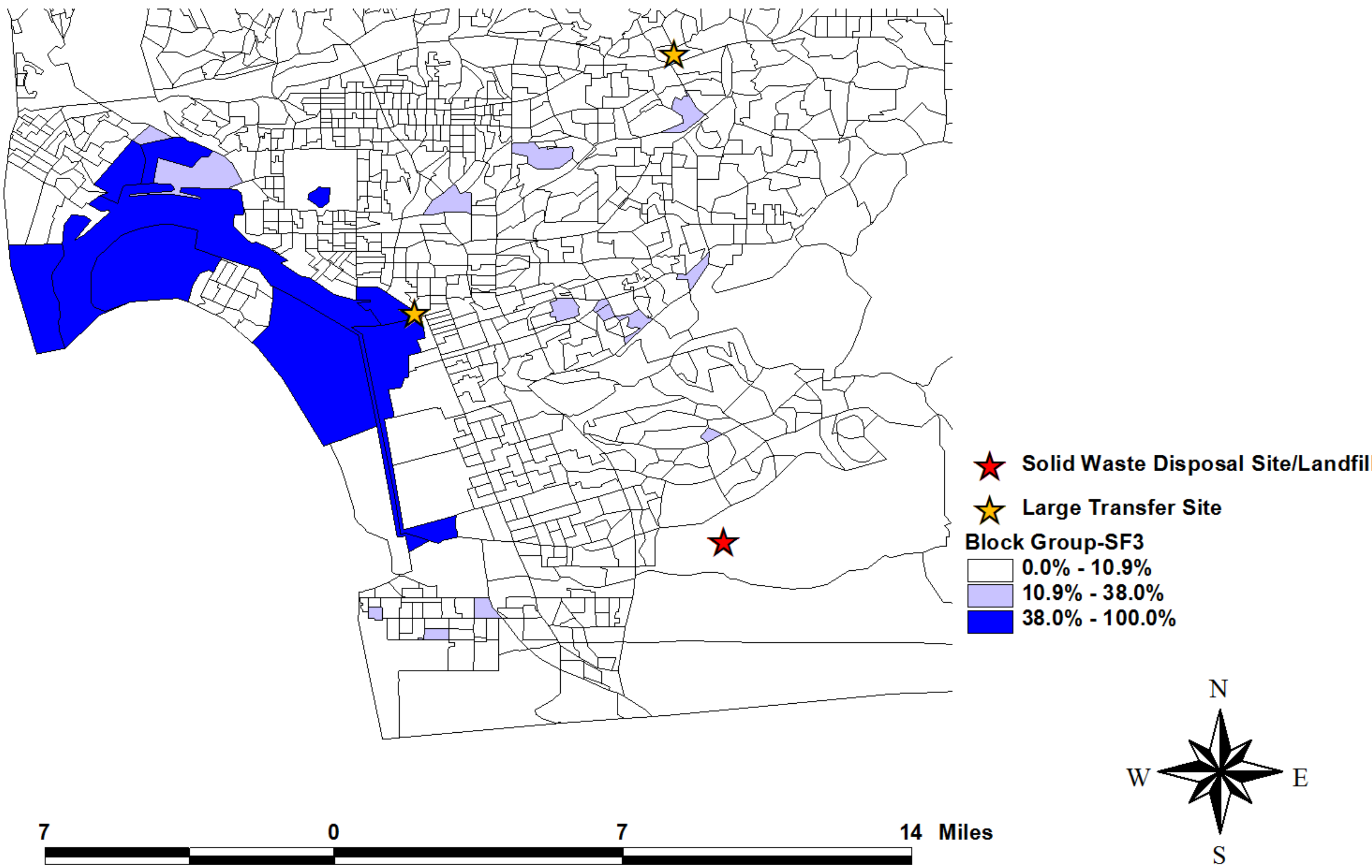
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Households with 1999 Income Below Poverty Level by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



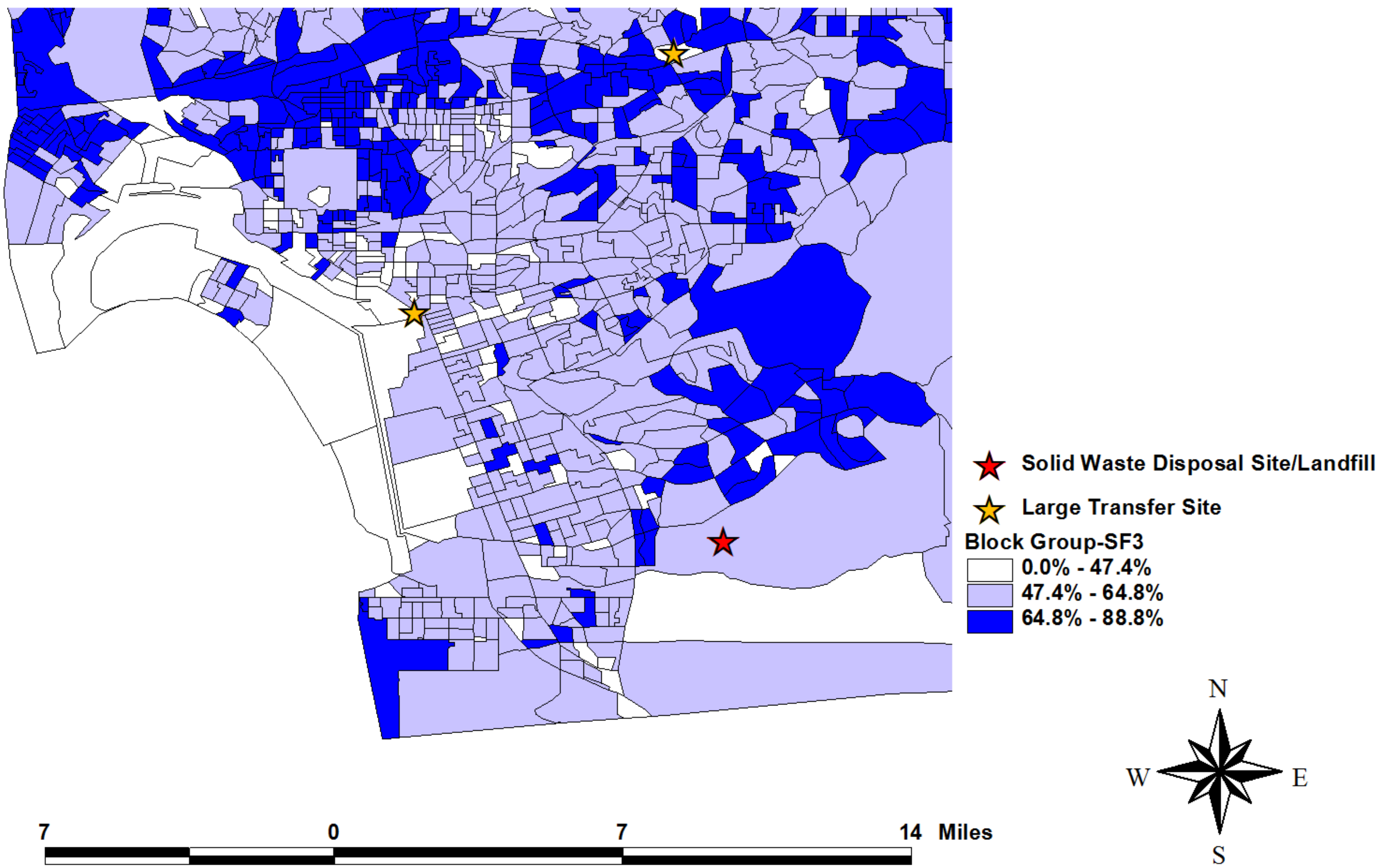
Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Housing Units That Are Renter-Occupied by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 1



Coronado-National City Area-Active Landfills/Large Transfer Sites and Percent of Population 16 and Over in the Armed Forces by Census Block Group Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



Coronado-National City Area-Active Landfills/Large Transfer Sites and
Percent of Population 16 and Over in the Civilian Labor Force by Census Block Group
Based on CIWMB SWIS Database and 2000 Decennial Census Summary File 3



APPENDIX D

Calculated San Diego Area Waste Composition and Tonnages

County of San Diego Residential Waste Disposal Tonnage

(Cal Recycle Solid Waste Characterization Database)

COUNTY JURISDICTION	TOTAL	PAPER	GLASS	METAL	PLASTIC	ORGANIC	C & D	HHW	SPECIAL	RESIDUE
San Diego County	1,193,714	327,674	48,178	55,231	105,600	537,142	53,461	3,858	14,804	47,766
San Diego Carlsbad	33,620	9,229	1,357	1,556	2,974	15,128	1,506	109	417	1,345
San Diego Chula Vista	71,464	19,617	2,884	3,306	6,322	32,157	3,200	231	886	2,860
San Diego El Cajon	39,606	10,872	1,598	1,832	3,504	17,822	1,774	128	491	1,585
San Diego Escondido	52,397	14,383	2,115	2,424	4,635	23,578	2,347	169	650	2,097
San Diego La Mesa	24,272	6,663	980	1,123	2,147	10,922	1,087	78	301	971
San Diego Oceanside	65,929	18,097	2,661	3,050	5,832	29,666	2,953	213	818	2,638
San Diego San Diego	523,652	143,742	21,135	24,228	46,324	235,630	23,452	1,693	6,494	20,954
San Diego Unincorporated	192,412	52,817	7,766	8,903	17,022	86,581	8,617	622	2,386	7,699

County of San Diego Residential Waste Disposal Tonnage

(Cal Recycle Solid Waste Characterization Database, based upon default state-wide business generator characterization studies)

COUNTY JURISDICTION	TOTAL	PAPER	GLASS	METAL	PLASTIC	ORGANIC	C & D	HHW	SPECIAL	RESIDUE
San Diego County	1,632,418	563,440	49,359	100,636	158,928	536,847	165,665	3,715	44,928	8,900
San Diego Carlsbad	61,658	21,632	1,930	3,917	7,034	18,558	6,259	138	1,744	446
San Diego Chula Vista	60,041	20,266	1,671	3,576	6,290	20,433	5,709	131	1,603	362
San Diego El Cajon	52,915	16,942	1,626	3,589	4,799	16,601	7,302	106	1,633	317
San Diego Escondido	67,776	22,268	2,023	4,391	6,170	21,412	8,661	145	2,365	341
San Diego La Mesa	31,323	10,463	892	1,863	2,708	11,203	2,995	65	1,005	129
San Diego Oceanside	60,871	20,370	1,676	3,739	6,193	20,386	6,268	121	1,795	323
San Diego San Diego	872,961	312,129	26,596	52,754	84,714	292,616	74,486	2,127	22,876	4,663
San Diego Unincorporated	143,758	46,030	4,372	9,696	13,795	44,812	19,672	317	4,249	815

SAN DIEGO COUNTY
WASTE SHED ANALYSIS

This study examines information that is needed to plan for a United States Navy pilot Conversion Program where municipal solid waste from San Diego County would be used to generate energy.

San Diego County was analyzed in terms of:
1. Jurisdictions in the county
2. Solid Waste Transfer Stations in the county.

Major considerations in the location of the pilot project(s) may be nearness of the selected transfer station to Naval facilities, daily tonnage available at the transfer station, future disposal at the jurisdictions surrounding the transfer station, and material types that can be used for the Conversion Program.

Jurisdiction Data

Data on annual tonnage disposed for each jurisdiction was obtained from the California Integrated Waste Management Board (CIWMB). In San Diego County, annual tonnage data from 1995 through 2006 was available for each incorporated city in the county, and the remainder of the county, termed the county unincorporated area.

Annual projections of disposed tons were made for each jurisdiction from 2007 through 2026 (a twenty year period). The technique of Exponential Smoothing was used to produce these projections. More detail on this technique can be found in the Technical Appendix.

Transfer Station Data

CIWMB also maintains a database on each solid waste facility (such as landfills and transfer stations) in the state in the Solid Waste Information System (SWIS) database. A transfer station is an intermediate disposal facility that receives waste from individual waste hauler trucks, consolidates this waste and then transfers this waste in large transfer trailers to landfills. Many transfer stations also recycle a portion of this waste before it is sent to the landfill. Additionally, some transfer stations only accept inert materials (such as concrete, asphalt, rocks and soil). These inert sites were considered out-of-scope for the analysis.

The SWIS database provides information such as the location of the facility, types of materials accepted, average daily tonnage, and the owner and operator of the facility. Each facility is identified by a SWIS Number.

Overview of San Diego County

The following table summarizes the CIWMB jurisdiction and transfer station data available for analysis.

COUNTY	NAVAL FACILITIES	CIWMB JURISDICTION DATA	CIWMB TRANSFER STATION DATA
San Diego	Extensive in the western portion of the County	18 Incorporated Cities 1 Unincorporated Area	16 Non-Inert Sites Range 2,500 to 9 tons a day

San Diego County Tables

In the tables that follow, there are two tables

The first (A table) provides summary information about each jurisdiction in the county that has CIWMB data. This is each incorporated city in the county and the remainder, which is termed the county unincorporated area. Jurisdictions are sorted alphabetically. The tables also show whether a particular jurisdiction has a Naval facility.

The latest year of CIWMB data is 2006. This is shown as DRS (Disposal Reporting System) in the tables. Annual projections were done using Exponential Smoothing for each individual year for the 20 year period from 2007 through 2026. The tables only show projections for selected years (2007, 2010, 2020, and 2026). Even if DRS data for a jurisdiction was not available in 2006, if enough years of jurisdiction data were available for prior years, projections were still done. An Excel file (***NavySDCountyOnly-JurisEstimates.xls***) provides the backup data and graphs for each jurisdiction. This file is described below.

The second table for each County (B table) provides summary information about each transfer station in the county from the SWIS database. For each transfer station, the table shows the SWIS number and name, the location city, the estimated tons per day and per year processed by the transfer station, and the general types of accepted materials. Transfer stations are sorted in descending order of daily tons processed.

For the Conversion Program not all materials will be used. For example, concrete and asphalt would not be usable materials. CIWMB breaks materials into approximately 60 detailed types. Final determination on the exact material types that will be used has not been determined at this time. However, the more detailed backup Excel file for transfer stations (***NavySDCountyOnly-TransferStations.xls***) provides estimates of daily and annual tons for each of these about 60 material types. This data was also obtained from CIWMB. For each transfer station, approximate percents of materials in each type are derived based on the number and types of businesses in a selected jurisdiction for about 40 business categories such as restaurants, food stores, schools, financial institutions, etc. The tables show which jurisdiction was chosen to represent each transfer station.

TABLE A. SAN DIEGO COUNTY - JURISDICTION ANNUAL DISPOSED TONS EXCLUDING TONS DISPOSED AT INERT LANDFILLS 2006 ACTUAL DRS AND SELECTED EXPONENTIAL SMOOTHING FORECASTS TO 2026						
	D R S	EXPONENTIAL SMOOTHING FORECAST				
COUNTY - JURISDICTION	2006	2007	2010	2020	2026	Naval Facilities
San Diego-Carlsbad	131,637	142,163	161,416	225,591	264,097	
San Diego-Chula Vista	204,378	221,733	248,254	336,657	389,699	
San Diego-Coronado	54,417	55,145	56,602	61,457	64,370	
San Diego-Del Mar	15,392	15,833	17,158	21,572	24,221	
San Diego-El Cajon	117,911	125,580	131,177	149,832	161,026	
San Diego-Encinitas	78,018	83,757	89,397	108,193	119,472	
San Diego-Escondido	146,888	157,504	170,268	212,818	238,348	
San Diego-Imperial Beach	18,272	19,505	19,879	21,123	21,870	
San Diego-La Mesa	60,902	62,303	66,507	80,520	88,928	
San Diego-Lemon Grove	25,182	25,387	25,797	27,163	27,983	
San Diego-National City	82,275	75,974	79,613	91,743	99,021	
San Diego-Oceanside	165,500	171,089	187,858	243,754	277,292	
San Diego-Poway	68,818	72,359	81,179	110,582	128,224	
San Diego-San Diego	1,898,490	1,939,917	2,043,771	2,389,950	2,597,658	
San Diego-San Diego-Unincorporated	593,170	616,261	685,532	916,435	1,054,977	
San Diego-San Marcos	102,230	106,934	119,742	162,436	188,051	
San Diego-Santee	55,737	60,123	66,794	89,031	102,374	
San Diego-Solana Beach	14,802	17,439	17,485	17,639	17,731	
San Diego-Vista	130,301	135,256	150,121	199,672	229,402	

TABLE B. SAN DIEGO COUNTY TRANSFER STATIONS SORTED BY ESTIMATED CURRENT DAILY AND ANNUAL TONS					
SWIS # = NAME	LOCATION	EST. TONS PER DAY	EST. TONS PER YEAR	ACCEPTED WASTE	CIWMB COMPOSITION USED FOR MATERIALS (U=Unincorp Cty)
37-AA-0906 = Escondido Resource Recovery	Escondido	2,500.0	750,000	Construction/demolition,Green Materials,Mixed municipal	SanDiegoEscondido
37-AA-0105 = Edco Transfer Station	San Diego	1,500.0	450,000	Construction/demolition,Industrial,Mixed municipal	SanDiegoSanDiego
37-AA-0929 = Universal Refuse Removal Recycling & T.S	El Cajon	1,000.0	300,000		SanDiegoElCajon
37-AH-0001 = Palomar Transfer Station, Inc	Carlsbad	800.0	240,000	Construction/demolition,Green Materials,Industrial,Mixed municipal	SanDiegoCarlsbad
37-AA-0923 = Fallbrook Recycling Facility	Fallbrook	500.0	150,000	Construction/demolition,Mixed municipal	SanDiegoU
37-AA-0925 = Ramona MRF And Transfer Station	Ramona	370.0	111,000	Construction/demolition,Green Materials,Mixed municipal	SanDiegoU
37-AA-0922 = Edco Station	La Mesa	200.0	60,000	Construction/demolition,Green Materials,Industrial,Mixed municipal	SanDiegoLaMesa
37-AA-0953 = EDCO Construction/Demolition Debris Recy	San Marcos	175.0	52,500	Construction/demolition	InertFacility
37-AB-0007 = City Of San Diego Water Operations	San Diego	50.0	15,000		SanDiegoSanDiego
37-AA-0103 = Viejas Rural Large Vol. Transfer Station	Alpine	46.1	13,830	Mixed municipal	SanDiegoU
37-AA-0952 = Amswede Recycling	Otay (In Chula Vista)	25.0	7,500	Construction/demolition,Inert,Metals,Wood waste	SanDiegoChulaVista
37-AA-0202	Boulevard	15.0	4,500	Mixed municipal	SanDiegoU

TABLE B. SAN DIEGO COUNTY TRANSFER STATIONS SORTED BY ESTIMATED CURRENT DAILY AND ANNUAL TONS					
SWIS # = NAME	LOCATION	EST. TONS PER DAY	EST. TONS PER YEAR	ACCEPTED WASTE	CIWMB COMPOSITION USED FOR MATERIALS (U=Unincorp Cty)
= Boulevard Limited Vol. Transfer Operatio					
37-AA-0203 = Campo Limited Vol. Transfer Operation	Campo	15.0	4,500	Mixed municipal	SanDiegoU
37-AA-0958 = Waste Mgt.North Co. Limited Vol.Trans Op	Oceanside	15.0	4,500	Construction/demolition,Inert,Metals	SanDiegoOceanside
37-AA-0204 = Julian Medium Volume Transfer Station	Julian	9.0	2,700	Mixed municipal	SanDiegoU
37-AA-0206 = Palomar Mountain Lvto	Palomar Mountain	9.0	2,700	Mixed municipal	SanDiegoU
37-AB-0010 = City of San Diego Env.Ser.Dept. LVTO	San Diego	9.0	2,700	Green Materials,Mixed municipal	SanDiegoSanDiego
37-AA-0928 = Waste Management Of North County	Oceanside	0.0	0		InertFacility

Backup File for Jurisdictions

The Excel file ***NavySDCountyOnly-JurisEstimates.xls*** provides the backup information and graphs for the A tables described above.

