Getting to Zero Waste in the City

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Getting to Zero Waste in the City
The Case of Oakland, California

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Statement of Authenticity

This thesis contains no material which has been accepted for the award of any other degree or diploma in any institution and to the best of my knowledge and belief, the research contains no material previously published or written by another person, except where due reference has been made in the text of the thesis.

I, (Nancy Joanne Cole) declare that this master's thesis "Getting to Zero Waste in the City: The Case of Oakland, California" has not been submitted elsewhere and was produced without external aid and is entirely my own work. All the materials that are used in the research are quoted or acknowledged as appropriate.

Signed,

(Place, Date) (Name)

Acknowledgements

The contents of this document are grounded by the accomplishments of several key organizations in California. On a global context, California needs much improvement to reduce its dependence on landfill disposal of waste. With great effort, however, the State is advancing forward in both policy and practice, and it is worth recognizing the following organizations that have been vital to this success: CalRecycle, California Environmental Protection Agency, California Air Resources Board (CARB), California Energy Commission (CEC), the California Biomass Collaborative and the University of California, Davis; as well as regional organizations including Alameda County StopWaste.org and Waste Management, Inc. Special thanks to the resources provided by Kevin Drew, Gary Liss and Mark Gagliardi for taking the time to answer all my questions.

This master's course inspired this research in concentrating on reducing waste through good decision-making by evaluating the best result for the least cost while several issues in parallel: climate change, waste prevention and energy scarcity. Certainly, we can never satisfy all the environmental interests at once, but we can figure a way to cultivate solutions that address several problems simultaneously. In my analysis, I address the need to end the use of landfilling, and the possibility to produce energy generated from appropriate sources.

My deepest appreciation is extended out to those who enabled me to attend this master's course. Thanks to Dr. Gordon Ashley, who provided me with guidance and financial support to attend the course. Without his encouragement and strong conviction that I can accomplish my goals, I would not have the courage to venture away from sunny and happy California and study in Germany. And thanks to my mother, Claudette Cole, who listened and offered guidance, perspective and a couch when I just needed to sit down and write this thing. Many thanks to my dear partner Bruno Borges who always sat down to help me with any questions or doubts I had about my thesis.

Executive Summary

The research provide an investigation into the City of Oakland, California's Zero Waste Plan of 2006. Oakland, a medium sized city and part of the metropolitan area of the San Francisco Bay, is aiming towards a 90% waste diversion rate by 2020. The City is currently at 65% waste diversion, and will be mandated by the State of California to achieve 75% diversion by 2020. The objectives of this study are 1) to provide an overview of the current waste management handling system, 2) to evaluate the strategies to achieve such high rates of waste diversion, and 3) to operationalize a new waste management system.

The analysis uncovered that the current waste management system for the residential sector in Oakland lacks pretreatment steps of its source separated materials. The separation efficiency in the City is low, and over half of the landfilled material can be recycled or recovered.

The term *'zero waste'* is a new concept that is evolving as it is coming more widely used. An analysis of the strategies set out by Oakland has demonstrated that upstream waste reduction measures alone are not politically feasible, or effective at the local level. Operationalization of the zero waste plan through decision-support tools can effectively help decision-makers identify the best available techniques and recognize key stakeholders that the City might engage. If Oakland is successful at achieving it's aim, it will be one of only a few cities in the world that can achieve 10% of its waste ending in a landfill with the absence of incineration technology.

Keywords: Zero Waste, Solid Waste Management, Energy Recovery, Anaerobic Digestion, Decision Support Tools.

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Definitions

Definitions of waste are highly dependent on how legislation interpets waste and what a government is responsible for, and thus placed first in this report to provide a common understanding of the terms and concepts that highly vary between regions. When clear distinctions between the legal definition and other definitions exist, a brief discussion of those differences will be made. Where there are no local formal definitions available, the European Union Waste Directive—one of the strictest waste regulations in the world—shall be used.

Anaerobic Digestion

Biological decomposition of organic substances in the absence of oxygen (California Environmental Protection Agency, 2011).

Best Available Techniques

The most effective and advanced stage in the development of activities and methods of operation to reduce the impact on the environment (European Commission, 1996)

Bioenergy

Renewable energy produced from biomass wastes including forest and other wood waste, agriculture and food processing wastes, organic urban waste, waste and emissions from water treatment facilities, landfill gas and other organic waste sources. Bioenergy comes in the form of electricity, heat, gas (biogas or biomethane as well as synthetic natural gas) (Levin, 2012).

Biofuels

Renewable energy that produces ethanol, biodiesel, or proposed drop-in substitute fuels for gasoline or diesel are used as an alternative transportation fuel. Such biofuel sources can

	come from agricultural waste, livestock waste, and urban biomass residues (Levin, 2012).
Biogas	Gas produced by converting biomass to a gaseous mixture of carbon dioxide and methane. Biogas can be used directly to produce electricity or can be converted to biomethane by removing carbon dioxide and other impurities (Levin, 2012).
Bio-waste	Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retailers (European Commission, 1996)
By-product	A substance or object resulting from a production process, which may be discarded as waste or used in a secondary process (European Commission, 1996).
Collection	Means of gathering waste, including preliminary sorting and/ or storage for purposes of treatment or disposal (European Commission, 1996).
Compost	Product resulting from the controlled biological decomposition of organic material. Compost feedstock materials include landscape trimmings, agricultural crop residues, paper pulp, food scrap, wood chips, manure and bio-solids (California Environmental Protection Agency, 2011).
Composting	Biological decomposition process of organic materials such as leaves, grass clippings, brush,

and food waste into a soil amendment (California Environmental Protection Agency, 2011).

Construction and Demolition debris (C&D) Waste generated by construction and demolition of building such as bricks, concrete, drywall, lumber, miscellaneous metal parts, packaging materials, etc. (Rapport, 2008).

Conversion technology Term used for the technologies that convert unwanted organic materials into high-value products such as energy, alternative fuels, solvents, and other products (California Environmental Protection Agency, 2011).

Digester gas Biogas and biomethane produced through anaerobic digestion (California Environmental Protection Agency, 2011).

Disposal Any operation where 'waste' materials are not recovered and discharged into a sanitary landfill (European Commission, 1996).

Diversion rate Fraction of all generated solid waste from industrial, commercial, construction and demolition, and residential sources that was not disposed in landfill (Cascadia Consulting Group, 2006).

End-of-Waste Criteria for what once was considered 'waste' to be considered by-products (European Commission, 1996).

Hazardous Waste	Substances and items most people frequently deal with, which have a potential to cause harm to people or the environment if improperly disposed (CalRecycle, 2012).
Incineration	Waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration and other high temperature waste treatment systems are described as "thermal treatment (California Environmental Protection Agency, 2011).
Landfill gas	Biogas produced in landfills from natural decomposition of organic (California Environmental Protection Agency, 2011).
Life-cycle analysis (LCA)	Tool that aids in the understanding of flows within a system: fossil fuels, chemicals, wood pulp, water and more. A lifecycle inventory is used to get a general idea of energy and material use and thus calculate operating costs (California Environmental Protection Agency, 2011).
Organics	Materials that are or were recently living such as leaves, grass, agriculture crop residue or food scraps (California Environmental Protection Agency, 2011).
Producer Responsibility	A legal provision requiring manufactures to perform or cover the cost of waste management services until the end of the life of the product (Christensen, 2011, p. 14)

Recovery	Any operation where waste is serving a useful purpose by replacing other materials which would otherwise serve the same function that can serve a different function then that which it was once conceived (European Commission, 1996).
Recycling	Any recovery operation by which waste materials are reprocessed into products, materials or substances. According to the European Commission, 'recycling' includes the reprocessing of organic material, but does not include energy recovery (European Commission, 1996). The Oakland Waste Hierarchy classifies energy recovery as a distictly different activity from recycling, but places it on the same level of priority (City of Oakland, 2006).
Reuse	Any operation by which products or components that are not waste are used again for the same purpose for which it was conceived (European Commission, 1996).
Separation Technology	The collection of a waste stream that is kept separately by type and nature so as to facilitate a specific treatment (European Commission, 1996).
Source separation	Setting aside compostable and recyclable materials from the waste stream before they are collected with other solid waste (California Environmental Protection Agency, 2011).
Thermal conversion	Process using heat that converts the carbon-based portion of the MSW waste stream into a

	synthetic gas which is subsequently used to produced products such as electricity chemicals or green fuels. [*Also see Incineration*] (California Environmental Protection Agency, 2011).
Transfer/ Processing Facility	Activities which receive, handle, separate, convert or otherwise process materials in solid waste or transfer solid waste directly from one container to another or from one vehicle to another for transport and/or store solid waste (California Environmental Protection Agency, 2011).
Treatment	Recovery or disposal operations, including preparation prior to recovery or disposal (European Commission, 1996).
Waste	Waste generated in the residential, commercial, institutional and industrial sectors but excludes industrial process waste, sludge, construction and demolition waste, pathological waste, agricultural waste, mining waste, and hazardous waste (US EPA, 2004).
Waste Characterization	Act of determining the types and amounts of materials in the disposed waste stream (Cascadia Consulting Group, 2006).
Waste Management	Collection, transport, recovery and disposal of waste, including supervision and after care of the disposal site (European Commission, 1996).

Waste Prevention	Reduction of material use and extension of the durability of the good. Waste prevention occurs before products or materials are recognized as waste (Christensen, 2011, p. 187–8).
Waste Producer	Anyone whose activities produce waste (original waste producer).
Waste Reduction	Important waste management strategy that encourages people to generate less trash through practices such as reuse, recycling and buying products with less packaging (Cascadia Consulting Group, 2006).
Zero Waste	Designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them (Levin, 2012).

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Abbreviations

AB	Assembly Bill
ACWMB	Alameda County Waste Management Board
AD	Anaerobic Digestion
ATC	Authority to Construct
BAAQMD	Bay Area Air Quality Management District
CA	California
Cal EPA	California Environmental Protection Agency
CARB	California Air Resources Board
CEQA	California Environmental Quality Act
CHP	Combined Heat and Power
DST	Decision Support Tool
EPIC	Electric Program Investment Charge
EU	European Union
GHG	Greenhouse Gas
IWM	Integrated Waste Management
IWMA	Integrated Waste Management Act
LCFS	Low Carbon Fuel Standards
LCA	Life-Cycle Analysis
LFGTE	Landfill Gas-to-Energy
LSE	Load Serving Entity
MSW	Municipal Solid Waste
MSW-DST	Municipal Solid Waste – Decision Support Tool
MW	Megawatts
NEM	Net Energy Metering
NGOs	Non-governmental Organizations
NOx	Nitrogen Oxides
NOI	Notice of Intent
ORWARE	Organic Waste Research
PG&E	Pacific Gas and Electric
PFD	Process Flow Diagram
POU	Publicly Owned Electric Utility
PPA	Power Purchase Agreement

PURPA	Public Utilities Regulatory Policy Act
QF/CHP	Qualifying Facilities: Combined Heat and Power
QAO	Quality Assurance Organization
RDF	Refuse-Derived Fuel
REC	Renewable Energy Credit
RMDZ	Recycling Market Development Zones
RPS	Renewable Energy Portfolio Standard
RWD	Report of Waste Discharge
SB	Senate Bill
SGIP	Self Generation Incentive Program
SWOT	Strengths/ Weaknesses/ Opportunities/ Threats
UN	United Nations
US	United States
US EPA	United States Environmental Protection Agency
WARM	Waste Reduction Model
WDRs	Waste Discharge Requirements
WMA	Waste Management Agency

Introduction

Context

The City of Oakland, situated in Northern California—six miles (10km) east of San Franciscohas recently passed a waste reduction ordinance, aiming for a 90 percent waste diversion rate by 2020 (City of Oakland, 2006). This surpasses the State mandate of 75 percent by 2020, and serves as an attractive case for research and assessment of how a city of its size might achieve such an ambitious goal (City of Oakland, 2006). There is a need for decision criteria to evaluate and compare different waste management strategies to achieve the zero waste aim.

The Oakland Zero Waste Strategic Plan, initiated in 2006, established a model for an alternative approach to conventional municipal solid waste management in Oakland (City of Oakland, 2006). This approach addresses the upstream emissions by advocating for manufacturer responsibility of product waste and ban sundesirable Oakland's Plastic Bag Ban Ordinance (Nadel, 2007).

In the context of waste management around the world, the City of Oakland is a success story; however, much improvement can be made in the formulation of decision-making and the ways by which the City evaluates new projects and programs.

The Oakland Zero Waste Strategic Plan calls for less policymaking and emphasizes more behavioral change from the residents of Oakland. The strategies reflect the effort to augment behavioral pattern change through the Zero Waste Sustainability Agenda to influence Oakland residents directly (City of Oakland, 2006).

The plan also calls for an increase in recycling efforts and composting derived from the 'green cart'—garden waste and food straps—through education in source separation. Low prices of raw materials in production create incentives to use more than necessary and are thus counterproductive to waste prevention (Christensen, 2011, p. 187–8). Oakland hopes to discourage incentives that increase landfill disposal (City of Oakland, 2006).

Problem Relevance

Several cities around the world are passing zero waste legislation (GAIA, 2012). As zero waste is a new concept, there are major changes in the characterization and operationalization of the concept. Since the passing of the zero waste legislation in the City of Oakland, there is a great opportunity to promote more wastereduction efforts; as well as updating the waste management system to the 'best available techniques' (a concept that will be described in detail).

Oakland's strict zero waste legislation—a mandate of 90 percent diversion—provides the impetus for implanting a new kind of waste management regime, one that restricts or eliminates materials from ever entering the landfill. European countries, such as Germany and Denmark, have met or exceeded the 90 percent waste diversion rates; however, they have accomplished this feat using advanced thermal treatment technology. This makes Oakland's Zero Waste Strategic Plan unique, in that it highly disfavors energy recovery from waste.

The primary emphasis for Oakland's Zero Waste Strategic Plan is to reduce generation from producers and in homes by encouraging changes in personal consumption. However, a cautionary tale from decades of waste management efforts in Europe—a continent plagued with waste issues for centuries—has shown that an emphasis in the production process is not enough to reduce the environmental efforts caused by waste generation. Consumption-related emissions and wastes in Europe have risen, even after attempts to reduce waste generation in production and consumption patterns (Christensen, 2011, p. 183-192).

Oakland's Zero Waste Strategic Plan attests to the concerns over the creation of a market for waste. There is significant apprehension due to fear over incentivizing waste generation (City of Oakland, 2006). It is than essential to estimate the effects of upstream waste generation reduction, such as producer responsibility legislation and education efforts for behavioral change to approximate the additional need for a new waste management system. Creating markets around secondary materials have proven most effective elsewhere, and show effective policies in reducing upstream waste generation.

Objectives

An analysis of the decision process for waste management in Oakland will be compared to several examples that exist and are in use around the world. Decision support tools are used by policymakers in the selection of a municipal solid waste (MSW) management system responsive of the local conditions. This assessment shall focus on evaluating methodology to assess new waste management systems for residential waste generation and provide comparable examples of success in other cities and regions.

Some decision support tools evaluate public opinion; others provide a deep understanding of the environmental effects and quantify emissions in terms of total greenhouse gas (GHG) emissions. Some tools have cost assessment built into the model (Kaazke, 2010). This assessment will make a comparison of the various evaluation criteria. The creation of a blueprint for policy-makers will:

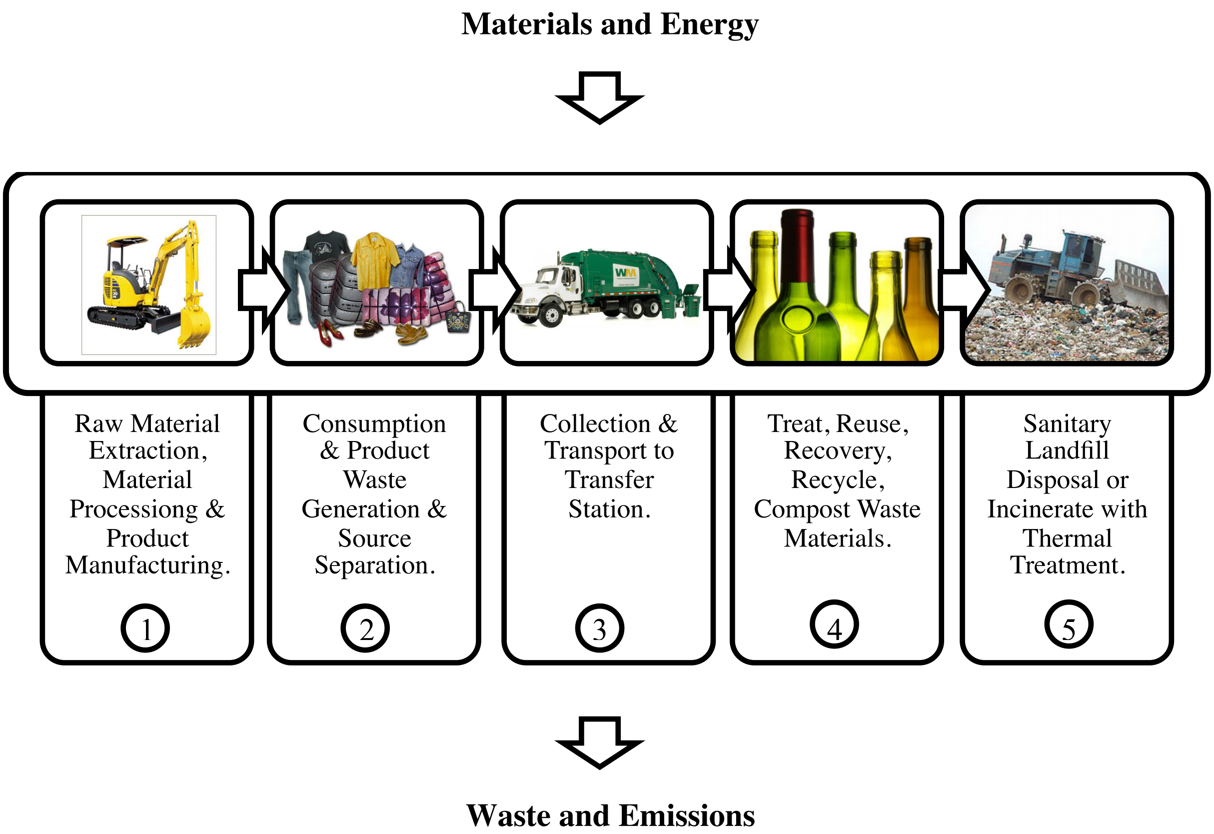
I. Provide an evaluation of the waste management structure that exists in the City of Oakland and the County of Alameda.
II. Evaluate the strategies suggested in the Oakland Zero Waste Plan.
III. Define operational steps to support an informed decision-making approach.

The system boundaries of 'zero waste' expands the current definition of municipal solid waste management to include upstream waste reduction measures that target producer responsibility strategies, requiring manufacturers to redesign packaging and products to reduce waste generation; as well as waste treatment measures that focus on material and energy recovery.

Figure 1. System Boundaries of Waste Management as defined in the 'Zero Waste' Concept shows the lifecycle of waste. Raw materials are extracted and used in manufacturing and production of products. Materials and energy are used in the production process. Products generate usable commodities and waste in the manufacturing process. The commodities are consumed and generate waste (Leonard, 2010).

The waste haulers pick up the waste that is source separated in the homes into 'recyclabes,' 'green waste,' and 'garbage' (described more later). The waste is transported to a transfer station, and recycled, composted, reclaimed, or disposed of in a sanitary landfill. Waste and emissions into the air, water and soil are generated throughout the process (Leonard, 2010).