For this file, use the following steps:

1. Either ***Enable Macros*** or ***Disable Macros*** may be selected. The macro merely switches to the graph when a jurisdiction is selected.
2. Click on the ***SelectJur*** tab.
3. Choose a jurisdiction from the drop down menu in cell B2. Jurisdictions are arranged alphabetically by county, and then by jurisdiction in the county.
4. When the jurisdiction is selected:
    a. Cell B4 will show the years of DRS data available.
    b. Column B will display the available non-inert facility DRS data from 1995 through 2006 for that jurisdiction.
    c. Column C will display the no inert facility Exponential Smoothing forecasts from 2007 through 2026.
    d. Column D will display the approximate lower bound for 90% Prediction Interval for Exponential Smoothing no inert facility disposal forecasts from 2007 through 2026.
    e. Column E will display the approximate upper bound for 90% Prediction Interval for Exponential Smoothing no inert facility disposal forecasts from 2007 through 2026.
    f. Column F will display the Straight Line no inert facility Exponential Smoothing forecasts from 2007 through 2026.
5. The graph of these numbers can be obtained by clicking on the tab ***Graph*** if you have disabled the macro.
    a. DRS data from 1995 through 2006 is shown as a solid magenta line.
    b. Exponential Smoothing forecasts from 2007 through 2026 are shown as a solid blue line.
    c. Lower and upper bounds for the 90% Prediction Interval on the Exponential Smoothing forecasts are shown as a dashed blue line.
    d. Straight line forecasts are shown as a solid yellow line.

The Technical Appendix provides a detailed explanation and rationale for the methodology and the name of the actual Excel file used in the calculations.

Backup File for Transfer Stations

The Excel file ***NavySDCountyOnly-TransferStations.xls*** provides the backup information and graphs for the B tables described above.

For this file, use the following steps:

1. Click on the ***SELECT*** tab.

2. Choose a transfer station from the drop down menu in cell B5. Transfer stations are arranged alphabetically by county, and then by transfer station name in the county.
3. Detailed information about the transfer station will be displayed in Rows 8 through 23.
4. Detailed material information will be displayed in Rows 25 through 96.
    a. Column C will display estimated percent for each material type.
    b. Column D will display estimated daily tons for each material type.
    c. Column E will display estimated annual tons for each material type.
    d. Column F will display estimated daily tons for each material type used in the Conversion Program (NOTE: Material types have not yet been determined).
    e. Column G will display estimated annual tons for each material type used in the Conversion Program (NOTE: Material types have not yet been determined).

TECHNICAL APPENDIX

RATIONALE FOR FORECASTS

Disposed tons are measured by the Disposal Reporting System (DRS), which is administered by the California Integrated Waste Management Board (CIWMB). The DRS information is available on a quarterly basis, and is obtained from individual vehicles entering disposal facilities such as landfills. Some facilities obtain the information from every vehicle entering the facility during a calendar quarter, while others obtain the information for a portion of the calendar quarter, and extrapolate the information to represent the entire quarter. Annual disposal tons are just the sum of the four calendar quarters in that year. Information obtained for each vehicle includes the disposal facility used, the jurisdiction(s) where the vehicle's waste came from, and the weight of the vehicle's waste.

On a countywide basis, this information can be summarized in two ways: (1) by a total for all jurisdictions in the county, and (2) by a total for all disposal facilities in the county. These totals are different for two reasons. First, some jurisdictions in a county export part of their waste to other California counties or out of state. This portion is not included in the disposal facility total for the county. Second, waste from other counties is imported to a county and disposed in the county's facilities. This portion is not included in the jurisdiction total for the county.

The principal use of forecasting in this project is to estimate future disposal for each jurisdiction in California to 2026. This project mainly examines waste at the jurisdiction level. There is a normal growth or decline in disposed waste for a jurisdiction due to increases in population and business activity. Additionally, disposal can be affected by increases in jurisdiction recycling and other diversion activities.

FORECASTING TECHNIQUES USED

Two statistical forecasting techniques were used to determine the best growth rate for disposed waste. In general, forecasting techniques fall into two general categories: (1) those that just use the 1995-2006 historical series of DRS tons, and (2) those that also use auxiliary information, such as population forecasts, in the procedures. Because of the constraints of this project, only category #1 techniques were used.

In category #1, two techniques were used: (1) straight-line projections, and (2) exponential smoothing. For category #2, past projects used two techniques: (1) regression, and (2) Kalman Filters. More information on these can be supplied as needed.

Straight-Line projections mathematically draw the best straight line that fits the DRS tons from 1995 to 2006 when they are graphed by year. This line is then extended out to 2026 to get projections. The technique is straightforward but it assumes that the average growth from 1995 to 2006 will continue to 2026.

Exponential Smoothing is a smoothing technique that forecasts a current year by a weighted average of past years' data. If the algorithm determines that past years' data influence the current year a lot, they are given a high relative weight. If the algorithm determines that past years' data influence the current year very little, they are given a low relative weight.

This Technical Appendix is provided as documentation for each of the forecasting techniques discussed above.

ADDITIONAL CONSIDERATIONS

In most cases, DRS data was obtained for each quarter from 1995 through 2006. However, in some counties, several jurisdictions have combined their individual jurisdictions into a Regional Agency. In general, CIWMB reports the Regional Agency data from the first year it was formed forward in time (e.g. the Imperial Valley Resource Management Agency was formed in 2006, so CIWMB reports data for this Regional Agency from 2006 forward). CIWMB only reports the constituent individual jurisdiction data from 1995 up to the year before the Regional Agency was formed (e.g. for Imperial County 1995 through 2005 only). This can cause problems in forecasts where only a few years of data exist for either the Regional Agency or a constituent jurisdiction. Consequently, we made an exception only for the Los Angeles Area Integrated Waste Management Authority (LARA). This Regional Agency was composed of 14 jurisdictions in 2003-2004, but increased to 16 jurisdictions in 2005. A consistent time series from 1995 through 2006 for each of the 16 constituent jurisdictions and LARA itself was obtained. For the Regional Agency itself, data is summed for 16 cities from 1995 through 2006. In the following files, the LARA data for the 16 cities and the LARA total, using the developed data from 1995-2006, has the prefix *LARA9506*- before the jurisdiction name. The data for the jurisdiction name without the prefix, is the CIWMB available data.

CIWMB changed its accounting methods in 2006 and no longer includes data for most inert landfills. An inert landfill is a facility that only accepts inert waste such as concrete, asphalt, stone and dirt. To get a consistent time series for forecasting, inert tonnage was removed from all jurisdictions and counties in all years. In any case, inert waste is not relevant to this project.

Excel File used for California Jurisdictions

Forecasts were made on an annual basis. Quarterly DRS data was summed to annual totals. The Excel file ***CaliforniaJurisdictionForecasts.xls*** displays the annual DRS data for each jurisdiction in California, as well as annual forecasts to 2026 with Straight Line and Exponential Smoothing.

Most Regional Agencies were formed after 1995, so there were not 12 years of data on which to make forecasts in either the Regional Agency or the constituent jurisdictions. If only one or two years of data exist to make forecasts, poor forecasts can result. In any case forecasts are made to 2026 for all Regional Agencies and their constituent jurisdictions, where possible.

For this file, use the following steps:

1. When opening the file, ***Enable Macros*** must be selected.
2. Click on the ***JurSelect*** tab.
3. Choose a jurisdiction from the drop down menu in cell B2.
4. Excel will ask if you want to accept the optimizer solution for the Exponential Smoothing, just click OK. (These steps are done by a macro.)
5. The tab ***JurPredictChart*** will automatically be displayed and show the following 5 series:
    a. DRS jurisdiction no inert facility disposal to 2006
    b. Exponential Smoothing jurisdiction no inert facility disposal forecasts to 2026
    c. Straight Line jurisdiction no inert facility disposal forecasts to 2026.
    d. Approximate Upper Bound for 90% Prediction Interval for Exponential Smoothing no inert facility disposal forecasts from 2007 through 2026.
    e. Approximate Lower Bound for 90% Prediction Interval for Exponential Smoothing no inert facility disposal forecasts from 2007 through 2026.
6. Click on the tab ***JurSelect*** again to view the actual numbers for:
    a. DRS jurisdiction total disposal to 2006
    b. DRS jurisdiction inert facility disposal to 2006
    c. DRS jurisdiction no inert facility disposal to 2006 (the difference between a and b)
    d. Exponential Smoothing jurisdiction no inert facility disposal forecasts to 2026
    e. Straight Line jurisdiction no inert facility disposal forecasts to 2026.
7. Click on the tab ***JurDRSChart*** again to view the graph for:
    a. DRS jurisdiction total disposal to 2006
    b. DRS jurisdiction inert facility disposal to 2006
    c. DRS jurisdiction no inert facility disposal to 2006 (the difference between a and b).

Only those years where data is available are used to calculate the Straight Line and Exponential Smoothing forecasts. Straight Line estimates are done from 1995 through 2026. Exponential Smoothing estimates are done for the first year data is available through 2026. Exponential Smoothing estimates prior to the first year data is available are shown as zero. Jurisdictions and Regional Agencies with only a few years of data can give poor forecasts.

For the Los Angeles Area Integrated Waste Management Authority (LARA), the calculated time series described above for the 16 constituent series and the overall LARA have a jurisdiction name prefixed by *LARA9506-*. The calculated series are continuous from 1995 through 2006 and give more reliable forecasts. The original CIWMB data for these 16 jurisdictions and overall LARA are listed as the jurisdiction name without the prefix.

EXPONENTIAL SMOOTHING ALGORITHM

Exponential Smoothing is done in the ***ExpSmooth*** tab of ***CaliforniaJurisdictionForecasts.xls*** for Jurisdictions.

The Exponential Smoothing algorithm uses a weighted average of past observations. The model used is called Holt Exponential Smoothing. This incorporates a linear trend in the data to show growth over time. For this model, the Smoothed forecast value for time t, is a sum of two components. It is a weighted average of: (1) the current DRS value, and (2) the Smoothed and Trend component for the preceding period (t-1). Annual data was used for the exponential smoothing forecasts.

The Smoothed value for a period t is a weighted average of DRS for period t and the Smoothed value and Trend value for the previous period (t-1). The weight on the current value of DRS is alpha:

$$Smoothed_t = (\alpha \; * DRS_t) \quad + \quad [(1-\alpha)*(Smoothed_{t-1} + Trend_{t-1})]$$

This is a recursive estimation formula, where the Smoothed value for period t-1 could be written as a weighted average of DRS in time period t-1 and the Smoothed and Trend value for period t-2, and so forth. The 1-alpha term for each previous period has an exponent one higher power than the later one. This is why it is called exponential smoothing. Since the 1-alpha weight is constrained to be less than or equal to 1, earlier periods receive less weight. These Smoothed values are shown in row 10 of the County file and row 11 of the jurisdiction file.

The Trend for a period t depends on a parameter gamma. It is:

$$Trend_t = \gamma * (Smoothed_t - Smoothed_{t-1}) \quad + \quad (1-\gamma)* Trend_{t-1}$$

These Trend values are shown in row 9 of both the County and Jurisdiction files.

The current estimate for period t is just the Smoothed value for period t.

The one-period ahead (or one-step ahead) forecasts for period t+1 are:

$$One-Step\ Ahead\ Forecast_{t+1} \quad = \quad Smoothed_t \quad + \quad Trend_t$$

The one-step ahead forecasts are shown in row 27 of the County file and row 29 of the Jurisdiction file.

The values for alpha (cell C7 in both files) and gamma (cell C8 in both files) are chosen by Excel's optimizer, using a Newton forward derivative search method. Values of alpha and gamma are chosen that minimize the error in the one-step ahead forecast from the original DRS number. The one-step ahead error in shown in row 11 of the County file and row 13 of the Jurisdiction file.

Four different methods of measuring the total error over the 1995 through 2006 period were calculated:

1. Root Mean Square Error: which is the square root of the average of the squared one-step ahead errors from 1995 through 2006. This is shown in cell B12 of the County file and cell B14 of the Jurisdiction file.
2. Mean Absolute Error: which is the average of the absolute values of the one-step ahead errors from 1995 through 2006. This is shown in cell B13 of the County file and cell B15 of the Jurisdiction file.
3. Root Mean Square Percent Error: which is the square root of the average of the squared one-step ahead percent errors from 1995 through 2006. This is shown in cell B14 of the County file and cell B16 of the Jurisdiction file.
4. Mean Absolute Percent Error: which is the average of the absolute values one-step ahead percent errors from 1995 through 2006. This is shown in cell B15 of the County file and cell B17 of the Jurisdiction file.

The 3rd Method (Root Mean Square Percent Error) was chosen as the best method to be used in the minimization, and is shown in cell B17 of the County file and B19 of the Jurisdiction file. Excel Solver minimizes the Root Mean Square Percent Error subject to the constraints that both alpha and gamma must have values that are greater than or equal to 0 and less than or equal to 1. Initial values of 0.1 are used for both alpha and gamma.

Starting values are needed for period zero for Smoothed and Trend. These are:

$$Trend_0 = \frac{DRS_{2006} - DRS_{1995}}{12-1}$$

$$Smoothed_0 = DRS_{1995} - \frac{Trend_0}{2}$$

In the Jurisdiction file, the 4 Methods of calculating the total error are only averaged over valid years, and the starting values of Smoothed and Trend are based on the first and last year of valid data.

Forecasts for Exponential Smoothing after 2006 (or the last year of valid data in the Jurisdiction file) are done by adding multiples of the Trend value for the last year in the valid period (T) to the Smoothed value for T. For example, if a forecast for the 4th year after the end of the valid period is needed, 4 times the Trend value for T would be added to the Smoothed value for T or, in general terms of *i* periods after the end of the sample period:

$$Forecast_{T+i} \quad = \quad Smoothed_T \quad + \quad \left(i * Trend_T\right)$$

Very approximate 90% Prediction Intervals were developed for the years 2007 through 2026. These were developed by estimating the standard error of the forecast from the last 3 periods of available data using the one-step ahead forecasts, and a t-value for the number of available years of data minus 2. The upper and lower bounds spread out as the years get closer to 2026.

<u>STRAIGHT-LINE ESTIMATES</u>

Straight-Line estimates are done in the ***StraightLine*** tab of ***CaliforniaJurisdictionForecasts.xls*** for Jurisdictions.

The estimates of the y-intercept (a) and the slope (b) coefficients of the Straight-Line are calculated using the matrix algebra functions of Excel.

For example, the following data exists for Orange County:

DRS	Constant	Trend
2,915,893.01	1	1
2,885,297.78	1	2
3,264,031.16	1	3
3,525,231.37	1	4
3,491,688.35	1	5
3,655,938.01	1	6
3,730,969.58	1	7

DRS	Constant	Trend
3,710,313.31	1	8
3,888,022.40	1	9
4,001,482.22	1	10
4,055,600.39	1	11
3,901,041.08	1	12

Cells H19 and H20 show the results of the calculations for the a and b coefficients. The following matrix formula is used:

$$Coefficients \quad = \quad (X'X)^{-1}(X'Y)$$

$$where:$$

$$Coefficients\ is\ a\ 2x1\ matrix\ of\ the\ y\text{intercept}\ and\ slope$$

$$Y\ is\ the\ 12x1\ matrix\ of\ DRS\ values$$

$$X\ is\ the\ 12x2\ matrix\ of\ \text{constant}\ and\ trend\ values$$

The symbol ‘ is used for transpose and the symbol –1 in used for inverse.

In the jurisdiction file, only valid years of data are used in the coefficient calculations for Regional Agencies and Jurisdictions that do not have continuous data from 1995 through 2006.

APPENDIX E: Energy Equivalents of Landfill Disposed Navy Waste

The following table lists the calculated theoretical energy (equivalent based on barrels of oil (42 U.S. gallons per barrel of oil) contained within the waste tonnage disposed of per year at landfills at the listed naval facilities.