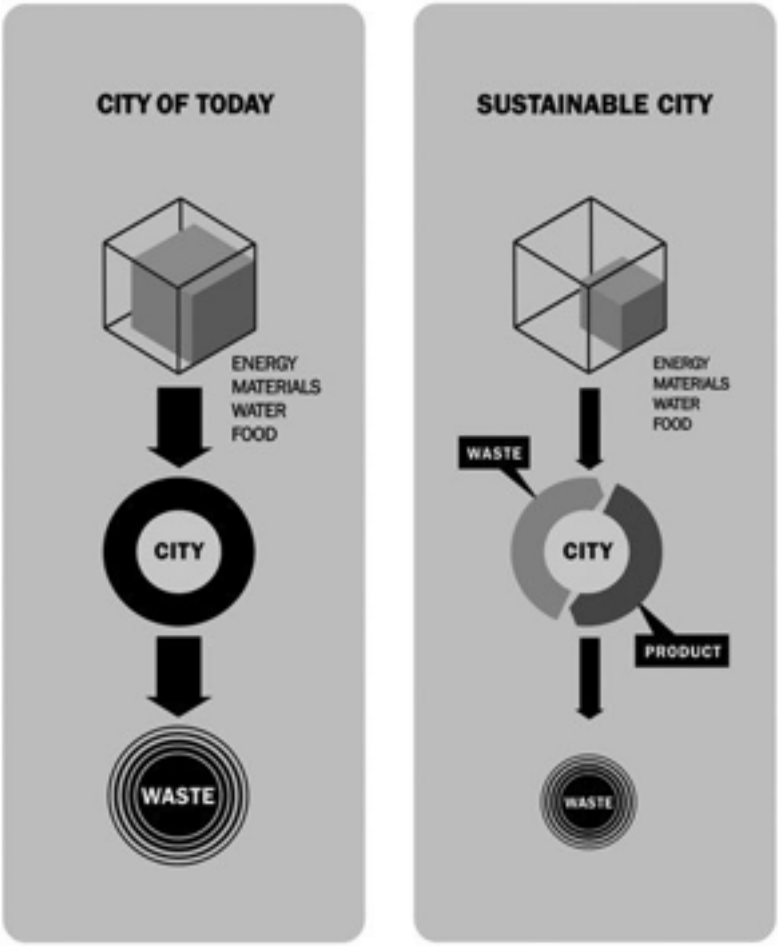
Figure 1. System Boundaries of Waste Management defined in the 'Zero Waste' Concept



The 'zero waste' concept includes the minimization of upstream sources of waste generation, as shown in stage 1 and 2 in Figure 1. above (City of Oakland, 2006). Upstream generation strategies propose a redesign of products by considering the use of raw materials required in the production process, how much energy is needed in manufacturing of that product, the presence of toxic materials, the life span and ease of repair or recycling of the product, and the effects of burying or burning the product at the end of its life (Leonard, 2010). The Oakland Zero Waste Strategic Plan has not specified how to attain all the sources of waste reduction quantifiably; rather they make suggestions in a set of strategies (City of Oakland, 2006).

Figure 2. Linear Metabolism to a Circular Metabolism of waste in a city shows the flow of materials in modern cities that consume great amounts of resources and produce waste linearly (Lehmann, 2011). Getting to a 'sustainable city' would mean to consume fewer resources and recycle and recover materials in what is called a circular metabolism and wasting much less (Lehmann, 2011).

Figure 2. Linear Metabolism to a Circular Metabolism of Waste in a City



Adapted from '*Designing for Zero Waste,*' Lehmann, 2011.

Scope of the Assessment

The main focus of this analysis will be residual waste from households that include biowaste; landfill operation and post-treatment; lightweight materials, such as packaging materials, plastic, tin, aluminum; and lop, green garden waste. A waste flow analysis will include a detailed description of the current domestic source separation system and describe the efficiency of the three-bin system: 1) the 'green cart' for food and garden waste, 2) the 'blue cart' for recyclables, and 3) the 'brown cart' for non-recyclable items.

Other waste materials, such as e-waste, hazardous waste and construction and demolition will be mentioned; however, a deep evaluation of management and disposal of this material is out of the scope of this assessment due to distinct collection and handling processes necessary for such rare and risky materials. Processing of the 'blue bin' materials will be mentioned;

however, most of this investigation will look into what happens and what can happen to organic materials in the 'brown' and 'green' bins due to the number of technical improvements of the last several decades in recovery and treatment of this material.

A waste stream analysis will describe what currently exists within the 'brown cart,' a bin that is source separated in the home, recyclable and organic material remains in great quantities. A process flow analysis of Oakland's waste shows pictorially how the three-bin system is source separated, collected, transported, treated, recycled, reused, and landfilled. The process flow diagram shows what processing steps can be improved and made more efficient. The material flow analysis shows how the materials are being moved and disposed.

A single definition of 'zero waste' is not clearly made in the literature, and therefore a thorough study of main definitions will be made. Later evaluation will discuss if the City has 'direct' control over the strategies using the City's own jurisdictional and legislative authority, or if the City has 'indirect' control over the strategies that assumes a higher level of government involvement, either regionally, statewide or nationally.

An assessment of the regulatory framework, a stakeholder analysis and discussion of the public participatory process shall help provide the context behind how the City of Oakland and the State of California might reach waste diversion figures only observed in some advanced countries in the European Union (Eurostat, 2008).

Germany, the Netherlands, Austria, Sweden, Belgium and Denmark are the only countries in Europe that landfill less than 10 percent of their waste (Eurostat, 2008), and all mentioned countries achieve this high diversion rate using advanced thermal treatment (incineration) for one-third or more of the waste generated (refer to the *Table 6. By Country, From Least to Most Landfilling*).

The European Union offers an alternative approach to waste classification observed in Oakland. The 'End-of-Waste Criteria' in the EU is the most similar concept to 'zero waste,' and yet the implementation and evaluation of waste is very different. The environmental hierarchy is most commonly used as a tool for decision-makers in Oakland. This evaluation shall demonstrate why environmental hierarchy is limited in its ability to compare differing waste management systems and how lifecycle assessment can fill those gaps.

Municipal programming for behavioral pattern change will highlight some strategies that have proven successful elsewhere in minimizing waste generation and the increase in separation efficiency. The Oakland Zero Waste Strategic Plan received strong public support, according to Mark Gagliardi, the City of Oakland Public Works Agency staff; however, a comprehensive public education campaign has not yet been prepared.

General sustainability education is provided to Oakland residents as part of the Sustainability Plan. This analysis might provide some insight into the development of programs that have yielded waste generation reduction and domestic source separation efficiency improvements.

New technology offers alternatives to landfilling through the physical build-out of pretreatment and recovery steps. A survey of the technical maturity, cost and performance of various waste management processing steps will be made. A summary of the technological maturity of each type of waste treatment process is shown in a graph with a brief description of the characteristics of each technology.

Case study research will explore the approaches to zero waste around the world. The cases have been selected to uncover contemporary phenomenon of cities or regions. These cases shall not be used to make any scientific generalizations, but rather provide a glimpse at the implementation approaches used elsewhere to achieve low to no landfilling. An investigation of how the cases structure the zero waste goals, as well as the legal framework. Basic comments regarding strengths and weaknesses of the plan or implementation will be described.

Two neighboring cities of San Jose and San Francisco will serve as local models comparison. These cities are both success cases for the US and world for their management strategies and achievements in waste diversion. The City of San Francisco's Kevin Drew—Residential Zero Waste Coordinator was interviewed by a phone conversation—provided insight into how a leading municipality in the Bay Area and the U.S. develop and evaluate waste programs.

San Francisco's goal is zero waste by 2020—now achieving 70 percent waste reduction—is set to reach the mandates. Mr. Drew responded to several questions regarding decision-making, evaluation criteria, and the relationship with their single waste service providing company, Recology.

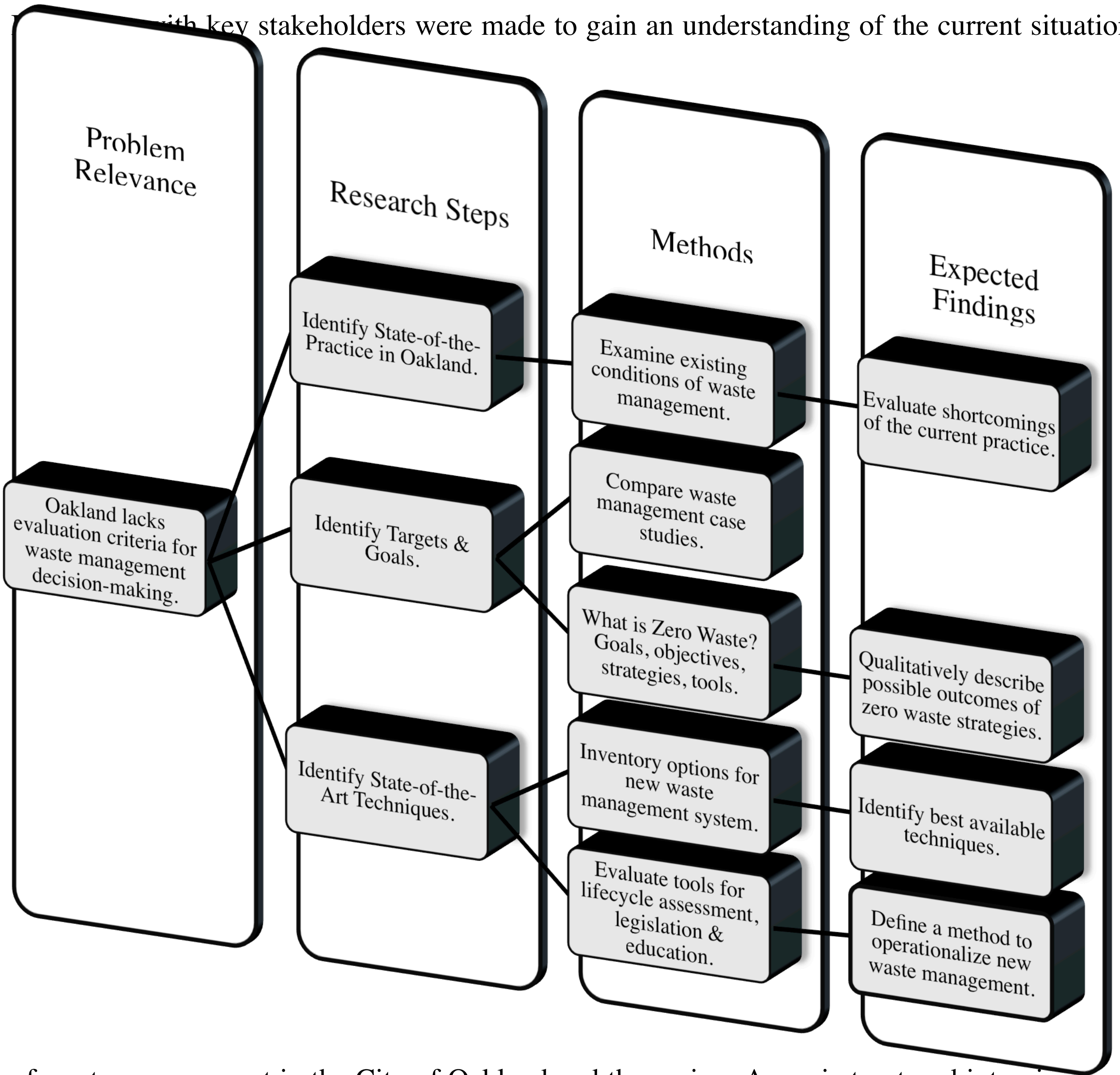
Cities are not often involved in in-depth research; however, ready-made decision support tools, coupled with public preference and economic assessments provide an abundance of information to the final implementation process. A discussion and outlook will investigate ways that Oakland can advance forward using evaluation criteria.

Research Strategy

Figure 3. Research Design for Getting to Zero Waste shows the approach to evaluating the need for decision-making criteria for Oakland's waste management system. An investigation into the current practices of waste management in the City will show the strengths and weaknesses in the current system.

Waste reduction goals and strategies are established without a clear description of how to achieve such an aim. A clear understanding of what zero waste means, as well as a comparison of other cities and regions is intended to provide several pathways to getting to zero waste in Oakland. 'Best available techniques' in decision-making gives Oakland some suggestions for operational steps while evaluating different options.

Figure 3. Research Design for Getting to Zero Waste



with key stakeholders were made to gain an understanding of the current situation of waste management in the City of Oakland and the region. A semi-structured interview was conducted to obtain specific answers to open-ended questions. Mark Gagliardi, the City of Oakland Public Works Agency staff; Gary Liss, chief author of Oakland's Waste Hierarchy; and Waste Management, Inc., the City's waste and recycling service provider were conducted by a phone conversation. Several questions were asked in regards to current and future efforts to achieve the waste diversion goal. The aim is to understand how decisions are made at the municipal level.

The main units of analysis for the case studies will be the legal framework, the proposed strategies and at what level the city or region is at in implementing those strategies. Many of the sources of data collection include original documents or waste management plans that the cities published; as well as literature found from peer reviewed sources. Multiple cases were selected to compare and contrast the approaches outlined by the City of Oakland.

Secondary data collection methods were also used, such as assessing City and State information to profile the region. Peer-reviewed literature was reviewed on the topics related to municipal waste. Current legal opinions for municipal solid waste were reviewed that includes the waste diversion mandates, permit requirements, regulatory incentives or disincentives, grid pipeline injection requirements, Renewable Energy Credit (REC) requirements, current State policy framework, current projects and issues from the State level. Further details on each state agency, including organizational function and regulatory oversight will be provided in the New Rules and Incentives Section.

Results

The analysis shall make recommendations for increasing waste reduction measures, linking to existing actions of the State and local government; as well as, link with ongoing efforts by providing guidance within the existing framework. An additional evaluation shall be made to incorporate the lessons learned from the case studies. The findings shall:

I. Evaluate shortcomings of the current waste management system.
II. Qualitatively describe possible outcomes of zero waste strategies.
III. Identify state-of-the-art techniques.
IV. Define a method to operationalize new waste management.

The review of several decision support tool shall be made to help develop a comprehensive guide for governments to evaluate various municipal waste management systems that include social and economic considerations.

Chapter 1. Oakland's Demographics & Waste Flow

Oakland, California—the second largest city in the San Francisco Bay Area—has approximately 400,000 inhabitants and is projected to grow five percent by 2020 (California Department of Finance, 2012). Oakland is a major transportation hub and trade center for the entire region, with a major port and international airport (City of Oakland, 2006). It is an ethnically diverse city, with one-quarter of Oakland's residents born outside the US (US Census Bureau, 2010).

Demographics

Area: 78 sq. mi (202.024 km^2)
Population: 400,000
Population Density: 7,000/sq. mi (2,700/km^2)
Average Annual Rainfall: 23.7 in. (602 mm)
Elevation: 42 ft. (12.8 m)
Average Temperature: 51.5° F (10.8° C) - 65.8° F (18.8° C)

The City of Oakland is part of Alameda County with over 1.5 million inhabitants in 2010 and 14 cities within the County (See *Figure 4. Location Map of the City of Oakland, California, USA*.) Oakland has an average density of 18,140 people per square kilometer (the average in California is 620 people/km^2) that is 30 times higher density than the California State average (US Census Bureau, 2010).

Figure 4. Location Map of the City of Oakland, California, USA

Half of the population in Oakland is of working age, between 15 and 44 years old (U.S. Census, 2009). Of the residents above 25 years old, 62 percent have achieve a high school education (including equivalency) or higher. The median household income is nearly US$50,000 per year, greater than that of the State average, but poverty remains to be higher than the State average (17.5% in Oakland and 13.5% in California). The rate of families below poverty level is also higher than the State average (15.1% in Oakland, compared to 9.9% in California) (US Census Bureau, 2010). Oakland's violent crime rate is higher than the national average by nearly 300 percent. The city's property crime rate is higher than the national property crime rate average by over 40 percent (Cityrating.com, 2010).

The rate of homeownership in the City of Oakland is 42.4 percent and the number of renters is 56.3 percent (the average rate of homeownership in the US is 33.1%). About half of the housing units are in multi-unit structures. The median value of a house in Oakland is approximately US$ 432,300, according to the United States Census Bureau (United States Census Bureau, 2010). There are four types of housing categories, according to the City of Oakland Planning and Zoning Department: 1) hillside residential (13 units per hectare), 2) detached housing (28 units per hectare), 3) mixed housing type residential (75 units per hectare), and 4) urban residential (313 units per hectare) (City of Oakland, 2011-b).

The kind of housing type is important to the waste collection system and the recycling efficiency. For example, multi-family buildings are not required to have a yard trimming and food scraps recycling bin, thus preventing the source separation of 'green waste' (City of Oakland, 2011-a).

State-of-the-Waste-Practice

The classification of '*waste*' has undergone major transformations in the last 30 years in California. 'Waste' is defined in several ways through time. Before the distinction between '*waste*' and '*recyclables*,' '*waste*' meant '*any item that is 'useless'* or '*worthless*' (O'Connell, 2006). The United States Environmental Protection Agency (US EPA, 2004) definition is:

> *"Waste generated in the residential, commercial, institutional and industrial sectors but excludes industrial process waste, sludge, construction and demolition waste, pathological waste, agricultural waste, mining waste, and hazardous waste."* —California Integrated Waste Management Board, 2004.

Municipal Solid Waste (MSW) management is defined by the United Nations as:

> *"A systems approach that recognizes several important dimensions, which all need to be addressed when developing or changing a solid waste management system."* –UN Habitat Unit, 2011

The State of California instituted the Integrated Waste Management Act of 1989 that mandated municipal solid waste diversion goals of 25 percent by 1995 and 50 percent by the year 2000 (Rapport, 2008).

The term '*municipal solid waste'* can be understood as an obstacle to getting society to think about the valuable materials they discard (Leonard, 2010). In the popular book 'The Story of Stuff,' Annie Leonard recommends that phrase '*municipal solid waste'* be replaced with '*municipal supply of discards*.' 'Municipal supply of discards' or MSD does not have the same connotation of worthless material that municipal solid waste does.

Waste is collected and transported to what is normally considered a '*dump*.' The concept of '*dump*' was changed as environmental controls were put in place to separate waste from the soil below (Humes, 2012). Soil cover is placed on top of the heap to reduce the odor. Today, waste disposal sites are commonly called '*sanitary landfills'* (Humes, 2012).

A '*sanitary landfill'* is designed to isolate municipal waste from the surrounding environment (groundwater, air, and rain) (CalRecycle, 2011). This isolation is accomplished with a bottom liner and covering soil, often using slag or other residue. Gases are generated by the natural degradation of municipal solid wastes due to anaerobic activity without the presence of oxygen (California Energy Commission, 2011).

Once the gas is produced within the landfill, it can be gathered by a collection system, which typically consists of a series of wells drilled into the landfill and connected by a plastic piping system (California Energy Commission, 2010). The gas entering the gas collection system is saturated with water, and that water must be removed prior to further processing. Gas collection began in the 1980s in California (Leonard, 2010).

Gas generation at the landfill is due to the absence of a preprocessing mandate, as seen in European Union (EU) member states. The EU initiated the Biodegradable Municipal Waste Policy of 1995 that encourages the avoidance of organic materials entering landfills. The environmental policy for biodegradable waste, also called the EU Composting Directive requires biological treatment of organic waste as a pre-treatment step before it enters the landfill. Under this policy, the biowaste should have separate collection, composting, anaerobic digestion (AD), biological treatment and use on land (described more in later sections). The intention of this directive is to insure the protection of soils and provide an agricultural benefit (Trittin, 2005).

Of all the waste management practices available, landfilling the worst environmental effects. Groundwater contamination from leaching landfills is an extreme risk human and environmental health (Randolph, 2004). This risk has led to stricter regulation, including dual liners and groundwater monitoring (CalRecycle, 2011).

California passed critical waste diversion legislation in the late 1980s, Assembly Bill (AB) 939. This legislation successfully diverted half of the municipal solid waste generation within a ten-year period. Recycling makes up a significant amount of the diversion activities (Goldman, 2001). AB 939 successfully increased diversion operations throughout the State and kick-started the diversion efforts in the City of Oakland.

Stakeholder Analysis

Several stakeholders are involved in the planning, policy-making, separation, collection, handling, treatment, reuse, recovery and disposal of waste in Oakland. Since the City of Oakland's waste management is part of the County of Alameda's broader waste management system, there are a great number of local and regional stakeholders that are involved.

The Oakland Office of Public Works reports to the elected officials in the City. The Environmental Services and Solid Waste department is responsible for providing the solid waste programs in the City. The department includes the Solid Waste and Recycling Support coordinator, several junior and senior Recycling Specialists and two Environmental Service Interns (Alameda County Waste Management Board, 2006).

Oakland has a service contract with Waste Management, Inc. Waste Management, Inc. provides the majority of residential solid waste collection services for the City of Oakland. Waste Management, Inc. operates the Davis Street Transfer Center and the Altamont Landfill (see *Figure 7. Map of the Waste System for the City of Oakland and County of Alameda*) (Waste Management, 2012).