Potential Energy Equivalent of Navy Waste in Barrels of Oil

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent in Barrels of Oil (42 U.S. gallons / barrel)			
		2006	2007	2008	Average	2006	2007	2008	Average
MCAS YUMA	AZ	2,445	2,072	5,480	3,332	3,863	3,274	8,658	5,265
NAVY REGION SOUTHWEST	CA	8,100	9,557	8,965	8,874	12,798	15,100	14,165	14,021
MCB CAMP PENDLETON	CA	37,374	30,158	35,599	34,377	59,051	47,650	56,246	54,316
MCAS MIRAMAR	CA	5,829	10,566	4,534	6,976	9,210	16,694	7,164	11,022
MARINE CORPS RECRUITING DEPOT	CA	2,244	2,050	2,161	2,152	3,546	3,239	3,414	3,400
NAS NORTH ISLAND	CA	20,283	13,431	13,404	15,706	32,047	21,221	21,178	24,815
NAVMEDCEN SAN DIEGO	CA	1,365	1,953	1,654	1,658	2,157	3,086	2,613	2,620
NAVBASE POINT LOMA SAN	CA	2,537	3,431	2,531	2,833	4,008	5,421	3,999	4,476
SPACE AND NAVAL WARFARE	CA	819	990	1,106	972	1,294	1,564	1,747	1,536
				SOUTHERN CA REGION	*73,547*				*116,204*
CBC PORT HUENEME	CA	7,945	8,093	7,696	7,911	12,553	12,787	12,160	12,499
WPNSTA SEAL BEACH	CA	748	761	2,878	1,462	1,182	1,202	4,547	2,310
NAD LEMOORE	CA	2,770	2,906	3,290	2,989	4,377	4,591	5,198	4,723
MCLB BARSTOW	CA	1,618	1,632	1,247	1,499	2,556	2,579	1,970	2,368
NAF EL CENTRO	CA	1,071	769	1,306	1,049	1,692	1,215	2,063	1,657
NAVPGSCOL MONTEREY	CA	4,663	4,030	3,961	4,218	7,368	6,367	6,258	6,664
NAVAL SUBMARINE BASE KINGS BAY	GA	7,311	6,374	5,392	6,359	11,551	10,071	8,519	10,047
USMC BLOUNT ISLAND COMMAND	FL	236	932	3,530	1,566	373	1,473	5,577	2,474
NAVAL AIR STATION JACKSONVILLE	FL	7,064	6,533	6,805	6,801	11,161	10,322	10,752	10,746
NAVAL STATION MAYPORT	FL	7,755	7,500	4,925	6,727	12,253	11,850	7,782	10,629
				EASTERN FL REGION	*21,452*				*33,894*
NAS PENSACOLA	FL	36,938	9,499	7,200	17,879	58,362	15,008	11,376	28,249
NAS WHITING FIELD	FL	423	1,313	724	820	668	2,075	1,144	1,296
NTTC CORY STATION	FL	3,621	1,825	1,350	2,265	5,721	2,884	2,133	3,579
NETPMSA SAUFLEY FIELD	FL	521	652	450	541	823	1,030	711	855
				WESTERN FL REGION	*21,505*				*33,978*
NAVAL UNDERSEA WARFARE WPB	FL	871	453	501	608	1,376	716	792	961
MCLB ALBANY	GA	3,638	3,201	2,660	3,166	5,748	5,058	4,203	5,002

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent in Barrels of Oil (42 U.S. gallons / barrel)			
		2006	2007	2008	Average	2006	2007	2008	Average
NAS ATLANTA	GA	1	672	7	***227***	***2***	***1,062***	***11***	***359***
NAVAL STATION PEARL HARBOR	HI	2,396	1,885	809	1,697	***3,786***	***2,978***	***1,278***	***2,681***
MCB HAWAII KANEOHE BAY		8,522	5,125	256	4,634	***13,465***	***8,098***	***404***	***7,322***
PEARL HARBOR NSY & IMF		2,612	9,772	3,641	5,342	***4,127***	***15,440***	***5,753***	***8,440***
NAS BARBERS POINT		338	306	121	255	***534***	***483***	***191***	***403***
FLEET AND INDUSTRIAL SUPPLY		327	256	109	231	***517***	***404***	***172***	***365***
NCTAMSPAC		53	50	50	51	***84***	***79***	***79***	***81***
NSGA KUNIA		44	52	43	46	***70***	***82***	***68***	***73***
NAVFAC HAWAII		437	472	391	433	***690***	***746***	***618***	***684***
NAVAL MAGAZINE LUALUALEI		445	351	157	318	***703***	***555***	***248***	***502***
				HI REGION	***13,007***				***20,551***
PACMISRANFAC BARKING	HI	530	459	459	483	***837***	***725***	***725***	***763***
NAVAL SUPPORT ACTIVITY	LA	2,356	3,088	2,251	2,565	***3,722***	***4,879***	***3,557***	***4,053***
NAS JRB NEW ORLEANS		1,680	3,638	1,370	2,229	***2,654***	***5,748***	***2,165***	***3,522***
				LA REGION	***4,794***				***7,575***
MOBCOM	MO	381	314	275	***323***	***602***	***496***	***435***	***510***
NAVAL AIR STATION MERIDIAN	MS	2,185	2,612	3,486	***2,761***	***3,452***	***4,127***	***5,508***	***4,362***
CBC GULFPORT	MS	2,770	2,500	1,087	***2,119***	***4,377***	***3,950***	***1,717***	***3,348***
MCB CAMP LEJEUNE	NC	50,059	43,924	43,233	45,739	***79,093***	***69,400***	***68,308***	***72,268***
MARINE CORPS AIR STATION		9,286	8,216	8,606	8,703	***14,672***	***12,981***	***13,597***	***13,751***
				NC REGION	***54,441***				***86,017***
NAVSHIPYD PORTSMOUTH	NH	2,077	2,062	2,145	***2,095***	***3,282***	***3,258***	***3,389***	***3,310***
WEAPON STATION EARLE COLTS NECK	NJ	843	673	880	799	***1,332***	***1,063***	***1,390***	***1,262***
NAVAIRENGSTA LAKEHURST		1,397	1,310	1,046	1,251	***2,207***	***2,070***	***1,653***	***1,977***
				NJ REGION	***2,050***				***3,239***
NAS FALLON	NV	1,259	1,173	1,129	***1,187***	***1,989***	***1,853***	***1,784***	***1,875***
NAVAL SUPPLY STATION	PA	1,911	2,228	2,534	2,224	***3,019***	***3,520***	***4,004***	***3,514***
NSA MECHANICSBURG	PA	2,394	735	736	1,288	***3,783***	***1,161***	***1,163***	***2,035***
NSA PHILLY BUSINESS CENTER		1,568	555	492	871	***2,477***	***877***	***777***	***1,376***
				PA REGION	***4,384***				***6,927***
NAVSTA NEWPORT	RI	3,164	1,810	1,877	***2,284***	***4,999***	***2,860***	***2,966***	***3,609***
MCRD PARRIS ISLAND	SC	3,477	3,854	3,939	3,757	***5,494***	***6,089***	***6,224***	***5,936***
MCAS BEAUFORT		2,044	3,122	2,044	2,403	***3,230***	***4,933***	***3,230***	***3,797***

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent in Barrels of Oil (42 U.S. gallons / barrel)			
		2006	2007	2008	Average	2006	2007	2008	Average
NAVAL HOSPITAL BEAUFORT		1,200	1,050	995	1,082	***1,896***	***1,659***	***1,572***	***1,710***
WPNSTA CHARLESTON		19,703	4,653	4,782	9,713	***31,131***	***7,352***	***7,556***	***15,347***
				SC REGION	***16,954***				***1,6787***
NAVSUPPACT MEMPHIS	TN	1,858	1,474	1,448	***1,593***	***2,936***	***2,329***	***2,288***	***2,517***
NAVAL AIR STATION CORPUS CHRISTI	TX	3,831	3,879	18,821	8,844	***6,053***	***6,129***	***29,737***	***13,974***
NAVAL AIR STATION KINGSVILLE		581	292	435	436	***918***	***461***	***687***	***689***
NAVSTA INGLESIDE		1,090	872	974	979	***1,722***	***1,378***	***1,539***	***1,547***
				EASTERN TX REGION	***10,258***				***16,208***
NAS JRB FORT WORTH	TX	2,781	5,185	4,586	***4,184***	***4,394***	***8,192***	***7,246***	***6,611***
WPNSTA YORKTOWN	VA	2,348	789	2,033	1,723	***3,710***	***1,247***	***3,212***	***2,722***
AFEXPTRAACT CAMP PEARY		600	1,023	841	821	***948***	***1,616***	***1,329***	***1,297***
NAS OCEANA		5,526	4,854	4,950	5,110	***8,731***	***7,669***	***7,821***	***8,074***
NAVSTA NORFOLK		14,316	15,845	15,775	15,312	***22,619***	***25,035***	***24,925***	***24,193***
NAVSHIPYD NORFOLK		4,693	7,173	2,506	4,791	***7,415***	***11,333***	***3,959***	***7,570***
				VA REGION	***27,757***				***43,856***
MCCDC QUANTICO	VA	235	988	6,676	2,633	***371***	***1,561***	***10,548***	***4,160***
SURFAC COMBAT SYS CTR		71	356	252	226	***112***	***562***	***398***	***357***
NSF DAHLGREN		668	584	1,988	1,080	***1,055***	***923***	***3,141***	***1,706***
NATNAVMEDCEN BETHESDA	MD	1,987	1,215	2,074	1,759	***3,139***	***1,920***	***3,277***	***2,779***
NAS PATUXENT RIVER		3,804	3,833	3,761	3,799	***6,010***	***6,056***	***5,942***	***6,002***
NSF CARDEROCK		1,077	1,193	1,126	1,132	***1,702***	***1,885***	***1,779***	***1,789***
U.S. NAVY, INDIAN HEAD		17,053	8,278	6,791	10,708	***26,944***	***13,079***	***10,730***	***16,919***
NDW SOUTH PATUXENT RIVER		37,256	16,495	13,750	22,500	***58,864***	***26,062***	***21,725***	***35,550***
NAVAL RESEARCH LAB WASHINGTON	DC	1,267	1,267	1,984	1,506	***2,002***	***2,002***	***3,135***	***2,379***
				DC REGION	***45,342***				***71,640***
NAVPHIBASE LITTLE CREEK	VA	3,961	4,933	5,423	***4,772***	***6,258***	***7,794***	***8,568***	***7,540***
NAVSTA EVERETT	WA	1,064	990	1,007	1,020	***1,681***	***1,564***	***1,591***	***1,612***
NAVAL SUBMARINE BASE BANGOR		4,658	3,636	3,921	4,072	***7,360***	***5,745***	***6,195***	***6,434***
NAVAL AIR STATION WHIDBEY ISLAND		1,916	1,845	1,842	1,868	***3,027***	***2,915***	***2,910***	***2,951***
NAVBASE KITSAP AT BREMERTON		7,696	6,029	6,424	6,716	***12,160***	***9,526***	***10,150***	***10,611***
WPNSUPFAC DET PORT HADLOCK		173	158	213	181	***273***	***250***	***337***	***286***
NAVHOSP BREMERTON		250	225	316	264	***395***	***356***	***499***	***417***
				WA REGION	***14,121***				***22,311***
NAVIOCOM SUGAR GROVE	WV	77	73	88	79	***122***	***115***	***139***	***125***
ABL ROCKET CENTER WV		711	821	986	839	***1,123***	***1,297***	***1,558***	***1,326***
				WV REGION	***919***				***1,452***

Note: Numbers may not add up due to rounding

To get an approximate value of the potential amount of electricity that could be generated from the solid waste stream using a potential waste-to-clean energy thermal conversion technology from each of the various Navy facilities, the following table provides the estimation based upon a factor of 0.5 megawatt-hour electrical energy that can be generated by thermally converting per ton of MSW

Potential Energy Equivalent from Thermal Conversion Technology in Megawatt Hours Per Year

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent from Thermal Conversion Technology Megawatt Hours per Year			
		2006	2007	2008	Average	2006	2007	2008	Average
MCAS YUMA	AZ	2,445	2,072	5,480	***3,332***	***1,223***	***1,036***	***2,740***	***1,666***
NAVY REGION SOUTHWEST		8,100	9,557	8,965	8,874	***4,050***	***4,779***	***4,483***	***4,437***
MCB CAMP PENDLETON		37,374	30,158	35,599	34,377	***18,687***	***15,079***	***17,800***	***17,189***
MCAS MIRAMAR		5,829	10,566	4,534	6,976	***2,915***	***5,283***	***2,267***	***3,488***
MARINE CORPS RECRUITING DEPOT		2,244	2,050	2,161	2,152	***1,122***	***1,025***	***1,081***	***1,076***
NAS NORTH ISLAND		20,283	13,431	13,404	15,706	***10,142***	***6,716***	***6,702***	***7,853***
NAVMEDCEN SAN DIEGO		1,365	1,953	1,654	1,658	***683***	***977***	***827***	***829***
NAVBASE POINT LOMA SAN		2,537	3,431	2,531	2,833	***1,269***	***1,716***	***1,266***	***1,417***
SPACE AND NAVAL WARFARE	CA	819	990	1,106	972	***410***	***495***	***553***	***486***
			SOUTHERN CA REGION		***73,547***				***36,774***
CBC PORT HUENEME	CA	7,945	8,093	7,696	***7,911***	***3,973***	***4,047***	***3,848***	***3,956***
WPNSTA SEAL BEACH	CA	748	761	2,878	***1,462***	***374***	***381***	***1,439***	***731***
NAD LEMOORE	CA	2,770	2,906	3,290	***2,989***	***1,385***	***1,453***	***1,645***	***1,495***
MCLB BARSTOW	CA	1,618	1,632	1,247	***1,499***	***809***	***816***	***624***	***750***
NAF EL CENTRO	CA	1,071	769	1,306	***1,049***	***536***	***385***	***653***	***525***
NAVPGSCOL MONTEREY	CA	4,663	4,030	3,961	***4,218***	***2,332***	***2,015***	***1,981***	***2,109***
NAVAL SUBMARINE BASE KINGS BAY	GA	7,311	6,374	5,392	6,359	***3,656***	***3,187***	***2,696***	***3,180***
USMC BLOUNT ISLAND COMMAND		236	932	3,530	1,566	***118***	***466***	***1,765***	***783***
NAVAL AIR STATION JACKSONVILLE		7,064	6,533	6,805	6,801	***3,532***	***3,267***	***3,403***	***3,401***
NAVAL STATION MAYPORT	FL	7,755	7,500	4,925	6,727	***3,878***	***3,750***	***2,463***	***3,364***
			EASTERN FL REGION		***21,452***				***10,726***
NAS PENSACOLA	FL	36,938	9,499	7,200	17,879	***18,469***	***4,750***	***3,600***	***8,940***

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent from Thermal Conversion Technology Megawatt Hours per Year			
NAS WHITING FIELD		423	1,313	724	820	212	657	362	410
NTTC CORY STATION		3,621	1,825	1,350	2,265	1,811	913	675	1,133
NETPMSA SAUFLEY FIELD		521	652	450	541	261	326	225	271
				WESTERN FL REGION	21,505				10,753
Base	**Location**	**Land-filled waste (tons)**				**Potential Energy Equivalent Megawatt Hours per Year**			
		2006	**2007**	**2008**	**Average**	**2006**	**2007**	**2008**	**Average**
NAVAL UNDERSEA WARFARE WPB	FL	871	453	501	608	436	227	251	304
MCLB ALBANY	GA	3,638	3,201	2,660	3,166	1,819	1,601	1,330	1,583
NAS ATLANTA	GA	1	672	7	227	1	336	4	114
NAVAL STATION PEARL HARBOR		2,396	1,885	809	1,697	1,198	943	405	849
MCB HAWAII KANEOHE BAY		8,522	5,125	256	4,634	4,261	2,563	128	2,317
PEARL HARBOR NSY & IMF		2,612	9,772	3,641	5,342	1,306	4,886	1,821	2,671
NAS BARBERS POINT		338	306	121	255	169	153	61	128
FLEET AND INDUSTRIAL SUPPLY		327	256	109	231	164	128	55	116
NCTAMSPAC		53	50	50	51	27	25	25	26
NSGA KUNIA		44	52	43	46	22	26	22	23
NAVFAC HAWAII		437	472	391	433	219	236	196	217
NAVAL MAGAZINE LUALUALEI	HI	445	351	157	318	223	176	79	159
				HI REGION	13,007				6,504
PACMISRANFAC BARKING	HI	530	459	459	483	265	230	230	242
NAVAL SUPPORT ACTIVITY		2,356	3,088	2,251	2,565	1,178	1,544	1,126	1,283
NAS JRB NEW ORLEANS	LA	1,680	3,638	1,370	2,229	840	1,819	685	1,115
				LA REGION	4,794				2,397
MOBCOM	MO	381	314	275	323	191	157	138	162
NAVAL AIR STATION MERIDIAN	MS	2,185	2,612	3,486	2,761	1,093	1,306	1,743	1,381
CBC GULFPORT	MS	2,770	2,500	1,087	2,119	1,385	1,250	544	1,060
MCB CAMP LEJEUNE		50,059	43,924	43,233	45,739	25,030	21,962	21,617	22,870
MARINE CORPS AIR STATION	NC	9,286	8,216	8,606	8,703	4,643	4,108	4,303	4,352

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent from Thermal Conversion Technology Megawatt Hours per Year			
				NC REGION	***54,441***				***27,221***
NAVSHIPYD PORTSMOUTH	NH	2,077	2,062	2,145	***2,095***	***1,039***	***1,031***	***1,073***	***1,048***
WEAPON STATION EARLE COLTS NECK		843	673	880	799	***422***	***337***	***440***	***400***
NAVAIRENGSTA LAKEHURST	NJ	1,397	1,310	1,046	1,251	***699***	***655***	***523***	***626***
				NJ REGION	***2,050***				***1,025***
NAS FALLON	NV	1,259	1,173	1,129	***1,187***	***630***	***587***	***565***	***594***
NAVAL SUPPLY STATION	PA	1,911	2,228	2,534	2,224	***956***	***1,114***	***1,267***	***1,112***
NSA MECHANICSBURG		2,394	735	736	1,288	***1,197***	***368***	***368***	***644***
NSA PHILLY BUSINESS CENTER	PA	1,568	555	492	871	***784***	***278***	***246***	***436***
				PA REGION	***4,384***				***2,192***
NAVSTA NEWPORT	RI	3,164	1,810	1,877	***2,284***	***1,582***	***905***	***939***	***1,142***
MCRD PARRIS ISLAND		3,477	3,854	3,939	3,757	***1,739***	***1,927***	***1,970***	***1,879***
MCAS BEAUFORT		2,044	3,122	2,044	2,403	***1,022***	***1,561***	***1,022***	***1,202***
NAVAL HOSPITAL BEAUFORT		1,200	1,050	995	1,082	***600***	***525***	***498***	***541***
WPNSTA CHARLESTON	SC	19,703	4,653	4,782	9,713	***9,852***	***2,327***	***2,391***	***4,857***
				SC REGION	***16,954***				***8,477***
NAVSUPPACT MEMPHIS	TN	1,858	1,474	1,448	***1,593***	***929***	***737***	***724***	***797***
NAVAL AIR STATION CORPUS CHRISTI		3,831	3,879	18,821	8,844	***1,916***	***1,940***	***9,411***	***4,422***
NAVAL AIR STATION KINGSVILLE		581	292	435	436	***291***	***146***	***218***	***218***
NAVSTA INGLESIDE	TX	1,090	872	974	979	***545***	***436***	***487***	***490***
				EASTERN TX REGION	***10,258***				***5,129***
NAS JRB FORT WORTH	TX	2,781	5,185	4,586	***4,184***	***1,391***	***2,593***	***2,293***	***2,092***
WPNSTA YORKTOWN		2,348	789	2,033	1,723	***1,174***	***395***	***1,017***	***862***
AFEXPTRAACT CAMP PEARY		600	1,023	841	821	***300***	***512***	***421***	***411***
NAS OCEANA		5,526	4,854	4,950	5,110	***2,763***	***2,427***	***2,475***	***2,555***
NAVSTA NORFOLK		14,316	15,845	15,775	15,312	***7,158***	***7,923***	***7,888***	***7,656***
NAVSHIPYD NORFOLK	VA	4,693	7,173	2,506	4,791	***2,347***	***3,587***	***1,253***	***2,396***
				VA REGION	***27,757***				***13,879***

Base	Location	Land-filled waste (tons)				Potential Energy Equivalent from Thermal Conversion Technology Megawatt Hours per Year			
MCCDC QUANTICO		235	988	6,676	2,633	***118***	***494***	***3,338***	***1,317***
SURFAC COMBAT SYS CTR		71	356	252	226	***36***	***178***	***126***	***113***
NSF DAHLGREN	VA	668	584	1,988	1,080	***334***	***292***	***994***	***540***
NATNAVMEDCEN BETHESDA		1,987	1,215	2,074	1,759	***994***	***608***	***1,037***	***880***
NAS PATUXENT RIVER		3,804	3,833	3,761	3,799	***1,902***	***1,917***	***1,881***	***1,900***
NSF CARDEROCK		1,077	1,193	1,126	1,132	***539***	***597***	***563***	***566***
U.S. NAVY, INDIAN HEAD		17,053	8,278	6,791	10,708	***8,527***	***4,139***	***3,396***	***5,354***
NDW SOUTH PATUXENT RIVER	MD	37,256	16,495	13,750	22,500	***18,628***	***8,248***	***6,875***	***11,250***
NAVAL RESEARCH LAB WASHINGTON	DC	1,267	1,267	1,984	1,506	***634***	***634***	***992***	***753***
				DC REGION	***45,342***				***22,671***
NAVPHIBASE LITTLE CREEK	VA	3,961	4,933	5,423	***4,772***	***1,981***	***2,467***	***2,712***	***2,386***
NAVSTA EVERETT		1,064	990	1,007	1,020	***532***	***495***	***504***	***510***
NAVAL SUBMARINE BASE BANGOR		4,658	3,636	3,921	4,072	***2,329***	***1,818***	***1,961***	***2,036***
NAVAL AIR STATION WHIDBEY ISLAND		1,916	1,845	1,842	1,868	***958***	***923***	***921***	***934***
NAVBASE KITSAP AT BREMERTON		7,696	6,029	6,424	6,716	***3,848***	***3,015***	***3,212***	***3,358***
WPNSUPFAC DET PORT HADLOCK		173	158	213	181	***87***	***79***	***107***	***91***
NAVHOSP BREMERTON	WA	250	225	316	264	***125***	***113***	***158***	***132***
				WA REGION	***14,121***				***7,061***
NAVIOCOM SUGAR GROVE		77	73	88	79	***39***	***37***	***44***	***40***
ABL ROCKET CENTER WV	WV	711	821	986	839	***356***	***411***	***493***	***420***
				WV REGION	***919***				***460***

Note: Numbers may not add up due to rounding. Also note that these tonnages are based on 2008 data that may not be consistent with current 2010 disposal tonnages.

(U.S. EPA, Compilation of Air Pollutant Emission Factors (AP-42) (PDF). Factors presented above assume 0.535 MWh electricity are generated per ton MSW combusted, based on 2005 data for MSW primary fuel units from eGRID. Use calculation factor of 0.5 MWh per ton for potential amount of recoverable energy by thermal combustion).

APPENDIX F: Existing Thermal Conversion Facilities

A list of existing thermal conversion facilities that utilize a solid waste and/or biomass feedstock was compiled by the University of California at Riverside in a report for the BioEnergy Producers Association is below.

The following table has been filtered to a limited number of thermal conversion projects which utilize municipal solid waste/biomass, and process approximately 100 tons per day or more, and which are currently in operation.

Selected Examples of MSW Thermal Conversion Facilities

ID #	Location	Company (Technology)	Start of Operation	Feedstock	Capacity	Syngas / Waste Heat Utilization
1	Kita-kyushu City (Shin-Moji), Japan	Nippon Steel	2007	MSW, Sludge	720 t/d	23.5 MW Power
2	Stuttgart, Arkansas, USA	Primenergy / Riceland	1996	Rice Hulls	600 t/d	Steam. Power
3	Kurashiki, Okayama Pref., Japan	Thermoselect /JFE	2005	MSW+Industrial	550 t/d	Fuel, Mizushima Works
4	Tokyo Rinkai Recycle Power, Japan	Ebara	2006	Industrial Waste	550 t/d	23 MW Power
5	Narumi Clean System, Nagoya, Japan	Nippon Steel	2009	MSW	530 t/d	9 MW Power
6	Ibaraki City #1, Osaka Pref., Japan	Nippon Steel	1980	MSW/CFC Gas	450 t/d	5 MW Power
7	RER Aomori RE Recycling, Japan	Ebara	2001	Industrial Waste, ASR	450 t/d	17.8 MW Power
8	Yorii, Saltama Prefecture, Japan	Thermoselect /JFE	2006	MSW+Industrial	450 t/d	SNG for Steam Turbine
9	Kawaguchi City, Japan	Ebara	2002	MSW	420 t/d	12 MW Power
10	Toyohashi City, Japan	Mitsui R-21	2002	MSW	400 t/d	8.7 MW Power
11	Akita City, Akita Prefecture, Japan	Nippon Steel	2002	MSW, Sludge	400 t/d	8.5 MW Power
12	Oita City, Oita Pref., Japan	Nippon Steel	2003	MSW, Sludge	387 t/d	9.5 MW Power
13	Hamm, Germany	Techtrade	2002	MSW, Sewage Sludge	353 t/d	Power Generation
14	New Bern, North Carolina, USA	Chemrec/Weyerhaeuser	1996	Black Liquor	330 t/d	Heat Energy for Mill
15	Chiba, Chiba Prefecture, Japan	Thermoselect /JFE	1999	Industrial Waste	330 t/d	Power for Steel Works

ID #	Location	Company (Technology)	Start of Operation	Feedstock	Capacity	Syngas / Waste Heat Utilization
16	Kita-kyushu Eco Energy, Japan	Nippon Steel	2005	Industrial Waste, ASR	320 t/d	14 MW Power
17	Ibaraki #2, Osaka Pref., Japan	Nippon Steel	1996	MSW	300 t/d	3.3 MW Power
18	Ishhaya, Nagasaki Pref., Japan	Thermoselect /JFE	2005	MSW	300 t/d	SNG for Steam Turbine
19	Goyang City, Republic of Korea	Nippon Steel/Posco E&C	2009	MSW	300 t/d	6 MW Power
20	Kagawa, Japan	Hitachi-Zosen	2004	MSW	300 t/d	Power Generation
21	Eco Valley, Utashinai City, Japan	Hitachi Metals	2004	MSW or ASW	274 t/d	7.9 MW Steam Turbine
22	Koga Seibu, Japan	Mitsui R-21	2003	MSW	260 t/d	4.5 MW Power
23	Kazusa Clean System #2, Japan	Nippon Steel	2006	MSW, Sludge	250 t/d	5 MW Power
24	University of South Carolina, USA	Nexterra Energy	2007	Wood Residues (Hog Fuel)	240 t/d	Steam & 1.38 MW Power
25	Ansbach, Germany	Thermoselect	2004	MSW	240 t/d	Power Generation
26	Yame Seibu, Japan	Mitsui R-21	2000	MSW	220 t/d	2.0 MW Power
27	Nishiiburi, Japan	Mitsui R-21	2003	MSW	210 t/d	2.0 MW Power
28	Nagareyama, Japan	Ebara	2004	MSW	207 t/d	3 MW Power
29	Izumo, Japan	Thide Environment	2003	MSW, Industiral & Sludge	70,000 t/y	Power Generation
30	Narashino City, Chiba Pref., Japan	Nippon Steel	2002	MSW, Sludge	201 t/d	2.4 MW Power
31	Itoshima Area, Fukuoka Pref., Japan	Nippon Steel	2000	MSW, Sludge, CFC gas	200 t/d	3 MW Power
32	Kazusa Clean System #1, Japan	Nippon Steel	2002	MSW, Sludge	200 t/d	3 MW Power
33	Yangsan City, Republic of Korea	Nippon Steel	2007	MSW	200 t/d	Hot Water Recovery
34	Ube City, Japan	Ebara	2002	MSW	198 t/d	4.1 MW Power
35	Sakata Area Clean Union, Japan	Ebara	2002	MSW	196 t/d	2 MW Power
36	Shiga Area Clean Union, Japan	Ebara	2007	MSW	180 t/d	3 MW Power
37	Lizuka City, Fukuoka Pref., Japan	Nippon Steel	1998	MSW, Sludge	180 t/d	1.2 MW Power
38	Tajimi City, Gifu Pref., Japan	Nippon Steel	2003	MSW, Sludge	170 t/d	2.0 MW Power
39	St. Joseph, Missouri, USA	Primenergy, Lifeline Foods	2006	Corn Fiber	168 t/d	Steam
40	Jonesboro, Arkansas, USA	Primenergy, Riceland	1997	Rice Hulls	168 t/d	Steam, Process Heat

ID #	Location	Company (Technology)	Start of Operation	Feedstock	Capacity	Syngas / Waste Heat Utilization
41	Chuno Union, Japan	Ebara	2003	MSW	168 t/d	2 MW Power
42	Ishikawa, Japan	Hitachi-Zosen	2003	MSW	160 t/d	Power Generation
43	Genkai Environmental Union, Japan	Nippon Steel	2003	MSW, Sludge	160 t/d	2.4 MW Power
44	Kyoboku Regional, Japan	Mitsui R-21	2003	MSW	160 t/d	1.5 MW Power
45	Burgau, Germany	Technip/Wast e Gen	1988	MSW, Sewage Sludge	154 t/d	Power Generation
46	Ibaraki #3, Osaka Pref., Japan	Nippon Steel	1999	MSW	150 t/d	1.7 MW Power
47	Nara, Japan	Hitachi-Zosen	2001	MSW	150 t/d	Power Generation
48	Shimada City, Shizuoka Pref., Japan	Nippon Steel	2006	MSW, Sludge	148 t/d	2.0 MW Power
49	Mutsu, Aomori Prefecture, Japan	Thermoselect /Mitsubishi	2003	MSW	140 t/d	SNG for Steam Turbine
50	Hata Regional Municipalities, Japan	Nippon Steel	2002	MSW, Sludge	140 t/d	1.8 MW Power
51	Ebetsu City, Japan	Mitsui R-21	2002	MSW	140 t/d	2.0 MW Power
52	Fukuroi City, Shizuoka Pref., Japan	Nippon Steel	2008	MSW	132 t/d	1.7 MW Power
53	Toyokawa Hoi Health Union, Japan	Nippon Steel	2003	MSW, Sludge	130 t/d	1.85 MW Power
54	Kagawa Prefecture #1, Japan	Nippon Steel	1997	MSW	130 t/d	1.6 MW Power
55	Trenton, Ontario, Canada	TRI/Norampa c	2006	Black Liquor Solids	127 t/d	Steam
56	Arras, France	Thide Environment	2004	Household Wastes	40,000 t/y	Industrial Steam
57	Iryu Health Facilities Adm., Japan	Nippon Steel	1997	MSW	120 t/d	1.1 MW Power
58	Niigata City, Niigata Pref., Japan	Nippon Steel	2002	MSW, Sludge	120 t/d	1.5 MW Power
59	Tokushima, Tokushia Pref., Japan	Thermoselect /JFE	2005	MSW	120 t/d	SNG for Steam Turbine
60	Nippon Steel, Nogoya Works, Japan	Nippon Steel	2006	Industrial Waste, ASR	120 t/d	Internal Steam Supply
61	Kamaishi City, Iwate Pref., Japan	Nippon Steel	1979	MSW/CFC Gas	100 t/d	Hot Water Recovery
62	Takizawa Village, Iwate Pref., Japan	Nippon Steel	2002	MSW	100 t/d	1.2 MW Power

APPENDIX G: Current Conversion Technology Developers

The following table provides a listing of “currently-proven commercial” (non-incineration) thermal technology developers compiled and maintained by Dr. Kay Martin of the BioEnergy Producers Association (BPA). BPA members participate as instructors in the UCLA Engineering Extension program and also serve as Advisors to the UCLA Engineering Extension’s Recycling / MSW Management Certification Training Program, and have provided an update for the purpose of this report. (Note: This is an ongoing effort, and does not include every project developer and/or technology.)

List of Developers of "Currently-Proven Commercial" Non-Incineration Technology
(Updated January 2010 by BioEnergy Producers Association)