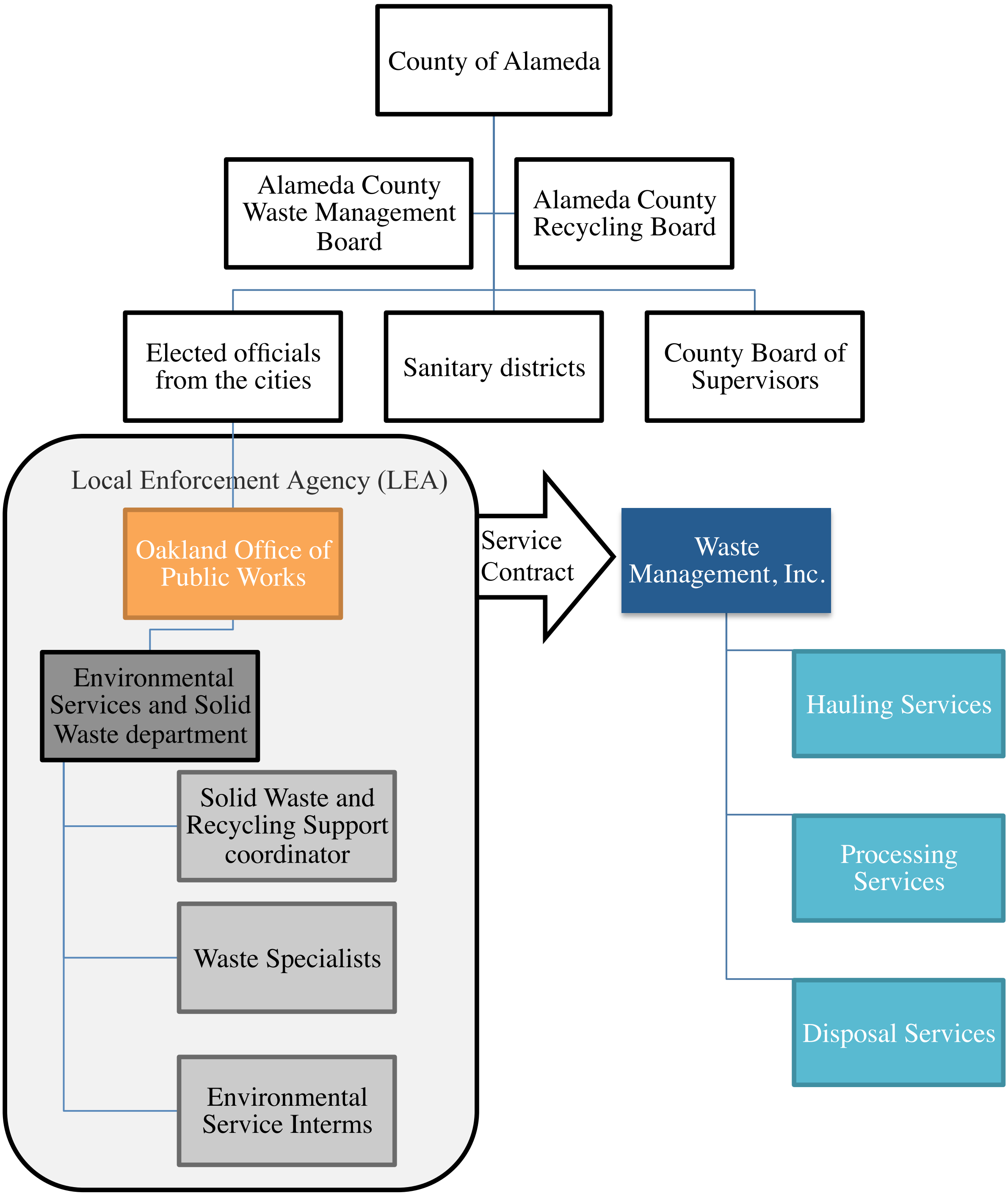
The Alameda County Waste Management Board (StopWaste.org) is responsible for managing and implementing waste reduction programs carried through by Waste Management, Inc. Many of these programs are paid for by the landfill surcharge generated by Measure D (see the Legislative Assessment). There are 11-member organizations on the Recycling Board and five elected officials. This organization offers grants to non-profit organizations, source reduction, market development, recycled product procurement, and administration (Alameda County Waste Management Board, 2006).

Waste Management, Inc. processes a wide variety of materials. These materials range from plastic, metals, glass, construction material, and a number of other materials that are sold to a variety of salvaging and recycling organizations. An exhaustive list of the major of salvaging and reuse operators in Oakland can be found in the appendix of Oakland's Zero Waste Strategic Plan.

The Alameda County Recycling Board is part of an integrated board with the Alameda County Waste Management Board (ACWMB); the Alameda County Recycling Board is comprised of 17-member agencies and elected officials appointed by each member agency. Fees on import mitigation fees and facility fees as part of Assembly Bill (AB) 939 fees generate funding for the Authority. The Authority implements public education activities, home composting initiatives, recycled product procurements, technical support and market development; as well as providing low-interest loans, and grants to non-profit organizations to lead the activities (Alameda County Waste Management Board, 2006).

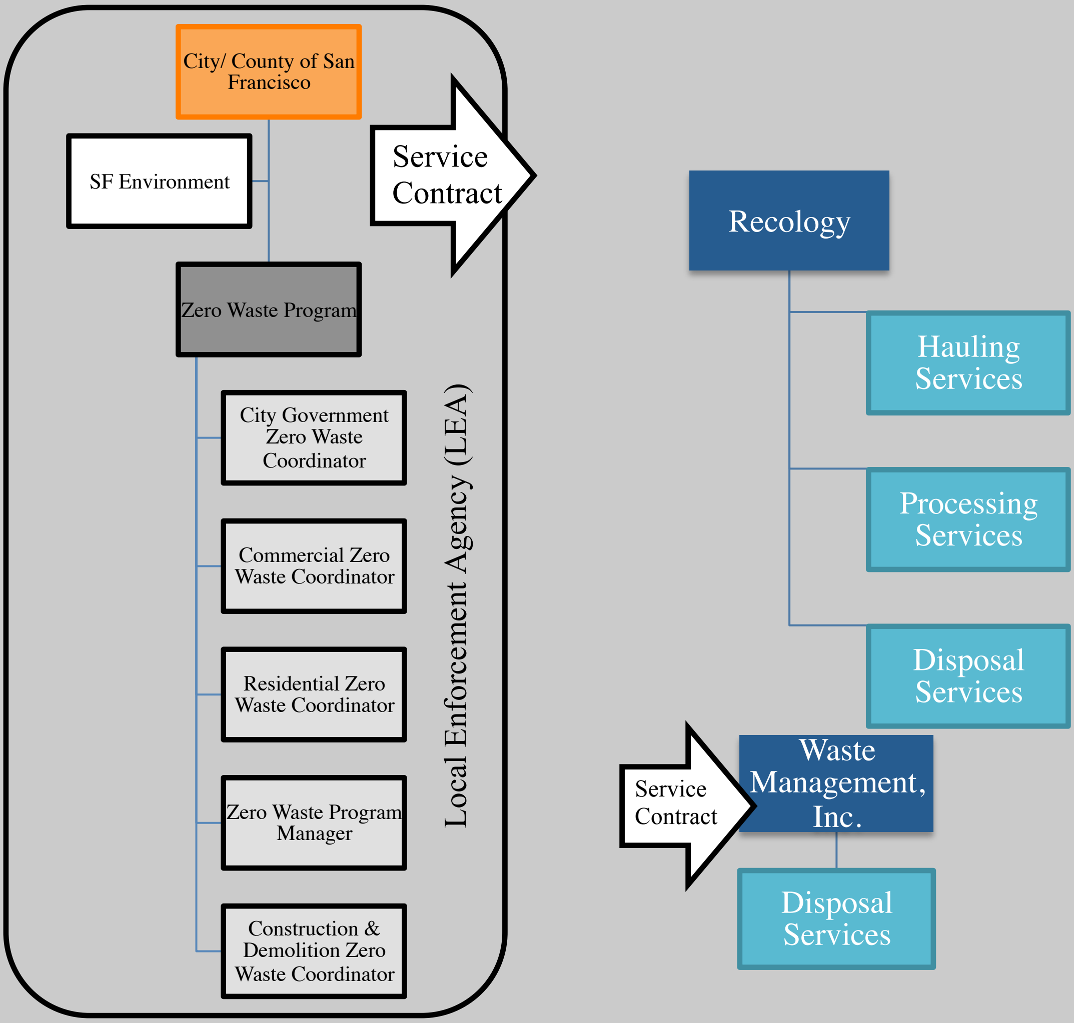
The Alameda County Waste Management Board (ACWMB) and the Alameda County Recycling Board operate under AB 939 and are responsible for preparing the County Hazardous Waste Management Plan and the Countywide Integrated Waste Management Plan (ACWMB, 2006). Several members sit on the Alameda County Waste Management Board that include elected officials from the cities in Alameda County as well as the two sanitary districts from the County's unincorporated areas, as well as the County Board of Supervisors, shown in the following figure:

Figure 5. Governance Structure of Waste Management at the Local and Regional Level



Comparative Case: San Francisco's Governance Structure

Vertical integration—the agglomeration of several services by one company—is a common practice of private collection and hauling services, and seen in the case of San Francisco with the hauling company, Recology. The rationale is that reducing competition will ensure delivery of service in the municipality, reducing the risk for the municipality in dealing with companies without past performance of service. The waste-hauling contractors are provided with long-term access to the landfill, ensuring a long-term revenue stream (O'Connell, 2000). San Francisco is both a city and county and has a consolidated governance model and decisions can easily be made without a high level of bureaucracy (Interview with Kevin Drew).



San Francisco sends the waste to Waste Management's Altamont Landfill—similar to the City of Oakland—as well as Recology's Jepson Prairie Compost Facility 60 miles (96.5 km) away (Tam, 2010)

California has a number of environmental authorities that set standards, regulations and incentives that municipalities must comply with. The California Environmental Protection Agency (Cal EPA) aims to protect and enhance the environment in the interest of public health, environmental safety, and economic vitality; as well as establishing the guideline for environmental performance standards of waste handling in the State of California (California Environmental Protection Agency, 2011).

Since the middle of the 1980s, the California Integrated Waste Management Board (IWMB) has promoted waste reduction, recovery, and recycling legislation (California Integrated Waste Management Board, 2004). Waste reduction of municipal solid waste is an important waste management strategy that encourages people to generate less trash through practices such as reuse, recycling and buying products with less packaging (Cascadia Consulting Group, 2006). Waste diversion is the fraction of all generated solid waste from industrial, commercial, construction, demolition and residential sources that was not disposed of in landfill (Cascadia Consulting Group, 2006).

The California Department of Resources, Recycling and Recovery (CalRecycle) is the regulatory overseer of permitting of solid waste activities within the State of California. These include solid waste handling, processing and disposal activities, comprising landfills, transfer-processing stations, material recovery facilities, compost facilities and waste to energy facilities ((Cal EPA, 2011).