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Ebara www.ebara.co.jp **11-1 Haneda Asahi-cho Ohta-ku, Tokyo 144-8510 Japan** **81-3-3743-6111**	Japan Plants: --Kawaguchi, --Nagareyama, --Ube City, --Sakata, --Chuno Union -Minami-Shinshu	Gasification With ash vitrification (TwinRec/TIFG technology)	500 TPD = approx. 5,300 – 6,400 kW	MSW	Ebara has ten commercial facilities in Japan that use the TwinRec/TIFG technology with capacities ranging from 15-550 TPD.
JFE Engineering Corporation www.jfe-eng.co.jp/en/ **Green Frontier Center 2-1, Suehiro-cho, Tsuri-ku, Yokohama, 230-8611 Japan** **Contact Person:** wakimoto-kazumasa@jfe-eng.co.jp **Tel: 045-505-6543**	Japan Plants: EcoFrontier 149 facilities	Gasification (with ash vitrification)	145 t/d (72.5 t/d x 2 lines) 7.2 MW	MSW (Also medical waste at same facility, with special unloading station co-located with MSW facility)	149 WTE facilities, 6 new facilities in construction state (2010)
Entech www.entech.net.au/ws2	"Over 50 international applications"	Pyrolytic gasification	Up to 20.5 MW of power & up to 95 MW of heat energy	Agricultural, forestry, food processing residues; MSW organics; medical, industrial, quarantine & hazardous wastes	Company markets individual modular units of .25-125 TPD with multiple systems up to 500 TPD. Plants in Korea, Hong Kong, Malaysia, P.N.G., Australia, Indonesia, Taiwan, and Poland.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Hitachi-Zosen **www.hitachizosen.co.jp** 7-89, Nanko-kita 1 chome Suminoe-ku, Osaka Japan 81-6-6569-0001	Japan plants: --Kagawa --Ishikawa --Nara --Nagasaki --Gifu	Fluidized bed gasification fusion	unknown	MSW	Company has 48 power generation plants operating in Japan (plants listed process MSW), with a total generating capacity of 280,000 kW. Plants contribute to lowering CO2 emissions in Japan by 1.25 million tons per year.
Interstate Waste Technologies (IWT) **www.iwtonline.com** 17 Mystic Lane Malvern, PA 19355 610-644-1665	Nagasaki, Japan Chiba, Japan Kurashiki, Japan	Thermoselect gasification	851 kWh/ton	110 TPD MSW, Industrial, Auto Shredder wastes 165 TPD MSW, Industrial waste 204 TPD MSW, Industrial, Plastic & Auto Shredder Residue	The Chiba facility has been operating since 1997, and the Nagasaki and Kurashiki facilities since 2005. The company also operates plants in Mutsu, Yorii and Tokoshima, opened in 2005, and in Izumi, opened in 2007. Company is an L.A. County solicitation demo project finalist.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Nippon Steel **www.nsc.co.jp** 6-3 Otemachi 2-chome Chiyoda-ku Tokyou 100-8071, Japan 81-3-3242-4111	Japan plants: -Ibaraki -Akita -Oita -Ibaraki #2 -Narashino City -Itoshima-Kumiai -Kazusa -Kagawatobu- -Kumiai -Lizuka City -Tajimi City -Genkai Environ-mental Union -Ibaraki #3 -Toyokama Union -Iryu-Kumiai -Maki-machi-kumiai -Kamaishi -Takizawa -Seino Waste -Kameyama	Gasification, pyrolytic thermal decomposition	unknown	MSW	Nippon Steel is primarily a steel manufacturing corporation, but operates a large number of small (88-500 TPD) facilities that process certain fractions of the municipal waste stream. The company claims to "recycle" (i.e. gasify) 30% of Japan's plastics, and 8% of the country's waste tires.
Ntech Environmental **www.ntech-environmental.com** **Devon, England** **00 34 971 549935**	-Malaysia -Hong Kong -Taiwan -Australia -Indonesia -Korea -P.N.G. -Poland	Entech gasification	573 kWh/ton	MSW	Over 100 Entech gasification units installed worldwide, with more than 20 fueled by MSW. Units range in size from 1.5-130 TPD, and have been in operation since 1990. The newest facility was permitted in 2006. Ntech is a finalist firm in the Los Angeles County solicitation for a demonstration facility.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
OE Gasification www.organicenergy.ca Organic Energy Inc. 32 Academy Crescent Waterloo, Ontario Canada N2L 5H7 519-884-9170	South Korea: -Jeanam -Gang Jin -Boseong -Pyungshan -Hapchon Norway: Hoff Sundnes Brennen	Gasification	unknown	Curbside MSW (200 metric TPD/6000 TPY)	Steam from gasification process utilized for power generation.
SilvaGas www.silvagas.com One Overton Park 3625 Cumberland Blvd. Suite 650 Atlanta, GA 30339 770-690-2450	Burlington, VT (scale demo) Winkleigh, Devon UK Forsyth Co., GA	Gasification	7 MW 23 MW Unknown	350 dry TPD of biomass 300 TPD wood wastes 400 TPD wood wastes, sawmill residue & ag wastes	Burling ton plant was a commercial scale demo that operated successfully from 1997-2002. The UK plant is currently under development. The proposed GA plant is intended to divert woody biomass from an adjacent operating C & D landfill.
Solena Group www.solenagroup.com The Ronald Reagan Building & International Trade Center 1300 Pennsylvania Avenue Suite G-0003 Washington, DC 20004 212-682-2405	Galicia, Spain	Plasma arc gasification	15 MW	Industrial, municipal & organic wastes	Solena Group builds, owns & operates renewable energy facilities throughout the world. Web site notes that Solena has five 40 MW renewable energy plants in CA, and two 90 MW plants in two major European cities, but specific site locations are not given. Solena is also partnering with Rentech (Los Angeles) for development of a syn-diesel plant in Gilroy, CA.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Takuma Co., Ltd www,takuma.co.jp 2-2-33 Kinrakuji-cho Amagasaki, Hyogo 660-0806 Japan	Kokubu, Japan Oshima, Hokkaido Island, Japan	Gasification	Unknown	89 TPD of MSW 66 TPD of MSW	Takuma has installed over 100 thermal power plants over the last 30 years, and specializes in the development and marketing of boilers and other plant components.
Technip Germany GmbH www.technip.com Theodorstrasse 90 40472 Dusseldorf Germany	Bergau, Germany	Pyrolysis	unknown	40,000 TPY of MSW	
Thermoselect www.thermoselect.com Piazza Pedrazzini 11 CH 6600 Locarno Switzerland 41-91-7562525	German plants: --Karlsruhe --Ansbach Fondotoce, Italy Japanese plants: --Chiba --Mutsu --Kurashiki City --Yorii, Saltama --Ishahaya, Nagasaki --Mutsu --Tokushima --Izumi, Osaka --Yamagata	Gasification	Unknown Unknown Unknown 1.5 MW 2.4 MW Unknown Unknown Unknown Unknown Unknown Unknown	225,000 TPY of MSW 240 TPD of MSW 30,000 TPY of MSW 100,000 TPY of MSW + commercial/industrial wastes 140 TPD of MSW 550 TPD of MSW + industrial 450 TPD of MSW + industrial 300 TPD of MSW 140 TPD of MSW Unknown Unknown	The Karlsruhe plant operated from 1999-2004. All other plants are currently operational.
Thidde/Hitachi	Izumu, Japan	Pyrolysis	Unknown	70,000 TPY of MSW	No additional information available on the web.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Waste2Energy Holdings Inc www.waste2energy.com www.enerwaste.com 1185 Avenue of the Americas 20th Floor New York, NY 10036 646-723-4000	Dumphries Dargavel, UK	Gasification	unknown	MSW and other biomass streams	Company acquired 95% interest in Enerwaste International Corp in Nov. 2007, which has over 40 projects installed or in design/manufacture worldwide. Modular Batch Oxidation System (BOS) units from 1-150 TPD. Hot effluent gas used to produce steam and electricity. Waste2Energy installing gasification and boiler units at UK plant.
Westinghouse Plasma Corp (WPC)/GeoPlasma www.westinghouse-plasma.com Plasma Center P.O. Box 410 Madison, PA 15663 *Project listed as under development	Japan plants: --Utashinai --Mihama-Mikata *St. Lucie, FL *New Orleans, LA *International Falls, MN *Tallahassee, FL	Plasma gasification	1.5 MW Unknown Phase 1: 60 MW Phase 2:120MW Unknown Unknown 30 MW	200-280 TPD of MSW + Auto shredder residue 20 TPD of MSW + 4 TPD of sewage sludge Phase 1: 1500 TPD of MSW Phase 2: 3000 TPD of MSW 2500 TPD of MSW 100 TPD of MSW MSW	The Japanese plants were developed by Hitachi Metals, Ltd. utiizing WPC technology. Florida plant being developed with Geoplasma. New Orleans plant under development with Sun Energy. Minnesota plant, the Coronal WTE project, being developed with the Koochiching Development Authority. This project will direct syngas to a neighboring paper mill to reduce natural gas usage. The Florida plant being developed with Green Power Systems. Two additional MSW processing facilities were scheduled for a 2008 start-up in Nagpur and Pune, India.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
ZEROS, Inc. www.zerosinc.com P.O. Box 888 Highlands, TX 775 62 281-424-2511	Killeen-Ft.Hood, Texas Monterey, Mexico Italy: 5 plants Tijuana, Mexico Bryan-College Station, Texas	Gasification	50 MW 100 MW 300 MW 50 MW 50 MW	MSW MSW MSW MSW MSW	ZEROS employs an Oxy-fuel two-stage reactor process. Reactors utilize pure oxygen instead of ambient air to oxidize feedstock fuels, and then the resultant syngas. Heat released by syngas oxidation is used to create steam for power generation. Syngas can also be steam-reformed by the F-T process to produce liquid diesel fuels. The Killeen-Ft. Hood, Monterey, Mexico and 5 Italian plants are all scheduled to begin construction in the 3rd Qtr. of 2009. Final project design and funding are pending for the Tijuana and Bryan-College station projects. In addition, ZEROS and its partners have announced 4 more Texas projects utilizing MSW feedstocks that are in various stages of procurement and permitting.

Updates provided by Dr. Kay Martin, BioEnergy Producers Association, January 22, 2010

APPENDIX H: Current Biological/Biochemical Technology Developers

The following table provides a listing of biological/biochemical technology developers compiled and maintained by Dr. Kay Martin of the BioEnergy Producers Association.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Abengoa Bioenergy **www.abengoabioenergy.com** 16150 Main Circle Drive Suite 300 Chesterfield, MO 63017 636-728-0508	York, NE (pilot plant) Salamanca, Spain (demo plant) Hugoton, KS (hybrid plant)	Enzymatic Hydrolysis	0.02 MGY 1.3 MGY 15 MGY (cellulosic) 85 MGY (corn)	corn stover wheat and barley straw 600 TPD of stover, plus straw, milo stubble & switchgrass	Abengoa is a major biofuels producer in the EU, US and Brazil, now moving into cellulosic ethanol. The York pilot plant was commissioned in 2007, and the Salamanca demonstration plant scheduled for 2008. The new $550M Kansas hybrid plant being developed in partnership with Mid-Kansas Electric Co. LLC (MKEC) and will add cellulosic production to a traditional corn ethanol plant. Abengoa will purchase 9M tons of local biomass @ $14.24/ton. Full-scale 2nd generation EtOH by 2012. The plant will also produce 29K TPY of lignin and 115 MW of power, 75 MW of which will be purchased by MKEC.
AE Biofuels **www.aebiofuels.com** 20400 Stevens Creek Blvd. Suite 700 Cupertino, CA 95014 408-213-0940	Butte, Montana (demo plant)	Enzymatic Hydrolysis	Unknown	Switch grass, grass seed straw, sugar cane bagasse, corn stover	AE Biofuels is a global vertically integrated biofuels company that owns or has optioned 5 permitted starch ethanol plants in the US, a 50M gallon biodiesel facility in India, and is planning a 75M gallon biodiesel plant in Argentina. The Montana demo plant is the first commercial application of its patent-pending cellulosic ethanol process. In September 2009, AE Biofuels, in partnership with Pearson Fuels, was awarded a $6.9 M grant through the DOE Clean Cities Program to build and supply 55 public E-85 fueling stations across CA. over the next 42 months.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Agresti Biofuels (formerly Indiana Ethanol Power, LLC) www.agrestibiofuels.com P.O. Box 216 Indianapolis, IN 46206 317-493-3246	Pike County, Ky. "Central Appalachian Ethanol Plant"	Dilute acid hydrolysis	20 MGY	1500 TPD of MSW	$200M plant ($87M in construction wages) planned for 40 acre Co. site near the Co. landfill. Project slowed due to setbacks in financing package, but construction slated for 2010. Plant will create 120 local jobs with average salary of $43K.
Agro Gas Industries LLC **www.kudzunol.com** 5430 Harper Street NW Cleveland, TN 37312	McMinn Co., TN	unknown	12 MGY	Agricultural & industrial wastes; native weed called kudzu.	Biodiesel project in planning phase.
Alpine Management Systems Inc. (formerly Colusa Biomass Energy Corp.) www.colusabiomass.com 1325 Airmotive Way Reno, NV 89502 775-852-7551	Colusa, CA	Ferments C5 and C6 sugars to ethanol using an existing closed-loop fermentation system employing genetically-engineered thermophilic bacteria (*Bacillus stearothermophilus*) developed by Agrol, Ltd. in the UK	10 MGY	waste rice straw and waste rice hulls	Will use approximately 120,000 tons per year of waste rice straw as the feedstock for the plant, which is located in a prime rice-producing area of the Sacramento Valley. The area -- which produces about 18% of the rice grown in the United States -- produces approximately 1.3 million tons of waste rice straw residue annually. Will produce ethanol, silica/sodium oxide and lignin from the waste biomass, including the waste rice straw, waste rice hulls and other cellulosics. Silica/sodium oxide is a widely used ingredient with applications in the paper industry, by detergent and soap producers and for the production of gels, catalysts and zeolytes. Also considering a site in Arkansas.

Company	Location	Technology	Production Capacity	Feedstock	Notes
American Ethanol Inc. **www.americasethanol.com** 2320 Thompson Way Santa Maria, CA 93455 805-925-0999	Santa Maria, CA	unknown	110 MGY	Molasses & waste biomass	Permitting reportedly near complete, & groundbreaking slated for late 2009. Plant site is converted sugar beet plant. Dry mill corn platform originally proposed, but molasses & waste biomass substituted to facilitate financing. Current plant status unknown.
American Process, Inc. **www.apiweb.com** 750 Piedmont Avenue, NE Atlanta, GA 30308 404-876-6704	Park Falls, WI	American Value Added Pulping (AVAP) utilizes alcohol sulfite cooking liquor to fractionate softwood chips into three lignocellulosic components	22.6 MGY	softwood chips	Co-produces ethanol and pulp.
BBI BioVentures LLC **www.bbibioventures.com** 300 Union Boulevard Suite 325 Lakewood, CO 80228 719-539-5655	unknown	Biochemical	4-5 MGY	Corn stover, wheat straw, wood	BBI Bioventures is a subsidiary of BBI International established in 2008 with the goal of operating multiple cellulosic ethanol plants in the US. Start-up of the first plant was projected for the second half of 2009, but no projects appear to have been initiated.
Bioenergy International LLC **www.bioenergyllc.com** 1 Pinehill Drive Batterymarch Park II, Suite 301 Quincy, MA 02169 617-657-5200 Clearfield Biorefinery Bionol Clearfield LLC 250 Technology Drive Clearfield, PA 16830	Clearfield, PA (pilot)	Enzymatic hydrolysis	unknown	Cellulosic wastes	Bioenergy International broke ground in Clearfield, PA on a 110 MGY corn ethanol biorefinery in 2008, with start-up slated for 1Q 2010. Cellulosic pilot plant to be collocated. Status unknown. Company CEO is Steve Gatto.

Company	Location	Technology	Production Capacity	Feedstock	Notes
BioGold Fuels Corp. www.biogoldfuels.com 1800 Century Park East Suite 600 Los Angeles, CA 90067 310-556-0025	Harvey County, Kansas	Unspecified "patented & proprietary technologies"	Unspecified volumes of electricity, "engineered fuel cubes, synthetic diesel fuel, and organic chemicals"	Mixed MSW. 33,500 TPY from Harvey County, plus imported waste	BioGold Fuels has 30-year agreement with Harvey County for 32 acre site, transfer station & existing processing equipment, plus profit-sharing on product sales. Long-term development agreement with ICM to engineer, design & build plant. Initial secured debt financing thru Heritage Opportunity Fund, LLC.
Biomass Converters, Inc www.biomassconvertersinc.com 5574 Clearfield Woodland Hwy Clearfield, PA 16830 814-765-5875	Clearfield, PA	Enzymatic hydrolysis	30 MGY	Hardwood waste	Technology proven at NREL test facility, and utilizes organisms developed at Purdue U. Facility start-up scheduled for 2011.
Biovision Technology, Inc www.biovisiontech.ca 1009 Peter Street New Minas, Nova Scotia Canada B4N 3L7 902-681-2314	New Minas, Nova Scotia, Canada (pilot)	Biochemical, utilizing steam fractionation and Vertical Linear Converter (VLC) technology	unknown	Wood chips	The company reports that it has completed the Proof of Concept Phase (technology choice and design, partner identification and acquisition, business planning, and financial modeling) and is now commercializing the technology. Phase 1 of the Commercialization Phase is underway and was scheduled to be completed by 1Q 09. No update available.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Bluefire Ethanol www.bluefireethanol.com 31 Musick Irvine, CA 92618 949-588-3767	Lancaster, CA Fulton, MS South Korea (proposed)	Arkenol Process Technology (Concentrated Acid Hydrolysis)	3.9 MGY; max of 18-19 MGY 18 MGY	Lancaster plant permitted for 170 TPD of green waste, wood waste, and other cellulosic urban wastes. Non-food cellulosic wastes	Lancaster permits complete. Recipient of $40M DoE grant, but project still not fully funded. Second plant originally planned for Mecca, CA moved to Fulton, MS. Project has received $88M in DoE funding and is currently in the permitting process. Professional Services Agreement (PSA) signed with Ubiex, Inc. in December 2008 to develop a cellulosic ethanol plant in South Korea. Recent agreement with algal synthetic biofuel producer Solazyme to test Bluefire sugars for creation of oils for renewable energy industry use.
Casella Waste Systems www.casella.com 25 Greens Hill Lane Rutland, BT 05701 800-227-3552 802-775-0325	Ontario Co., NY	Gasification	Unspecified yields of liquid fuel for County vehicles	MSW	Proposed $7M pilot plant, with possible $100M full-scale commercial operation. Life of landfill operated by Casella under contract to the County could be extended by 25 years.
Catalyst Renewables Corp www.catalystrc.com 2602 McKinney Avenue Suite 200 Dallas, Texas 75204 214-880-3400	Lyonsdale, NY	Biochemical technology developed by SUNY's Environmental Science & Forestry College	130,000 GY	Wood chips	Biorefinery to be constructed adjacent to the company's existing 19 MW wood biomass CHP facility. Project received over $10.3 million in funding from New York State.
Chemrec AB www.chemrec.se Floragatan 10B SE – 114 31 Stockholm, Sweden +46-8-440-4060 **Chemrec USA Inc** 500 Lake Cook Road, Ste 350 Deerfield, IL 60015 847-580-4267	Pitea, Sweden Weyerhauser New Bern, NC	Gasification	unknown	Pulp mill black liquor	Company is developing pulp mill biorefineries to produce biofuels (DME, methanol, and F-T diesel) from syngas.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Chloren Industries GmbH www.chloren.com Frauensteiner Strasse 59 09599 Freiberg Germany +49 3731 2662 266	Freiberg/Saxony Germany	Gasification/F-T catalysis	unknown	"Agricultural and forestry biomass, biogenic waste & recycling substances"	Construction on first commercial-scale biomass-to-liquids (BTL) plant nearly complete. Product will be synthetic diesel (SunDiesel).
Clean Earth Solutions www.reinventingenergy.com 1525 South Escondido Boulevard Suite D Escondido, CA 92025 619-463-0723	Shreveport, LA	Pressurized Steam Classification (PRC)	2 MGY	MSW	Company recently acquired the PSC equipment from Taormina Industries (Republic) MRF in Anaheim. PSC is a pressurized autoclave unit that separates cellulose from the MSW stream. No information on the cellulose conversion process planned for the Louisiana demo plant.
CleanTech Biofuels www.cleantechbiofuels.net 7386 Pershing Avenue St. Louis, MO 63130 314-802-8670	Golden, CO (demo plant) Chicago, Illinois transfer station	Testing acid hydrolysis reactor purchased from UC Berkeley Acquired patent from World Waste for SW preprocessing (steam classification)	Testing phase on feedstock processing; 36K GPY from 4 TPD of MSW	MSW biomass, converted to homogeneous biomass feed through Pressurized Steam Classification (i.e. hydropulper).	Pilot plant to be completed by 2010 at Hazen Research Inc's 8-acre research site in Golden. Development of commercial demonstration plant to follow. Transfer station acquired in Chicago for testing of feedstock pre-processing technology. Venture capital firms Burrill & Co. and Khosla Ventures have recently invested in the company.
Clear Fuels Technology, Inc. www.clearfuels.com Hawaii Agriculture Research Center 99-193 Aiea Heights Drive Suite 308 Aiea, HI, 96701 808-221-2570	Alea, Hawaii	Gasification	unknown	Sugar cane bagasse & cane trash	Planned integration of thermochemical ethanol and syngas production from cellulose with existing sugar mills and sugar fermentation facilities. Clear Fuels received a $23M DoE grant with Rentech in Dec. 2009 to build an integrated biorefinery at Rentech's Denver PDU utilizing CFT's gasifier.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Cobalt Technologies www.cobaltbiofuels.com 500 Clyde Avenue Mountain View, CA 94043 650-230-0760	Mountain View, CA	Enzymatic hydrolysis	unknown	Forest waste & mill residues	Biobutanol production plant opened in January 2010. Appears to be a pilot demo, with a larger commercial scale-up planned.
Coskata www.coskata.com 4575 Weaver Parkway Suite 100 Warrenville, IL 60555 630-657-5800	"Project Lighthouse" Madison, PA	Gasification and fermentation	40,000 GY	Woody biomass, and agricultural & industrial wastes. Can use any carbon-based material.	$25M semi-commercial demonstration project collocated with Westinghouse Plasma Corp/Alter NRG Corp. gasification facility that delivers syngas to Coskata plant. Under partnership with Coskata, GM will use ethanol for testing in flex-fuel vehicles at Milford, MI proving grounds. Coskata has retained Alter NRG for engineering of full-scale 50-60MGY commercial plant slated for 2011.
DuPont Danisco Cellulosic Ethanol LLC **www.ddce.com** **Genera Energy LLC** **(UT Research Foundation)** **www.generaenergy.net** **www.utbioenergy.org** **Itasca, IL** **585-256-5272**	Pilot-scale biorefinery at Niles Ferry Industrial Park, Vonore, TN	DuPont's Genencor enzymatic hydrolysis	250,000 GY	Switchgrass & corn stover	Joint project between DuPont & University of Tennessee via Genera Energy. State funding commitment of $70.5 M, including $40.7M for plant construction. Plant completed with production commenced in January 2010.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Dynamotive Energy **www.dynamotive.com** Vancouver, BC, Canada	Willow Springs, MO. El Dorado, AK	"Fast pyrolysis"	12MGY unknown	Wood product & wood residues	Company operates Canadian bio-oil plants in Waterloo, Guelph & W. Lorne. Missouri plant will produce cellulosic ethanol. Arkansas plant, scheduled for construction in 2010 and deployment in 2011, will produce bio-oil.
Ecofin, LLC (subsidiary of Alltec Inc.) 3031 Catnip Hill Road Nicholasville, KY 40356 859-885-9613	Washington County, KY	Biochemical solid state fermentation process	1.3 MGY	Corn cobs and other lignocellulosics	One of three companies to receive DoE biorefinery funding in April 2008. Pilot facility estimated to be operational in 2010.
EcoTech Fuels LLC **www.ecotech.com** P.O. Box 341697 Los Angeles, CA 90034	Crow Creek Sioux Reservation, SD	Gasification/catalysis	6 MGY	MSW	Tribe has approved an MOU with EcoTech to develop a $39M 100 TPD plant for conversion of MSW to torqualine, a high-octane oxygenate fuel additive, or neat fuel for FFVs. MOU involves a 10% profit share for tribe, raising to 33% if they assist in securing federal grant monies for the project. EcoTech projects plant completion in 2011-2012.