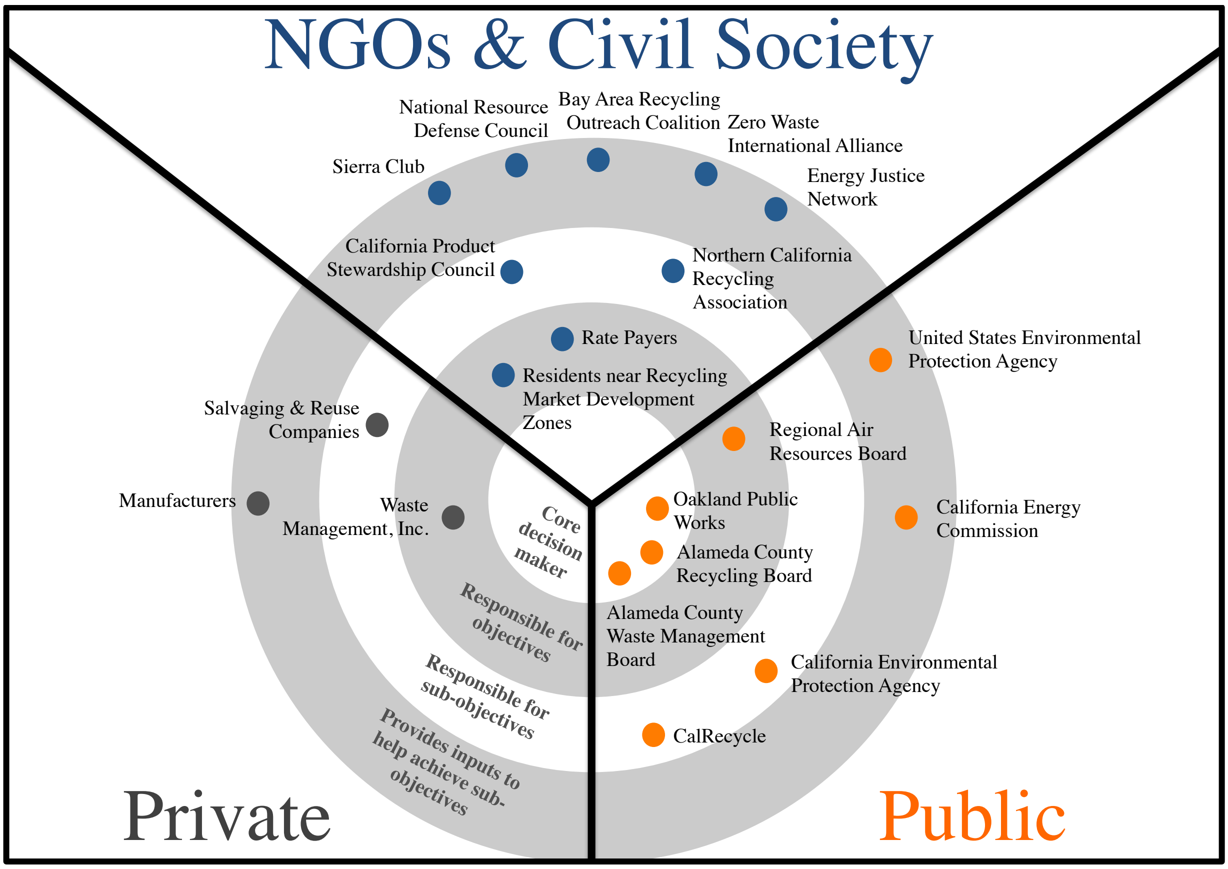
In California's municipal solid waste management services, a coalition is well established between the municipality and the private waste collection and hauling company, as observed in Oakland between the City and Waste Management, Inc. (Waste Management, 2012). The municipality is legally bound to provide high-quality collection and disposal services. A reciprocal relationship is established, whereby the private waste franchise takes the legal risk for the municipality, and the franchise assumes the administrative authority to determine the landfilling procedures (O'Connell, 2000).

The Bay Area Regional Water Quality Control Board is responsible for regulating discharges of waste to land in California. They are responsible for protecting the surface water, groundwater, and coastal waters. Waste discharge requirements (WDRs) take into consideration beneficial uses to be protected (Cal EPA, 2011).

The Bay Area Air Quality Management District (BAAQMD) is responsible for implementing and enforcing federal, state, and local air quality regulations. As part of the California Air Resources Board (CARB), any waste project must go through review of BAAQMD to obtain Authority to Construct (ATC), CEQA documentation, description of waste management system being proposed. The County of Alameda and the City of Oakland require local land use permits for waste facilities; as well as a discretionary permit of the California Environmental Quality Act (CEQA), and building permits (Cal EPA, 2011).

Core decision-making for the current and future implementation of the zero waste goals are primarily conducted at the regional level, however several private and NGOs play are responsible for the sub-objectives or provide key input to achieving the City's aim, as shown in the following figure:

Figure 6. Stakeholder Map of the City of Oakland's Waste Management System



Residential Waste Management System

Residential waste is considered to comprise household waste, bulky waste, garden waste and household hazardous waste (Christensen, 2011, p. 85–96). Household waste varies from country-to-country; however, in the US, typically one-third is organic kitchen waste, one-third is paper products and one-third is other waste. Since many households in the US have 'garbage disposals'—a small grinder in the kitchen sink that disposes solid vegetable waste and deposits the material into the sewer—the amount of food waste is marginally lower than in other countries (Christensen, 2011, p. 85–96).

The current municipal solid waste management practice in the City of Oakland—including recycling, diversion and composting—contribute to the increase in waste diversion (CalRecycle, 2012). Even after recycling, diversion and composting efforts, there is still a significant amount of organic material and recyclables in municipal solid waste.

The reported tons of municipal solid waste generated—including residential, commercial and institutional waste generation—is 400,000 tons per annum, as of 2005 (City of Oakland, 2006). As of 2008, the annual waste generation figurers for the residential sector were 107,176 tons (Alameda County Waste Management Authority, 2011). Waste Management, Inc. provides the solid waste, recycling and plant debris and food services, and CSW provides additional recycling services (Alameda County Waste Management Authority, 2011).

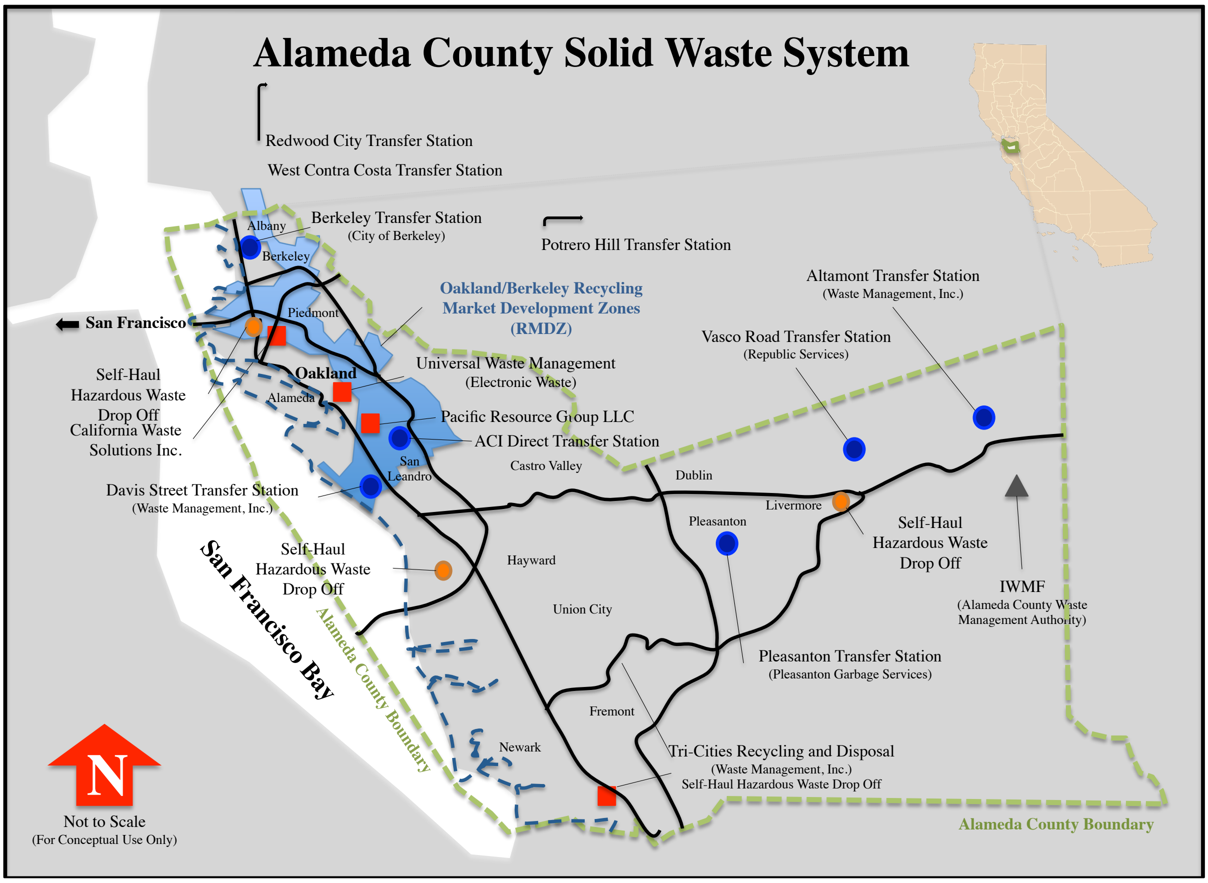
The Davis Street Transfer Station operates as the primary transfer station for the City of Oakland, and operates under the Solid Waste Facilities Permit[1] established in 1980 that will expire in 2016 (City of Oakland, 2006). Oakland's waste travels from the Davis Street Transfer Station in San Leandro, California (approximately ten miles from the City of Oakland) and is transferred to the Altamont Transfer Station and Sanitary Landfill in Livermore, California (approximately 30 miles east of San Leandro) (Waste Management, 2012). The regional distribution of the waste disposal services is shown in *Figure 7. Map of the Waste System for the City of Oakland and County of Alameda*.

Oakland has met and exceeded the minimum requirements of 50 percent diversion rate as mandated by the California Integrated Waste Management Act (IWMA) (CalRecycle, 2012). Those include stakeholders, technical elements, and aspects to achieve the desired results. The

[1] Solid Waste Facilities Permit (SWFP) 01-AA-0007 (Alameda County Waste Management Authority, 2011)

current diversion rates for Oakland are 45 percent of the waste is sent to the landfill, and 55 percent is diverted through recycling, and composting (City of Oakland, 2006).

Figure 7. Map of the Waste System for the City of Oakland and County of Alameda



Source Separation System

The current system for collection and hauling differs greatly between regions. In most jurisdictions, there are multiple waste streams separated from the total waste stream at the point of generation. In Oakland, waste is source separated at the point of generation and collected in three carts; 'green,' 'blue,' and 'brown,' which will be described in greater detail in the next section (See *Figure 10. The City of Oakland's Waste Flow Diagram*).

Construction and demolition waste includes concrete, asphalt paving, asphalt roofing, clean recyclable wood, and other recyclable wood, which is picked up periodically throughout the year. Under Oakland Resolution 612253: Construction and Demolition Recycling Ordinance of 2002, the City is required to reduce disposal of construction and demolition waste by 50 percent (ACWMB, 2006).

The County of Alameda has encouraged domestic composting by subsidizing household compost bins for residents (Leonard, 2010). This reduces the cost for the municipalities because they save money by not having to pick up the compostable material. Since beginning the program in 1991, the County has allowed food scraps in the green bin and added a separate collection system for the waste (ACWMB, 2006).

Residential green waste ('Green Cart') includes 123,455 tons per annum of food waste, such as fruit and peelings, vegetables and peelings, eggshells, pasta, bread and rice, landscape pruning's, etc. (Alameda County Waste Management Authority, 2011). The residential organics are combined with commercial organics (green waste, food scraps and food-contaminated paper) are picked up in a compost truck by Waste Management, Inc. and transported to the Davis Street Transfer Station in San Leandro, California (Waste Management, 2012). The material is hand sorted to reduce contaminants, such as plastic received, shredded, and sent to composting facilities, and turned to aerate to create mulch that is sold on-site (Waste Management, 2012).

'Recycling' ('Blue Cart') includes 93,858 tons per annum of uncoated corrugated cardboard, paper bags, newspaper, white and colored ledger paper, office paper, etc. Recycling is either picked up by a recycling truck or in a combined with garbage by Waste Management and than transported to either the Davis Street Transfer Station in San Leandro, California or on of the Transfer Station shown in *Figure 7. Map of the Waste System for the City of Oakland and County of Alameda* (Waste Management, 2012). The curbside recyclables are separated and then sold to recycling companies for profit (ACWMB, 2006).

'Garbage' ('Brown Cart') includes all other commercial and industrial waste, excluding toxics, e-waste, reusable and recyclable material (Waste Management, 2012). The garbage is also taken to either the Davis Street Transfer Station in San Leandro, California or on of the Transfer Station and disposed of on-site with any sort of on-site source separation or undergoes material recovery measures (Waste Management, 2012).

Waste Stream Analysis

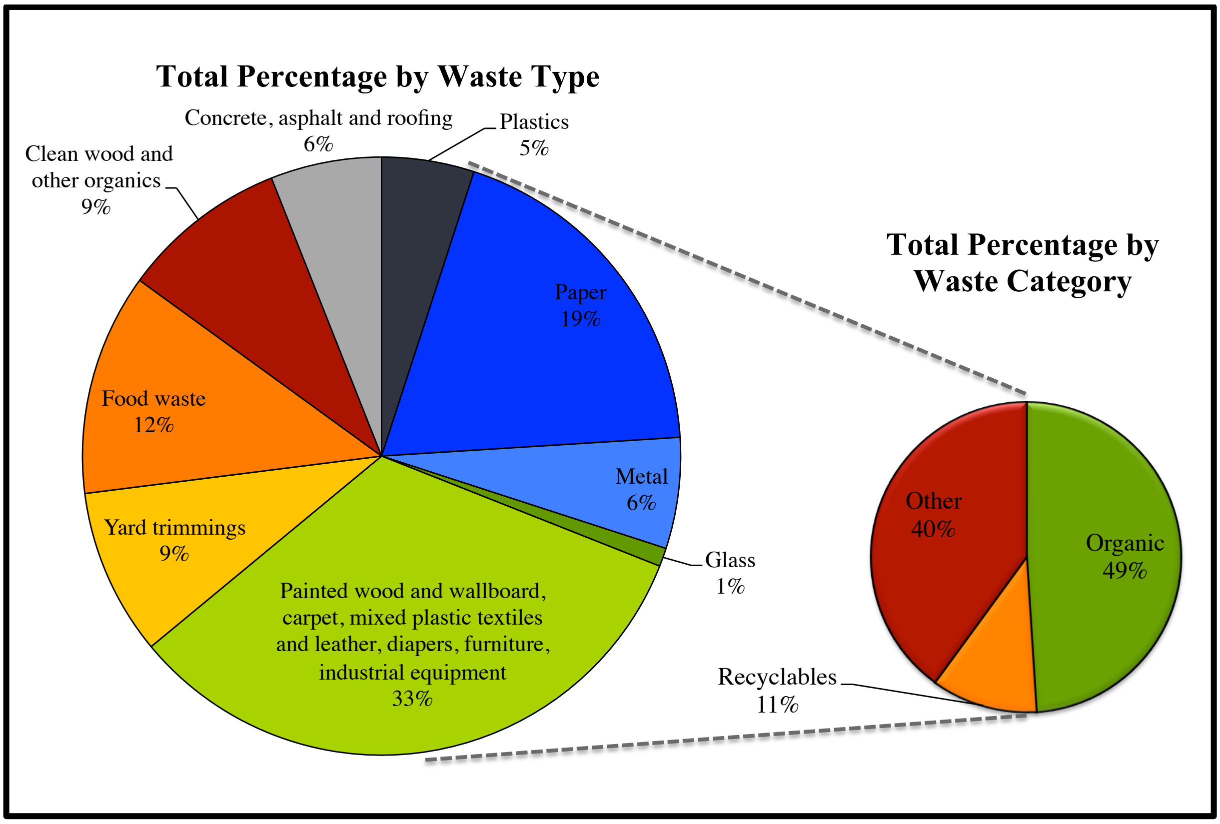
A waste characterization study is provided to determine the efficiency of the current recycling scheme and quantifies the amount of recovered and non-recovered materials. The waste characterization study has the purpose of providing data on waste quantities and the composition for policymaking on recycling. The waste characterization study shows the efficiency of the existing recycling scheme by showing the amount of recovered and non-recovered material (Christensen, 2011, p. 266–75). There is a substantial amount of uncertainty in the waste characterization method and it is important to know that the spatial and temporal variations are essential to the analysis.

Alameda County Waste Management Board (ACWMB), also known as StopWaste.org, conducted the waste characterization study that the City of Oakland used in the Oakland Zero Waste Strategic Plan. The methodology includes the collection and sorting of samples periodically throughout the year over four seasons reduces uncertainty related to seasonal variations in the waste stream (ACWMB, 2008).

Each sample was at least 200 pounds each from both the residential and commercial sector. Less variability is observed in the residential sector than the commercial sector, and therefore fewer samples were necessary in the residential sector to achieve a high level of statistical accuracy. The methodology used is the same from year-to year for comparability.

Of the 400,000 tons of garbage (waste found in the 'brown cart' after source separation, as described in the above section) disposed in the landfill—after in-house source separation—per annum, the waste composition for the City of Oakland is as follows: plastics (5%); paper (19%); metal (6%); glass (1%); painted wood and wallboard, carpet, mixed plastic textiles and leather, diapers, furniture, industrial equipment (16.3%); yard trimmings (9%); food waste (12%); clean wood and other organics (9%); and, concrete, asphalt and roofing (6%), as shown in *Figure8. Oakland's Waste Composition after Source Separation*. An analysis of potential separation and treatment steps of each waste category shall be discussed in further sections (City of Oakland, 2006).

Figure 8. Oakland's Waste Composition after Source Separation as of 2005



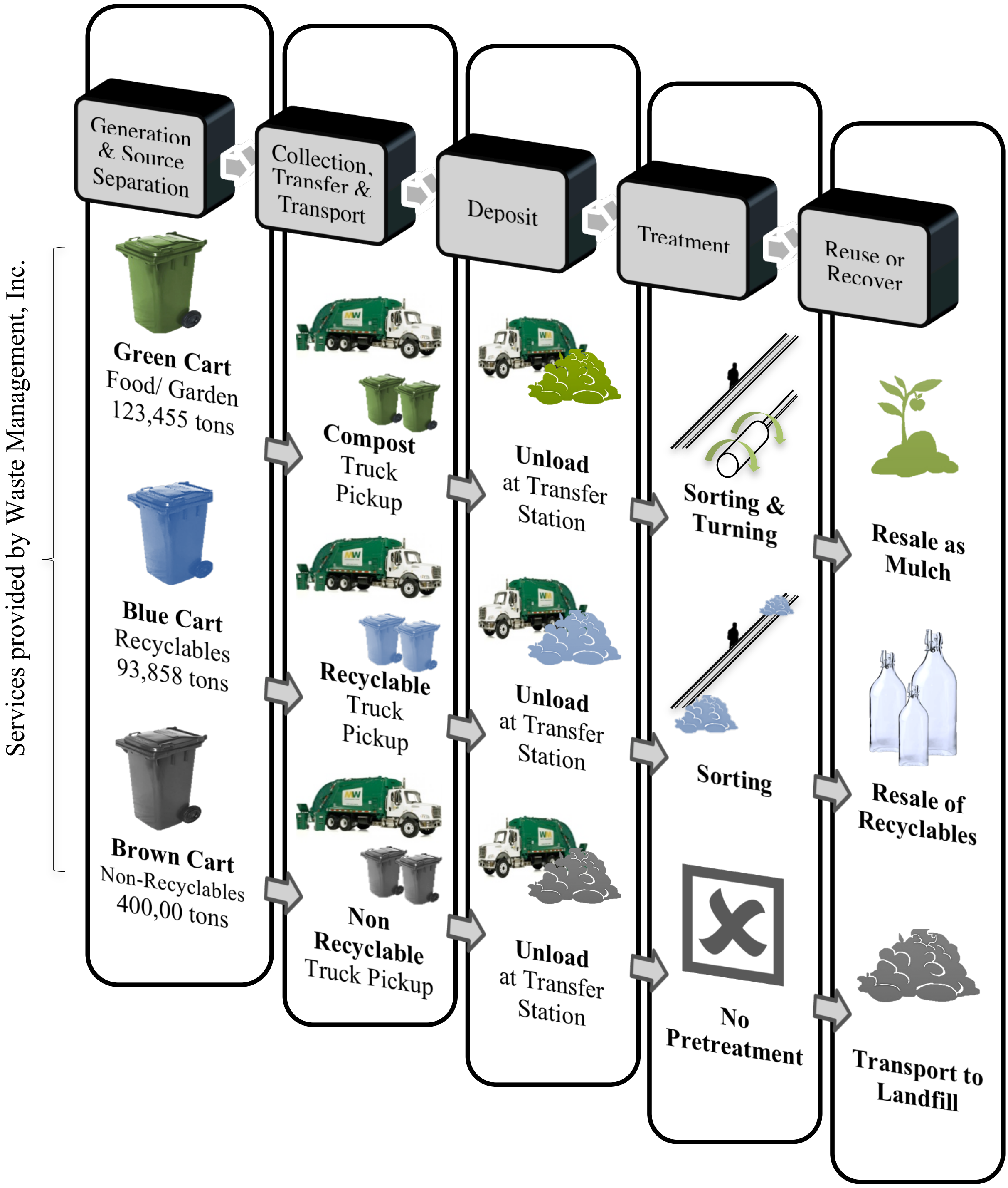
Adapted from City of Oakland, (2006). Zero Waste Strategic Plan.