Company	Location	Technology	Production Capacity	Feedstock	Notes
EdeniQ **www.edeniq.com** 1520 N. Kelsey Street Visalia, CA 93291 559-302-1777 (Spin-off from AltraBiofuels) **www.altrabiofuels.com** EdeniQ partnering with: Logos Technologies **www.logostech.net** 2300 First Street, Ste 228 Livermore, CA 94550 925-344-4339	Visalia, CA "Visalia Industrial Park Pilot Plant"	Unspecified proprietary biorefining process ("neither syngas nor acid hydrolysis")	50,000 GPY	Corn stover, switchgrass, wood chips from recycling & composting facilities central CA	Altra Biofuels is a mid-West corn ethanol producer, and acquired the Goshen, CA plant operated by Phoenix BioIndustries, LLC. Altra Biofuels owns over 30% of EdeniQ's outstanding equity and is its largest shareholder. EdeniQ reportedly started licensing its technology in Fall 2008, which it characterizes as low-cost/high yield. Partnering with Logos Technologies, which received a $20.4M DoE grant in Dec. 2009 to demo 2 TPD ethanol production from non-food cellulosic biomass.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Enerkem www.enerkem.com 615 Rene-Levesque Blvd. W Suite 820 Montreal, QC H3B 1P5 Canada 514-875-0284	Edmonton, Alberta Westbury, Quebec Pontotoc, Miss.	Gasification/catalysis	36M liters or 9.5 MGY 1.3 MGY 10 MGY	100,000 tpy of post-recycled MSW Creosoted telephone poles; also designed to process sorted MSW and forestry biomass. The technology produces 95 gallons of ethanol per ton of waste. MSW	The two plants are a JV with Greenfield Ethanol, a Canadian company that currently produces ethanol from corn. Enerkem has operated a pilot plant (4 tpd) in Sherbrooke, Quebec since 2003. The Westbury plant has been completed, and initiated start-up operations in January 2009. The Edmonton plant is being developed in partnership with GreenField Ethanol, Canada's largest ethanol producer. Permits were granted in May 2009, and the $10 M advanced energy research facility is expected to be completed in the first quarter of 2010. Enerkem has a 25-year agreement with the City of Edmonton to build, own, and operate the plant. The City will supply 100K TPY of sorted MSW to the plant. Enerkem awarded $50M DoE grant for 300 TPD Pontotoc facility, slated for construction in 2010. Supply agreement for 189K TPY of unsorted MSW with Three Rivers Solid Waste Management Authority. Second module planned, to bring production to 20 MGY.

Company	Location	Technology	Production Capacity	Feedstock	Notes
EnerTech Environmental Inc www.enertech.com 675 Seminole Avenue, Suite 207 Atlanta, GA 30307 404-355-3390	Rialto, CA	SlurryCarb Process	60,000 TPY of EFuel	270,000 TPY of sewage sludge	EnerTech converts biosolids into a solid fuel (EFuel) for use in cement kilns. Biosolids are macerated into a slurry, and then undergo pressurization and heating to produce a chemical reaction (carbonization). The cellular structure ruptures, splitting off CO2 from the biosolids, and the slurry is then dewatered and dried. The EFuel product has a heating value of 7,000 Btu/lb., and produces essentially zero net GHG's.
Evolution Resources www.evoresources.com 43 Yazoo Avenue Clarksdale, MS 38614 662-655-1077	Moses Lake, WA Bastrop (SE US)	Unknown	4 MGY 60 MGY	Wheat straw Wood chips	Company received a $1M from Washington State's Energy Efficiency & Renewable Energy loan facility to develop the Moses Lake pilot demo, expected to come on line in mid-2010. Company also exploring retrofit of closed paper pulp mill in Bastrop for future plant, to include 1000 acre test plot of bamboo for new feedstock.
Fiberight LLC www.fiberight.com P.O.Box 21171 Catonsville, MD 21228 800-728-9886	Lawrenceville, Virginia (pilot) Blairstown, Iowa (proposed retrofit)	Pulping pretreatment Enzymatic hydrolysis Plastics depolymerization	Unknown 8.6 MGY (2 MGY in 1st full yr. of operation)	MSW, Paper mill sludge	Pilot facility operational since 2006. Company purchased shuttered Blairstown ethanol plant formerly owned by Xethanol , and is completing $20M retrofit for MSW. Pretreatment of MSW includes separation of plastics, to be depolymerized into oils to power the plant.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Flambeau River Biofuels, LLC www.flambeauriverpapers.com 200 1st Avenue N Park Falls, WI 715-558-1630	Durham, NC (pilot) Park Falls, WI	Thermochemical (gasification with Fischer-Tropsch catalysis)	6 MGY pilot 18 MGY of FT liquids & waxes	Forestry residue, other wood wastes & noncommercial wood 350,000 BDTY woody biomass	Company granted $30M from DoE for development of pilot facility. Pilot located at Southern Research Institute in Durham with 1000 hrs. of testing to meet requirements of DoE loan guarantee. $257M Park Falls commercial scale plant in engineering phase. Plant will get feedstock supply from adjacent paper mill in exchange for supplying mill with steam valued at $10M/yr. Groundbreaking in 2010, and operations by 2012.
Florida Crystals Corp www.foridacrystals.com 1 N. Clematis Street Suite 200 West Palm Beach, FL 33401 561-366-5100	Okeelanta, FL (research pilot)	Biochemical	unknown	Sugar cane bagasse	Florida Dept of Environmental Protection awarded a $1M grant to Florida Crystals Corp and Florida International University's Applied Research Center to develop new preprocessing treatment for bagasse conversion to sugars that can be readily fermented into ethanol. Pilot facility planned to assess the feasibility of commercialization of the technology.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Fulcrum BioEnergy, Inc. www.fulcrum-bioenergy.com 4900 Hopyard Road Suite 220 Pleasanton, CA 94588 925-730-0150	Storey County, Nevada "Sierra Biofuels Plant" at Tahoe-Reno Industrial Center	Plasma-enhanced gasification process licensed by Integrated Environmental Tech-nologies with patented catalytic technology for syngas conversion to ethanol	10.5 MGY	90,000 TPY of post-recycled MSW	Fulcrum announced on September 1, 2009 that their technology has been successfully demonstrated at the company's Turning Point Ethanol Demonstration Plant. The scale-up $120 M Sierra Biofuels Plant will begin construction in 2009, with operations starting in 2011. Company awaiting notification of receipt of DOE loan guarantee, and may be awaiting completion of intermediate scale-up demonstration of technology by Nipawin Biomass Ethanol New Generation Co-operative Ltd. and Saskatchewan Research Council. Fulcrum will design, finance, construct, own and operate the Sierra Biofuels plant. Company states that it is one of several currently under development across the country.
Genahol LLC www.genahol.com P.O. Box 611 Wooster, OH 44691 330-264-9878	Canton, OH	unknown	16-32 MGY	500-1500 TPD of MSW	Target groundbreaking has been set for 2010. Site development reportedly underway, but project funding requirements have not been met.
Global Clean Energy www.globalcleanenergy.net 1241 South Parker Road, Ste 201 Denver, CO 80231 303-522-8449	Salaberry-de-Valleyfield, Quebec	Gasification	10MGY at commercial scale	MSW	Agreement between GCE & City of SdV to test a gasification technology to convert MSW into syngas & biodiesel. Project has received a grant from the Green Municipal Fund of the Federation of Canadian Municipalities. Scale-up planned in two phases: demo processing at 12.5K metric TPY, and commerical at 30-50K metric TPY.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Gulf Coast Energy www.gulfcoastenergy.net	Livingston, AL	Gasification w/F-T catalysis	PDU, with planned 20-60 MGY expansion	Wood wastes	PDU built in an abandoned lumber mill, and supplying small amounts of ethanol to nearby City of Hoover. Other projects planned for Hawesville, KY, Hodges, AL, Cleveland, TN, and Mossey Head, FL.
ICM, Inc. www.icminc.com 310 N. First Street Colwich, KS 67030 877-426-3113	St. Joseph, Missouri (pilot)	Biochemical and thermochemical	1.5 MGY	Corn fiber, switchgrass, corn stover, and sorghum	One of 4 small biorefinery projects selected by DoE to share up to $114M in funding over four years. Biorefinery to be collocated with existing 50M gallon corn ethanol facility. DoE negotiations halted in Jan 2009, and status unknown.
Inbicon www.inbicon.com Kraftvaerksvej 53 7000 Fredericia Denmark +45 99 55 11 11	Kalundborg, Denmark (PDU)	Enzymatic hydrolysis	1.5 MGY	Corn stover, barley & rice straws, bagasse, palm oil processing waste, garden & household wastes	25 TPD PDU built in Biomass Technology Campus and integrated with Dong Energy Power Plant, which supplies the PDU with feedstock pretreatment steam in exchange for lignin fuel.
Integrated Environmental Technologies LLC (InEnTec) www.inentec.com 595 SW Bluff Drive, Suite B Bend, OR 97702 509-946-5700 **S4 Energy Solutions LLC** www.s4energysolutions.com (InEnTec Joint Venture with Waste Management, Inc.)	Richland, WA (Pilot demo at InEnTec Technology Center)	Plasma Arc (Plasma Enhanced Melter—PEM™)	Unknown Products from syngas include power, chemicals & transportation fuels	Initial focus on medical & other special waste streams; future plans include MSW	Technology initially developed at MIT & Pacific Northwest National Lab. PEM units operated successfully in Pacific Rim & Hawaii. Can process hazardous, medical, radioactive, industrial, municipal & tire wastes. Richland demo has been used to process portions of City of Richland's MSW & to further commercialize the technology. Joint venture with Waste Management, to be known as S4 Energy Solutions LLC, announced in May 2009 to develop, operate and market plasma gasification facilities.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Iogen Corp. www.iogen.com 1749 Old Meadow Road Suite 640 Mclean, VA 22102 703-752-9660	Ottawa, Canada (pilot plant) Saskatchewan (proposed commercial plant)	Enzymatic hydrolysis	2.5M liters or 650K gal/yr 90M liters or 23M gal/yr	Agricultural residues including wheat straw, barley straw, corn stover, switchgrass and rice straw	PDU operating since 2004. Partnerships with Petro-Canada, Royal Dutch/Shell Group and Canadian government. Shell has 50% stake in Iogen Energy Corp. Pilot plant shipped first 100K liters of an 180K initial order to Royal Dutch Shell in Sept. 2008. Site selected for Saskatchewan plant, but no commitments yet to develop. Plans to build first US plant in Shelley, ID under DoE grant abandoned.
KL Energy Corp. (formerly KL Process Design Group, LLC) www.Klenergycorp.com 306 East St. Joseph Street Suite 200 Rapid City, SD 57701 605-718-0372	Upton, WY "Western Biomass Energy Facility" Hudson Bay, Saskatchewan	thermal-mechanical process	small scale 5 MGY	soft wood, waste wood, including cardboard and paper Wood wastes	Began producing ethanol in January 2008. Technology developed in conjunction with South Dakota School of Mines and Technology. Letter of intent signed in March 2009 for scale-up facility with Prarie Green Renewable Energy (see entry below).
Liberty Industries, Inc. Lowry, Florida 850-379-9366	Hosford, FL	unknown	7MGY plus 5.4 MW of power	Forestry wastes, crop residues, and MSW	$38M cellulosic ethanol plant under development. Recipient of $4M "Farm to Fuel" grant.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Lignol Energy Corp **www.lignol.ca** 4705 Wayburne Drive Burnaby, British Columbia Canada V5G 3L1 604-222-9800	Burnaby, BC Grand Junction, CO (project suspended 2/09)	Biochemical (using solvent-based pre-treatment technology)	100,000 liters/yr. 10 MGY	Forestry residues 100 TPD of hard & soft wood	Lignol Energy has received major funding for construction and testing of their Burnaby commercial demo plant, including over $5M from the Alberta Government, $6.24M from Sustainable Development Technology Canada, $1.96M from BC's Innovative Clean Energy Fund, $1.82M from the BC Bioenergy Network, and $3.4M from the BC Liquid Fuels from Biomass Program. Construction began in June 2009, and start-up in April 2009. A planned project with Suncor Energy in Colorado was awarded a $30M DoE biorefinery grant in 2008, but plans were suspended in February 2009 due to ethanol market uncertainty. Lignol Energy has also entered into an MOU with Weyerhaeuser to explore potential collocation of a biorefinery with a mill site.
Liquifaction Corp and Moses Lake Ethanol LLC **www.liquacorp.com** 2221 180th Place NE Redmond, WA 98052 206-399-9717	Moses Lake, WA	Enzymatic hydrolysis w/ Low Temperature Steep Delignification (LTSD) pretreatment	60 MGY	Straw, paper waste, wheat	All permits obtained. Targeted groundbreaking for retrofitted former ethanol plant was Spring 2009.
Losonoco **www.losonoco.com**	West Palm Beach, FL	Plasma arc gasification (Skygas process)	25 MGY	Agricultural and urban yard wastes	Skygas technology demonstrated in Italy. Company plans a 125 TPD demo at one of their Florida corn ethanol plants. Losonoco plans to build 4 plants in Florida with a total capacity of 300 MGY.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Masada Resource Group, LLC www.masadaonline.com 2170 Highland Ave, Ste 200 Birmingham, AL 35205 205-558-4665	Middletown, Orange County, New York Dominican Republic	CES OxyNol (acid hydrolysis/ fermentation)	9 MGY 30 MGY	800 TPD of MSW biomass, plus sewage sludge; contracts with 20 local communities to handle over 200,000 tpy of MSW MSW	Efforts to develop New York plant ongoing for over a decade. Plant fully permitted, but major challenge is financing— cost est. at $130M in 2000 has reportedly escalated to $285M. 20-year agreement signed in December 2007 with Dominican Republic WM firm, R.J. Zapata & Assoc., to develop local plant. Company focus on partnering with WM firms in Carribean, Central & South America. Partnership with international entrepreneur Robert H.J.Lee to market waste-to-ethanol facilities abroad announced in October 2009.
Mascoma/University of Tennessee **Mascoma**/ New York State Energy Research and Development Authority/New York State Department of Agriculture and Markets **Mascoma**/Michigan Economic Development Corporation/Michigan State University/ Michigan Technological University www.mascoma.com 1380 Soldiers Field Road Second Floor Boston, MA 02135 617-234-0099	Monroe County, TN Rome, NY (pilot demonstration plant) Kinross, Michigan	"Consolidated Bioprocessing (CBP)" (Enzymatic hydrolysis)	5 MGY Up to 200K gallons 40 MGY	lignocellulosic biomass, including switchgrass , paper sludge, and wood chips Wood chips, grasses, corn stover, and sugar cane bagasse Wood chips	The business partnership with the University of Tennessee is the result of Gov. Bredesen's Biofuels Initiative. It includes a $40 million investment in facility construction and $27 million for research and development activities. Rome plant funded in part by grants from the State of New York. Start-up in Feb 2009. October 2008 press release announced a $26M award from DOE and $23.5M from State of Michigan for dev. of the full-scale commercial plant. Support also provided by General Motors and Marathon Oil Company. A strategic partnership with GM was announced in May 2008. Construction slated to begin in 2010, and start-up projected for 2011-2012.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Minnesota Cellulosic Ethanol Partners	Little Falls, Minn.	SunOpta's steam implosion pretreatment & biochemical conversion	10 MGY	Wood chips	Plant is a JV between SunOpta (see chart entry below), Central Minnesota Ethanol Co-op, & Bell Independent Power Co. to be collocated with the Co-op's existing 21.5 Mmgy ethanol plant in Little Falls. Each partner has a one-third ownership. Project awarded a $1Million grant by the Minnesota Dept of Agriculture. In addition to ethanol production, the plant will generate its own electricity.
INEOS New Planet BioEnergy, LLC www.newplanetenergy.com www.ineosbio.com 2600 South Shore Blvd, Ste 200 League City, TX 321-368-2044	Vero Beach, FL	INEOS Bio Ethanol process (gasification, fermentation and distillation)	Stage 1: 8 MGY Stage 2: 42 MGY	Municipal solid waste (MSW); unrecyclable paper; Construction & Demolition debris (C&D); tree, yard and vegetative waste; and energy crops	New Planet Energy & its partner INEOS Bio received $50M DoE grant in Dec. 2009 for construction of Vero Beach plant. Site preparation early 2010, with stage 1 in operation late in 2011 and stage 2 in operation in 2013. Technology also produces steam from syngas cooling that can be utilized for power production without combustion.
Old Town Fuel & Fiber P.O. Box 56424 Old Town, Maine 04468	Old Town, Maine	Enzymatic hydrolysis (sugar fermentation)	2.2 MGY	Waste paper pulp	Paper mill working with University of Maine to develop onsite $60M demonstration plant for converting paper pulp into ethanol. $30M DoE grant awarded in April 2008.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Pacific Ethanol **www.pacificethanol.net** 400 Capitol Mall, Suite 2060 Sacramento, CA 95814 916-403-2123	Boardman, OR	BioGasol wet explosion pre-treatment with enzymatic hydrolysis (fermentation)	2.7 MGY	120-125 TPD (40K metric tons/yr.) of wheat straw, corn stover & poplar hybrid residues	$48.7M demo plant to be collocated with an existing 40 MGY corn ethanol plant. $24.3M grant received from DoE. Facility intended for scale-up as add-on to corn ethanol plants or stand-alone commercial cellulosic plants beginning 2012-2013. Three of Pacific Ethanol's 4 corn plants are offline due to adverse market conditions. Current challenge is to raise cost-share for DoE funding. Company recently filed for bankruptcy protection.
POET, LLC **www.poet.com** 4615 North Lewis Avenue Sioux Falls, SD 57104 605-965-2200	Emmetsburg, IA "Project Liberty" Scotland, SD	Integrated corn- and cellulose-to-ethanol	125 MGY 20,000 gal. pilot	Corn fiber, corn cobs and corn stalks Corn cobs and fiber	The $200M commercial plant in Emmetsburg, IA after expansion will produce 125 mgy of ethanol, of which approx. 25 mgy will be cellulosic ethanol. Cellulosic production by 2011. DoE funding contribution to the project will total $100M by 2011. Grand opening of $8M Scotland, SD. pilot plant held in January 2009. $76.3M in federal funding received for cellulosic component. Poet to make cellulosic ethanol at all 26 of its starch ethanol plants, with a combined capacity of 1.5 billion gal/year. Poet proposing to build a dedicated 1800-mile, $3.5 billion ethanol distribution pipeline from South Dakota to major terminals in the Northeast, terminating in New Jersey.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Powers Energy of America Powers Energy One of Indiana **(formerly Genahol-Powers 1, LLC)** **www.genahol.com** P.O. Box 5404 Evansville, IN 47716 **Powers Energy Two of Kentucky**	Lake County, Indiana Henderson or Webster Co, KY	INEOS Bio Ethanol process (gasification/fermentation)	30 MGY 47MGY	2000 TPD of MSW 2000 TPD of auto fluff & small amount of tars	Technology licensed. Actual funding or project construction uncertain. Powers Energy One recently won the Lake County bid to build the $80M plant. Currently in the permitting stage. Air permit has been obtained for Kentucky plant, along with $335K planning grant and $15M energy grant. Targeted groundbreaking was May 2009.
Prairie Green Renewable Energy www.prairiegreenenergy.com 888 3rd Street SW, Suite 1000 Calgary, Alberta Canada T2P 5C5 403-444-5985	Hudson Bay, Saskatchewan	KL Energy thermal process	5 MGY	Wood wastes	Prairie Green Renewable Energy is developing a 50.3 Mmgy dry mill plant (barley & peas) at Hudson Bay, and has signed a letter of intent with KL Energy for development of a companion cellulosic plant (see KL Energy entry above).
Pure Vision Technology **www.purevisiontechnology.com** 51 McKinley Fort Lupton, CO 80621 303-857-4530	Fort Lupton, CO (PDU/pilot facility)	Biochemical (biomass fractionation w/ enzymatic hydrolysis)	unknown	1000 lb/day of cellulosic biomass (corn stalks and corn cobs, wheat straw, woody biomass, grasses, bagasse)	PDU operated on 100 lb/day thruput from 2004-2008. Pilot scale-up to ½ TPD this year. Planned scale-up to 20 TPD reactor, to be deployed at a targeted site in 2010.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Qteros (formerly SunEthanol) www.qteros.com 100 Campus Drive Marlborough, MA 01752 508-281-4060	Unknown	Q MicrobeT fermentation	N/A	Woody biomass or other cellulosics	Company currently improving the strain of the Q Microbe, that produces its own enzymes and combines enzymatic breakdown of sugars and fermentation into one step. Bioconversion yields of over 90%/70 grams per liter. Qteros working with DOE and Dept. of Ag, and exploring scale-up with potential partners. Funded by BP, Valero, Soros Quantum Fund, Battery Ventures, and Venrock. Internal pilot plant to be built in 2009, external pilot plant in 2010, and large-scale demo by 2011. JV in Oct. 2009 with Applied CleanTech (Israel) to produce ethanol from biosolids and municipal wastewater.
Range Fuels Inc. www.rangefuels.com 11101 W. 120th Avenue Suite 200 Broomfield, CO 80021 303-410-2100	Broomfield, CO (demo facility) Soperton, GA	Two-step thermo-chemical process (heat, pressure & steam used to produce syngas, which is then passed over a catalyst to produce ethanol)	10 MGY under construction, with intent to to 100 MGY	Wood residues and wood-based energy crops, grasses and corn stover	Facility under construction. Phase I broke ground on November 6, 2007. Production expected to begin in 2010. Technology proven at bench and pilot scale for 7 years on 20 different non-food feedstocks. USDA recently awarded Range Fuels an $80M loan guarantee—the first ever for a cellulosic ethanol plant.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Raven Biofuels International www.ravenbiofuels.com 61 South Paramus Road Paramus, NJ 07652 866-929-7823	Kamloops, BC, Canada Ackerman, Miss. Washington State	Dilute acid hydrolysis	7 MGY 21 MGY ethanol + 12MGY of speciality organic chemicals 11MGY	Forestry wastes (beetle-killed wood) Wood chips & wood waste 500 TPD of wood chips, C&D wastes	The British Columbia project is being developed under an MOU with the Kamloops Indian Band, and will include the biorefinery and a co-gen plant. The Mississippi project is being developed on a 35 acre site in the Red Hills EcoPlex located in the Gulf Opportunity Zone, and includes an adjacent co-gen facility. The Washington State plant cost has been estimated at $30 Million.
Renewable Energy Institute International (REII) www.reiinternational.org 5022 Bailey Loop McClellan, CA 95652 916-239-6220 (see also **Synterra Fuels**)	Toledo, OH (PDU) Gridley, CA	Pyrolysis/steam reforming plus F-T catalysis	350K GPY (syndiesel)	Waste biomass Rice straw, wood waste and other local biomass residue	The Toledo project, a 25 TPD PDU located near the Port of Toledo, will employ a technology developed by Red Lion Bio-Energy to produce synthetic diesel. REII formed an alliance of academic, government & industry organizations (including the Synterra JV partners), and received a $19.9M DoE grant in Dec. 2009 to upgrade the PDU. Under contract administration by DOE, assessments were completed for development of a proposed Gridley Ethanol Project that would co-produce biofuel and electricity from local rice straw. Diesel fuels are now the focus for the Gridley Biofuels Project. REII plans to begin deploying commercial-scale plants during 2011-12, each of which will have the capability of producing 5-42 MGY of clean diesel.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Rentech, Inc. www.rentechinc.com 10877 Wilshire Blvd., Ste 710 Los Angeles, CA 90024 310-571-9800	Sand Creek, CO (PDU) Gilroy, CA (JDA w/ Solena Group) East Dubuque, IL (proposed) Rialto, CA (Rialto Renewable Energy Center)	Fischer-Tropsch gas-to-liquids/coal-to-liquids Solena Group gasification technology + Rentech Fischer-Tropsch Biomass gasification + Rentech proprietary technology SlivaGas Corp. Gasification	10 barrels/day of ultra-clean diesel, aviation fuels, naphtha & specialty waxes & chemicals 1500-3000 barrels of jet fuel and naptha Unspecified “advanced bio-fuels & bio-fertilizer” Synthetic diesel +35 MW power	Natural gas, coal, and biomass (sugarcane bagasse, wood wastes & other cellulose) Biomass Biomass Urban green waste; biosolids	Rentech converts syngas from biomass and fossil resources into hydrocarbons that are processed into ultra-clean synthetic fuels, specialty waxes and chemicals. Received $23M DoE grant in Dec. 2009 with Clear Fuels Technology to develop integrated biorefinery at the PDU site using CFT's gasifier. Rentech has aquired a 25% interest in Clear Fuels. US Air Force is currently testing Rentech’s synthetic jet fuel. Joint Development Agreement in place with Solena Group for a standalone biomass facility billed as the first commercial biomass to jet fuel production facility in the country. Rentech also plans to build a biomass energy technology center at their existing Rentech Energy Midwest Corp (REMC) ammonia nitrogen fertilizer facility in East Dubuque, Illinois. Rentech plans to build a waste-to-synthetic fuel plant in the Rialto Eco-Industrial Park. The company has a licensing agreement with SilvaGas for the gasification technology which will be combined with Rentech’s proprietary technology for syngas clean-up. Finally, Rentech signed a multi-year agreement in August 2009 to supply 8 airlines at LAX with synthetic diesel (1.5 MGY) for ground service equipment beginning in 2012

Company	Location	Technology	Production Capacity	Feedstock	Notes
Southern Research Institute Carbon-to-Liquids Development Center (C2L) **www.southernresearch.org** 5201 International Drive Durham, NC 27712 919-282-1050 Thermo-Chem Recovery International (TRI) **www.tri-inc.net** 3700 Koppers Street, Suite 405 Baltimore, MD 21227 410-525-2400	Durham, NC (Pilot)	TRI PulseEnhanced steam reforming gasification system	Unknown	5.5 TPD of MSW with potential scale-up ranging from 100-1000 TPD	The C2L Center has entered into a 5-yr. agreement with TRI to build and operate a biomass gasification plant to convert MSW into ethanol, F-T diesel, F-T jet fuel, chemical feedstocks, & electricity. Pilot commissioned in May 2008.
SuGanit Systems, Inc. **www.suganit.com** Reston, Virginia 703-736-0634	Toledo, OH	Enzymatic hydrolysis	80-100 gal/day pilot; commercial scale capacity undeclared	Compost/yard waste	Technology includes an ionic liquid pretreatment process enabling fermentation of both glucose and zylose, increasing yields up to 30%. Commercial-scale facility a joint project with City of Toledo, University of Toledo, and Toledo-Lucas Port Authority. City of Toledo is providing funding for the pilot , which is scheduled to open in early 2010.
Sun BioEnergy, LLC	Tipton, CA	Dilute Acid and Enzymatic Hydrolysis; Gasification/Fermentation Wastewater & CO2 from fermentation utilized to produce algae for biodiesel	12 MGY of ethanol 1-2 MGY of biodiesel	200-300,000 tons of citrus peels; other agricultural waste biomass Algae	Integrated biorefinery pilot plant being built in Albany, CA in conjunction with USDA & BioEnergy Development, LLC. Start-up in 2009. Permitting phase for full-scale $100M commercial facility at Sunkist Tipton plant that will convert citrus waste products into ethanol, biodiesel, and electricity. Billed as first closed-loop process integrating four separate biomass conversion technologies.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Sun Opta BioProcess, Inc. **www.sunopta.com** 2838 Bovaird Drive West Brampton, Ontario Canada L7A OH2 905-455-2528	Brampton, Ontario, Canada	Biochemical, utilizing Sun Opta's "steam implosion" preprocessing technology	10 MGY	Wood chips	JV with Central Minnesota Cellulosic Ethanol Partners (Sun Opta also a partner in CMCEP's Minnesota ethanol project). Biorefinery to be built adjacent to CMCEP's existing 21.5 MGY corn ethanol plant. Lignin will be used to power both the corn & cellulosic plants.
Syntec Biofuel Inc. **www.syntecbiofuel.com** Vancouver, BC Canada V6B 6A8 604-648-2092	Grand Forks, ND (research PDU at UND EERC)	Gasification/catalysis		MSW, wood, ag wastes	Joint development program initiated with the University of North Dakota's Energy & Environment Research Center for conversion of biomass to biobutanol. Syntec projects yields of 110 gallons per ton.
Synterra Fuels **www.synterrafuels.com** Pacific Renewable Fuels Inc. **www.prfuels.com** 5022 Bailey Loop McClellan, CA 95652 888-714-5450 Red Lion Bio-Energy **www.redlionbio-energy.com** 387 West Dussel Drive Maumee, OH 43537 409-897-6868	Denver, CO Toledo, OH (modular PDU) Gridley, CA	Thermochemical/catalysis Pyrolysis/steam reforming	unknown	Biomass wastes Rice straw & other biomass	Synterra Fuels a new JV announced in Dec. 2009 between Pacific Renewable Fuels & Red Lion Bio-Energy. PDU for fully integrated biorefinery producing both syndiesel & electricity first built & operated by Red Lion in Denver, then moved to University of Toledo. Commercial plants in planning stages, including participation in the Renewable Energy Institute International alliance and Gridley Biofuels Project, with funding from DoE, NREL & CA Energy Commission, to co-produce syndiesel & electricity from rice straw and other biomass wastes.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Taylor Biomass Energy, LLC www.taylorrecycling.com 336 Neelytown Road Montgomery, NY 12549 845-457-4021	Montgomery, NY	Gasification	24 MW	370 TPD of post-recycled MSW	The Montgomery facility will include 3 components: an MSW MRF & C&D recycling facility; a 370 TPD gasifier; and a power generating plant. Future plans are to add a 2 MGY MSW-to-ethanol production facility.
Team P3 LLC Tennessee	2 plants under development at “undisclosed locations in SE United States”	Gasification w/ F-T catalysis	25 MGY 50 MGY	Wood wastes & MSW	Little available information. Company Chief Engineer Richard Molsbee stated: “We’re pushing forward,” “Nothing has stopped, but we’re trying to stay under the radar.”
Terrabon, LLC www.terrabon.com 20333 State Highway 249 Suite 200 Houston, TX 77070 281-378-8073	Bryan, Texas	MixAlco acid fermentation technology developed at Texas A&M	unknown	400 dry tons of biomass	Commercial scale-up after 3 years of testing at College Station pilot facility, which processed 200 dry pounds/day of paper wastes & chicken manure. New plant will produce fuels, and bioproducts such as animal feed & adhesives. Texas oil refiner Valero Energy Corp has become the lead investor in Terrabon. A partnership with Waste Management, Inc. has also been completed. WMI will help Terrabon secure organic waste feedstocks for the production of high-octane gasoline.
Tetra Point Fuels www.tetrapointfuels.com P.O. Box C Denton, TX 76202 940-349-6999	Denton, TX	Biochemical	4-5 MGY	Waste sugar-based liquids (sodas, sports drinks, beer)	Facility acquired local permits in Fall 2007, with start-up in Spring 2008. Company produces ethanol from waste liquids that would otherwise go to disposal.

Company	Location	Technology	Production Capacity	Feedstock	Notes
ThermoChem Recovery International (TRI) www.tri-inc.net 3700 Koppers Street, Ste 405 Baltimore, MD 21227 410-525-2400	Durham, NC (PDU)	Steam reforming gasification/catalysis		4 BDT of biomass	Gasifier developed in 2003 for pulp & paper industry to convert black liquor to power. PDU evaluating various biomass feedstocks for production of biofuels from syngas. TRI gasifiers also utilized in Flambeau River Biofuels and NewPage Corp. biorefinery projects.
UOP LLC www.uop.com 25 East Algonquin Road P.O. Box 5017 Des Plaines, IL 60017 847-391-2000	Kapolei, Hawaii (PDU)	Pyrolysis		Agricultural wastes, pulp, paper, woody biomass, algae & dedicated energy crops	UOP, a division of Honeywell, received $25M DoE grant in Dec. 2009 to build a PDU for conversion of biomass to pyrolysis oils & transportation fuels using technology developed by Ensyn Corp. Plant will be built at Tesoro Corp refinery, and biofuels produced will be evaluated by a panel of petroleum refiners. Plant start-up in 2012.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Verenium **www.diversa.com** 4955 Directors Place San Diego, CA 92121 858-526-5000	Jennings, LA	Acid & enzymatic hydrolysis (C5 and C6 fermentations)	1.4 MGY demo; 60+ MGY at commercial scale	Sugarcane bagasse and specially-bred energy cane	Jennings plant received $90M from BP in August 2008. Demo operations begun in January 2009, producing ethanol from wood chips, grass straw & energy cane.
Vercipia Biofuels **www.vercipia.com** 55 Cambridge Parkway, 8th floor Cambridge, MA 02142 617-674-5375	Highlands County, Florida	Acid & enzymatic Hydrolysis and fermentation bacterium developed by U of Florida	36 MGY	Energy cane & forage sorghum	Verenium has formed JV, Vercipia, with British Petroleum to build first cellulosic ethanol plant in Florida. Plant being developed in partnership with feedstock provider Lykes Bros. Inc. The $300M facility will be built on a 20,000 acre site owned by Lykes Bros. Construction planned for 2010, and commercial production expected in 2011. BP to commence cellulosic ethanol production in Brazil in 2013.
Viresco Energy LLC **www.virescoenergy.com** 1451 Research Park Dr., Ste 200 Riverside, CA 92507 951-784-7238	No operating plants listed	Gasification	Unknown	Coal, green & woody wastes, MSW, & industrial wastes	Viresco owns the exclusive licensing option for the Viresco Process, originally developed by CE-CERT at UC Riverside. Technology is based on a combination of steam hydrogasifi-cation and reforming. The use of slurry feeds allows the process to utilize wet feedstocks. Production of high energy density liquid fuels such as F-T diesel is the primary focus of the company.

Company	Location	Technology	Production Capacity	Feedstock	Notes
Whole Energy Fuels Corp www.whole-energy.com 2950 Newmarket St., Ste 101-204 Bellingham, WA 98226 888-600-8611 **Mercurius Biofuels** www.mercuriusbiofuels.com 360-941-7207	Pilot demo facility planned	Hydrolysis	N/A	Non-food cellulose	Whole Energy partnering with and obtaining a license from the Energy & Environment Research Center (EERC) at U of South Dakota to commercialize their hydrolysis technology for converting biomass into cellulosic biodiesel. License will be used to jump start a new company called Mercurius Biofuels that will develop the pilot plant.
Woodland Biofuels, Inc. www.woodlandbiofuels.com 220 Superior Boulevard Mississauga, Ontario Canada L5T 2L2 905-670-5502	Atlantic, Canada	Catalyzed Pressure Reduction technology (pyrolytic gasification & catalysis)	76M liters/year	Wood and agricultural wastes	Woodland Biofuels received $9.8M in funding from Sustainable Development Technology Canada in 2007. The plant is scheduled for completion by the end of 2009, and will also produce power for use by a neighboring industrial facility.
Zea-Chem www.zeachem.com Union Tower 165 S. Union Blvd., Suite 380 Lakewood, CO 80228 303-279-7045	Boardman, OR	Biochemical/thermochemical hybrid technology	250,000 GY (PDU) 25-50 MGY (commercial scale-up)	Hardwood, softwood, switch grass, corn stover	ZeaChem has raised $34M in venture capital and has received a $25M DoE grant for construction of a "semi-commercial" facility to produce ethyl acetate & ethanol. Construction underway, with operations by end of 2010. Commercial scale-up slated for 2012-2013. Initial feedstock will be short-rotation poplars, but PDU will also test ag residues & energy crops. Valero Petroleum has joined as a strategic investor.

APPENDIX I: Emerging Non-Incineration Technologies

The following Table is a listing of “Emerging” Non-Incineration Technologies that are in the demonstration and/or scale-up phase of technology development. These are not considered commercially mature because they do not have multiple full scale commercial operating facilities, but are far enough along that they can potentially become commercially available within the next 10 years.

List of Developers of "Emerging" Non-Incineration Technology (Updated January 2010 by BioEnergy Producers Association)

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Biomass Gas & Electric LLC www.biggreenenergy.com 3500 Parkway Lane, Suite 440 Norcross, GA 30092 770-662-0256	Port St. Joe, FL (NW Florida RE Center) Atlanta, GA (Atlanta, GA Bio-Energy Park)	SilvaGas Process Air-blown gasification w/heat recovery (steam generators)	42 MW 50 MW	735 BDT of forest residue, ag byproducts & wood waste Untreated wood waste & saw mill residue, ag waste & urban green waste	The Port St. Joe facility was originally proposed for Tallahassee, but after citizens raised objections it was moved to the nearby county where community leaders have embraced the project. It is currently in the permitting stage, with a projected January 2010 construction start, and 2011 completion. The Atlanta facility is in the planning phase.
Compact Power Holdings plc www.compactpower.co.uk Hydro House St. Andrews Road Avonmouth, Bristol United Kingdom 0117 9802910	Avonmouth, Bristol Dumfries, Dargaval	Pyrolysis & gasification	unknown	MSW	Company operates MSW energy-from-waste facilities in the UK. Facilities consist of hopper & feed systems, pyrolysis, gasifier, thermal reactor, steam boiler, and power generation.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Envergent Technologies LLC www.honeywell.com Honeywell International Inc 101 Columbia Road Morristown, NJ 07962 973-455-2000	Italy	Pyrolysis	unknown	150 BDT of pine forest residues and clean demolition wood	Envergent, a Honeywell Company, has signed an agreement with Industria e Innovazione to pursue Europe's first RTP (rapid thermal processing) technology to convert biomass to pyrolysis oil for power production. Facility start-up projected for 2012.
Envirepel Energy, Inc. www.envirepel.com 1390 Engineer Street, Ste A Vista, CA 760-598-9194	Project Kittyhawk, Vista Vista II, Vista, CA Ramona, CA	Gasification	2.2 MW 7.5 MW 7.5 MW	Tree trimmings, clean wood wastes	Contract signed with PG&E to develop woody biomass facilities. Ramona project located at Ramona Landfill and will divert wood wastes at site.
EnviroArc Technologies www.enviroarc.com P.O. Box 673, Skoyen N-0214 Oslo Norway +47 24 11 12 50	Osteroy, Norway	Gasification, Plasma, Vitrification & Flash Smelting	unknown	Waste materials from Borge tannery	Company focus is on waste treatment and destruction. Organic compounds recovered as fuel gas (syngas). Inorganic compounds recovered as non-leaching slag and metal alloy. Ash vitrified to produce building material.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Environmental Energy Resources Ltd. www.eer-pgm.com 7 Jabotinsky Street Ramat-Gan. 52520 Israel 972-3-7511350	Yblin, Israel (demo) United Kingdom	Plasma gasification melting	Unknown	MSW	Core technology developed at Kurchatov Institute in Russia. Demo facility operated in Israel since late 2006 & processes 12-20 TPD of MSW. Company has 20-yr agreement with London-based Gowing & Pursey to construct 30K TPY plant in UK. EER also in permitting stage for medical waste processing plant in Houston.
Frontline Bioenergy LLC www.frontlinebioenergy.com 1421 S. Bell Avenue, Ste 105 Ames, IA 50010 515-292-1200	Benson, MN	Gasification	Unknown	Corn cobs and crop residues	Principal owner of Frontline Bioenergy is Chippewa Valley Ethanol Company. Frontline 75 TPD gasifier located at existing 48 MGY corn ethanol plant. 60-65% of feedstock from local farmers. Syngas displacing natural gas in boilers. Goal is to provide 90% of plant's power needs. Plans to market gasifiers to other ethanol plants to displace coal power production.
Grand Teton Enterprises www.grandtetonenterprises.com P.O. Box 1767 Lake Arrowhead, CA 92352 909-520-2542	Operational units at unspecified locations in North America and India	Pyrolysis/gasification	unknown	Hog fuel, MSW, plastic, tires, wood, ag waste	Company claims that it has been operating units for 25 years. Modular systems from 500 Kw to 50 MW being marketed.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
ILS Partners/Pyromex www.ils-partners.com 1 Como Circle Palm Desert, CA 92211 760-568-9369	Germany (25 TPD Pyromex operating plant)	Pyromex gasification technology	Unknown	MSW & sewage sludge	Pyromex a Swiss company joined with ILS-Partners. Partnership marketing systems ranging from 10-500 TPD. German plant meeting all international emissions standards, with 1% inert residual.
Integrated Environmental Technologies LLC (InEnTec) [S4 Energy Solutions, LLC] www.inentec.com 595 SW Bluff Drive, Suite B Bend, Oregon 97702 509-946-5700	Richland, WA Iizuka City, Japan	Plasma Enhanced Melter (PEM)	unknown	MSW Wood & plastic waste	InEnTec has operating plants for the processing of commercial and industrial waste streams in Michigan, Taiwan, Japan & Malaysia. Formed the S4 Energy Solutions joint venture with Waste Management, Inc. in May 2009 to operate and market plasma gasification facilities with PEM technology. Initial emphasis will be on medical and C&I streams. Richland facility successfully processed City of Richland's MSW.
International Environmental Solutions www.wastetopower.com 25685 Sherman Road Romoland, CA 92585 951-928-5671	Romoland, CA	Pyrolysis	489 kWh/ton	50 TPD of MSW	Proposed scale-up of demo unit to 125 TPD. Company is a finalist the Los Angeles County conversion technology demonstration project solicitation.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Intrinergy, LLC www.intrinergy.com 1309 East Cary Street Suite 200 Richmond, VA 23219 804-381-4000	Wiggins, Mississippi	Gasification	Unknown	Wood chips, forest residue, yard waste	Intrinergy is a builder, owner and operator of renewable energy facilities, specializing in the use of biomass gasification for onsite CHP industrial applications. The Wiggins energy facility supplies 50 lbs/hr. of steam produced from wood residues, reducing the paper mill's energy costs by 40% and CO2 emissions by 20K TPY. Intrinergy has operating facilities in Ohio, Germany & the Dominican Republic, and plants under development in Belgium, Conn., Del., and Penn..
Plasco Energy www.plascoenergygroup.com 1000 Innovation Drive Suite 400 Ottawa, ON K2K 3E7 Canada 613-591-9438	Ottawa, Canada Red Deer, Alberta Salinas, CA (proposed)	Plasma arc	21 MW	400 TPD of post-recycled MSW	75 TPD commercial demo plant operated since July 2007 on 6-acre site near city-owned and –operated landfill. Project supported by $9.5 M grant from Sustainable Development Technology Canada (SDTC). Letter of intent with Ottawa for 400 TPD facility. Contract with Central Waste Management Commission in Red Deer for 200 TPD facility. Plasco also a finalist in the Salinas Valley Solid Waste Authority RFP.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
PowerHouse Energy www.powerhouseenergy.net 145 N. Sierra Madre Blvd., #4 Pasadena, CA 91107 626-683-3338	No project site data	Pyromex gasification process	60kW - 1 MW	All types of organic wastes	PowerHouse indicates it has installed over 400 on-site energy systems, and has formed a strategic alliance with Pyromex to pursue waste-gasification-to-energy projects. Company is marketing 5-100 TPD modular units for syngas and power production.
Primenergy www.primenergy.com P.O. Box 581742 Tulsa, OK 74158 918-835-1011	Jonesboro, AK Stuttgart, AK Little Falls, MN Philadelphia, PA Rossano, Italy	Gasification	Process heat & steam 15 MW 1000 kW + process heat & steam Process heat & steam 4 MW	175 TPD of Rice Hulls Rice Hulls 288 TPD of Wood Waste 240 wet TPD of Sewage Sludge 4.5 TP Hour of Olive Waste	Primenergy has multiple gasifiers in commercial operation operating on a wide variety of feedstocks. The company has also invested heavily in research and development of syngas treatment technologies.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
PRM Energy Systems Inc **www.prmenergy.com**	Southern Italy (Rossano Energia plant) Malaysia (Bernas Berhad) Costa Rica (El Pelon) Cargill plant Riceland Foods plant	Gasification	4050 kW 225 kW + 12mm Btu/h 500 kW +12mm Btu/h 6.5 MW + 15K PPM of steam 12 MW + 100K PPH of steam	4500 kg/h of sansa (olive oil processing waste) Rice husks/straw Rice husks/straw 330 TPD of biomass 520 TPD rice husks/straw	PRM has worldwide commercial gasification projects in operation for power production, co-generation, and heat/steam applications.
Simeken, Inc **www.simekeninc.com** Long Beach, CA 805-750-9994	Bakersfield, CA	Pyrolysis	unknown	Wood wastes, tires, MSW, ag wastes, sludge, medical & hazardous wastes	Pilot plant operated for 5 years in Matamoros, Mexico, processing 75 TPD of wood waste, tires, & sludge. Pilot capable of processing up to 300 TPD, producing 5 MW of power and 30 TPD of carbon. Bakersfield project is a test/demonstration plant.

Updates provided by Dr. Kay Martin, BioEnergy Producers Association, January 22, 2010

APPENDIX J: Developmental Non-Incineration Technologies

The following Table is a listing of “Developmental” Non-Incineration Technologies that are in the either in the “research and development” level or at a “bench scale” level of development.

List of Developers of “Developmental” Non-Incineration Technology (Updated January 2010 by BioEnergy Producers Association)

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
AdaptiveARC www.adaptiveARC.com 7683 Sitio Manana Carlsbad, CA 92009 858-704-0508	Watsonville, CA (proposed demo facility)	Plasma Arc gasification	unspecified	200 TPD of post-recycled MSW	AdaptiveARC has offered to build a $15M demo facility at no cost to Santa Cruz County, to be sited at the existing Buena Vista Landfill. The trailer-size plant would also include generators for conversion of the syngas to electricity onsite. The company is marketing modular plant configurations for 100-9000 TPD of MSW, greenwaste, C&D wastes, medical wastes, biohazard wastes, tires, some toxic wastes, and also offers operational and management services. No operating plants listed. 15% of produced syngas powers reactor, with remainder going to grid.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Balboa Pacific www.balboa-pacific.com 13155 Portofino Drive Del Mar, CA 92014 858-259-7621	No operating units listed	Pyrolytic gasification	Output varies with feedstock: i.e. 7000+BTUs/ lb for MSW = 3.8 kWh; 14000+BTUs/lb. for rubbers and plastics= 8+kWh	Contaminated soils, industrial & petroleum-based sludges, MSW, other hazardous waste materials	The BalPac Thermal Conversion System has been marketed commercially for several years, primarily for the processing of industrial wastes. There is no information on current operations, although the company is still actively marketing their units.
Bull Moose Energy www.bullmooseenergy.com P.O. Box 231501 Encinitas, CA 92023	South Otay Mesa, CA	Gasification	20 MW	450 TPD of wood waste and urban green waste	$60M in financing received from Morgan Stanley in June 2007. 20-year contract with SDG&E to buy 20 MW of biomass power. After three years of effort, still has not received air permit from CARB.
Community Power Corp www.gocpc.com 8110 Shaffer Parkway, Ste. 120 Littleton, CO 80127 303-933-3135	Winters, CA	Gasification	2lbs. biomass = 1kWh power + 2kWh heat	Walnut hulls & shells Modular units can also operate on wood chips, any pelletized biomass residue, waste paper & cardboard, plastics, leather, cotton cloth & latex	Company specializes in small, modular bipower systems. BioMax 50 model capable of processing 100 lbs/hr. Units tested and met CA emission standards for distributed generators in May 2006. Ash residue is non-toxic.
Energy-Inc. www.energy-inc.com 9030 West Sahara, Suite 409 Las Vegas, NV 89117 877-671-4954	Elkhart, Indiana	Gasification/pyrolysis		MSW	Company has just won an RFP to build a facility associated with the Elkhart landfill. The project will provide power to a nearby prison and to the grid.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
GEM America www.gemamericainc.com **908-608-0491**	No information on commercial plants	Thermal cracking technology (TCT)	Unknown (high BTU syngas)	Organic solids, MSW, commercial waste, sludge, wood, ag waste, used oil, rubber tires, non-recyclable plastics	Company marketing modular systems with 90% landfill diversion capability.
Geoplasma LLC www.geoplasma.com 171 17th Street, NW Atlanta, GA 30363 770-399-9930	No information on commercial plants	Plasma gasification	unknown	MSW	Company a division of Jacoby Development, Inc. and Jacoby Energy formed in 2003. Company claims that their technology can convert 1000 TPD to enough energy to power 25,000 homes.
GP Fuels & Energy, Inc. P.O. Box 44 Lakeside, Halifax Nova Scotia, Canada B3T 1M6 902-452-0797	Commercial demos planned for Georgia & California	Gasification	Syngas energy value of 350 Btus per cubic ft 750 TPD = 65 MW of power	MSW	First plant was projected to be operational by Dec. 2008, followed by 2 additonal plants in 2009. Average projected capital cost of $1600/kW. No information on current status.
Heat Transfer International www.heatxfer.com 4720 44th Street SE Kentwood, MI 49512 616-551-5420	Howard City, MI Italy	Gasification	unknown	Turkey litter Cattle manure, ag crop residue	HTI developing several partnerships to build small gasification plants utilizing ag biomass. Howard City facility provides CHP to Sietseme Farm Feeds mill via gasification of turkey litter. Also partnering with PHP Equipment Srl of Italy to develop Italian plant with Spring 2010 startup. Formed waste-to-power partnership with Michigan-based Morbark, Inc. to market turn-key plants.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Liberty Energy Resources, Inc www.libertyenergyresources.com 1601 Skyway Drive, Suite 205 Bakersfield, CA 93308 661-391-5840	Lost Hills, CA Hamilton, Ontario, Canada Banning, CA	Gasification	Unknown 10 MW 15 MW	Compost Noncompostible green waste & biosolids Organic waste streams	Lost Hills (Liberty V) project is an upgrade of an existing compost operation to mitigate VOCs. Ontario (Liberty VII) project to be developed as Liberty Energy Centre. Banning (Liberty XXIII) project to be sited next a Wastewater Treatment Plant.
Nexterra www.nexterra.ca 650 West Georgia Street Suite 1300 P.O. Box 11582 Vancouver, BC V6B 4N8 Canada 604-637-2501	British Columbia (Pristine Power project for up to 15 interior communities)	Gasification	5-10 MW	Wood residues (hog fuel), logging slash, pine beetle-kill wood	Nexterra has developed several projects for gasification of wood residues to syngas, and utilization of process steam for heating or industrial applications. These include campus heating at the Oak Ridge National Lab & University of South Carolina; process steam for a paper (Kruger Products) and lumber mill (Tolko Industries), and heating & hot water projects for a residential development (Dockside Green). The Pristine Power project will develop small (5-10 MW) power plants utilizing wood waste gasification and steam turbines.
Plasma Waste Recycling Inc www.plasma-wr.com 250 Finney Drive Huntsville, AL 35824 256-258-2800	Montgomery, AL (proposed)	Plasma gasification	1 ton = 450-850 kW/hr	MSW	The City has signed an agreement with PWR for completion of a $1M feasibility study to develop a 175K TPY plant in Montgomery.

Name of Company	Location	Technology	Energy Output	Feedstock	Notes
Thermogenics Inc www.thermogenics.com 7100-F Second Street NW Albuquerque, NM 87107 505-463-8422	No operating units listed	Gasification	300kW-6000kW	MSW, tires, sewage sludges, wood wastes, auto shredder residue, industrial sludges, oil field wastes	Thermogenics is marketing gasifier systems operating on 500 lbs/h to 6000 lbs/h, with a heating value of 5000 BTU per lb.
ThermoChem Recovery International (TRI) www.tri-inc.net 3700 Koppers Street, Ste 405 Baltimore, MD 21227 410-525-2400 D	Trenton, Ontario Canada	Gasification	Unknown	200 TPD of paper mill waste (black liquor solids)	Spent liquor gasification system operating since 2003 at Norampac paper mill (division of Cascades Inc. Canada, the largest manufacturer of containerboard in Canada).
WSI Management LLC www.wsimgt.com P.O. Box 3749 Plant City, FL 33563 813-797-0778	No operating plants listed	Gasification Waste Elutriation Technology (WET System)	Unknown	MSW cellulose-based material	Company marketing WET System technology, which involves autoclaving of incoming MSW to separate cellulose and recover recyclables. Cellulose is converted into high calorific fuel cubes (RDF) and gasified for power production, or alternatively may be used to produce ethanol.
Ze-Gen www.ze-gen.com 1380 Soldiers Field Road Second Floor Boston, MA 02135 617-674-2443	New Bedford, MA (demo plant)	Gasification	unknown	1500 TPD of incoming C&D wastes, tires, and MSW	Current demo has pit, crane, and sorting lines for pre-processing of feedstock, which is then loaded into a molten metal boiler. Primary future use of syngas is for power production. Plans to operate full-scale facilities in US by 2012. Company announced in January 2009 that it has raised $20M in Series B financing to commercially deploy Ze-gen's technology.

Updates provided by Dr. Kay Martin, BioEnergy Producers Association, January 22, 2010