Process Flow Analysis

To understand the waste flow system that exists in Oakland, a process flow approach is used to understand the waste, recycling and composting system through a process flow diagram (PFD) (UN-Habitat, 2011). The process flow diagram shows visually how the waste is source separated, collected, transported, diverted, transformed, or land applied (Waste Management, 2012).

Figure 10. The City of Oakland's Waste Flow Diagram is the PFD for the City of Oakland, which provides a fast illustration of what is happening in the waste system, and easily shows if any waste streams are left out in the system. Such as 'brown cart' waste, which is 'non-recyclable' waste; however, contains nearly 50 percent organics and 11 percent recyclables (as shown in *Figure 8. Oakland's Waste Composition after Source Separation*) and is not pretreated before being landfilled (City of Oakland, 2006).

Figure 9. Process Flow Diagram of the City of Oakland's Waste Stream in 2005



The PFD shows the degree of private-sector participation, as made clear in *Figure 9. Process Flow Diagram of the City of Oakland's Waste Stream*, by the amount of services provided by Waste Management, Inc. (UN-Habitat, 2011).

Every resident in the City of Oakland is obliged to pay for waste services from the municipal waste service company Waste Management, Inc. The residential recycling and 'green waste' pick up—as described in the above section—is included in the tipping fee (the cost to pick-up, haul and dispose of waste). The waste service pricing is determined by the size of the waste bin. The prices for single family residential rates are as follows: a 20 gram bin is US$21.34 per month; a 32 gram bin is US$28.63 per month; a 64 gram bin is US$62.43 per month; and, a 96 gram bin is US$96.19 per month (Waste Management, 2012). The multi-family residential rates depend on the number of tenants and the frequency of the pick-up.[2]

The 'brown cart' material is then transported to the Altamont Landfill, where it is combine with MSW from Dublin, Davis St. Transfer Station, All Alameda County, San Francisco, Brentwood, and San Ramon (Alameda County Waste Management Board, 2006). There is an energy recovery system at the Altamont Landfill that collects landfill gas used as a transport fuel for the waste collection vehicles. Further description of the process flow will be discussed in the following sections (Alameda County Waste Management Board, 2006).

[2] A detailed rate structure for multi-family residential units can be found on the Oakland Website: http://www2.oaklandnet.com/oakca1/groups/pwa/documents/report/-oak026043.pdf

Chapter 2. Oakland's Zero Waste Strategic Plan

There are significant differences in waste management strategies. A report of the European Environment Agency distinguishes three main approaches (Trittin, 2005):

I. Dependence primarily on incineration to divert waste with a high level of recovery and treatment from biological treatment,
II. High material recovery and high composting rates, and
III. Relying on landfills.

The City of Oakland currently falls into the category of depending on landfills and is attempting to transition to a having a high material recovery and high composting rate.

Emergence of the 'Zero Waste' Concept

There exists no definitive definition in the literature of 'zero waste,' but rather several definitions, each with their own scope and focus. In the 1970s, Paul Palmer— a chemist from the City of Oakland—coined the term 'zero waste.' Palmer's focus was on the reduction of the amount of chemicals produced and disposed of in the electronic industry (Palmer, 2005).

Since the 1970s, the definition has gone through a number of iterations to include the aim to reduce or eliminate upstream and downstream waste generation through policy and behavioral change. The term is now used as a political term to discourage the practice of landfilling and incineration in waste management systems. Table 1. *Definitions of Zero Waste* provides a set of descriptions to give the impulse behind the 'zero waste' concept:

Table 1. Definitions of Zero Waste

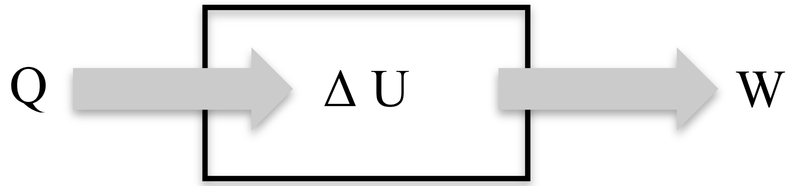
Name/ Organization	Definition	Scope
Paul Palmer	***"A process that redirects all end-of-life products toward future applications in the marketplace, rather than to a landfill."*** *– Palmer, 2005.*	Focuses on reuse of chemicals produced by the electronics industry.
Zero Waste International Alliance	"***A goal that is both pragmatic and visionary, to guide people to emulate sustainable natural cycles, where all discarded materials are resources for others to use. Zero waste means designing and managing products and processes to reduce the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them."*** *– Liss, 2010.*	Focuses on pollution prevention to land, water or air that may be a threat to planetary, human, animal or plant health.
Global Recycling Council	***"A philosophy and a design principle that goes beyond recycling by taking a whole system approach to the flow of resources and discarded materials. Zero waste tries to mimic natural systems where there is no such thing as waste. In nature, everything is a resource or home for something else. Zero waste systems strive to eliminate waste, or get darn close."*** *– Global Recycling Council, 2012.*	Aims to reduce consumption and ensure that producers' must take-back products and packaging for reuse, repair or recycling back into nature or the marketplace.
Oakland's Zero Waste Strategic Plan	***"A goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles…Implementing Zero waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health.***" *– City of Oakland, 2006.*	Targets upstream strategies of designed to avoid or eliminate the volume and toxicity of waste materials, conserve and recover all resources, rather than incineration or landfilling.

Zero waste is not, in practice, how nature works. The First Law of Thermodynamics says that when heat energy is added to a system (Q), two things happen: First, work (W) is produced and internal energy increases (ΔU) (Giancoli, 2000), as shown in *Equation 1. The First Law of Thermodynamics*. This cannot happen in real life (Giancoli, 2000).

$$Q = \Delta U + W$$

(Equation 1)

Figure 10. First Law of Thermodynamics, as it Applies to the Principal of Zero Waste



System Boundary

Thermodynamic efficiency (η) states that the highest efficiency has the maximum amount of work (W) produced for the least amount of heat (Q) added, as seen in *Equation 2. Definition of Efficiency* (Giancoli, 2000).

$$\eta = W/Q$$

(Equation 2)

In practical applications, the term 'zero waste' can be understood as a philosophy of eliminating waste as much as thermodynamics allows. *Equation 2. Definition of Efficiency* shows that waste cannot be completely eliminated, but rather minimized by implementing a highly efficient system (Giancoli, 2000). Consider that when processes are cascaded wherein the waste of one process is the feedstock of the subsequent process. The total efficiency is the product of the efficiencies of the individual processes.

The second law of thermodynamics—the law of entropy—has many statements that reject the possibility of attaining 'zero waste.' Thermodynamics shows that not all heat applied to a system results in work. Some of that thermal energy waste is lost to increasing the internal energy and has the term "waste heat." It has long been desired to eliminate this waste heat. However, the second law says such is not possible. A measure of this impossibility is the entropy (S) (Giancoli, 2000).

"A transformation whose only final result is to transform into work heat extracted from a source at the same temperature throughout is impossible." – Postulate of Lord Kelvin

Entropy can be understood as a property of thermodynamic property that is the measure of a system's thermal energy per unit temperature that is unavailable for doing useful work. There is a relationship between entropy and the many ways a thermodynamic system can be arranged, as shown in *Equation 3. Boltzmann's Equations* (Atkins, 1984).

$$S1 = k \ln N1 \;\;\&\;\; S2 = k \ln N2$$

(Equation 3)

Where, S is the entropy, k a constant (Boltzmann constant) and N the number items in a system. The idea is to evaluate S1 and S2 over time. To evaluate the sum of the two entropies, S = S1 + S2 always gets larger with the number of changes (Atkins, 1984).

Classical thermodynamics (first and second laws) can be used as a tool to attain the closest waste management system to "zero waste" by valuating which system is the most efficient in terms of energy use. Of course, other factors must still be considered, such as public preferences, environmental guidelines and economics to see which is best suited for the local conditions. That might not be the one that is thermodynamically best.

Zero Waste vs. End of Waste

The EU has developed the 'End of Waste' (EoW) criteria that parallels many of the designed aims presented in the Zero Waste Strategic Plan. There are key distinctions that highlight the approach and limitations of using a zero waste conceptual framework as a means to minimize waste disposal to the smallest sum.

A comparison of the European approach shall underline the main differences a 'Zero Waste' strategic approach with an 'End of Waste' criteria approach. An important point to underline is that a *'strategy'* describes an approach to achieve a designated aim, whereas, *'criteria'* define the constraints by which to operationalize procedures to achieve that aim. This analysis will use some of the analysis tools described by the European Union to fill the gaps that are not addressed by the zero waste concepts.

Table 2. Comparing the Concepts: 'Zero Waste Strategy' vs. 'End of Waste Criteria'

	Zero Waste Strategy	End of Waste Criteria
Goals	• To eliminate discharges to land, water or air that threaten human and environmental health.	• To promote more recycling and use of waste materials. • To reduce consumption of natural resources. • To reduce the amount of waste sent to disposal.
Objectives	• To attain the 'highest and best use' of materials. • To reduce both upstream and downstream waste generation.	• To define technological criteria to determine when waste ceases to be waste, without endangering the environment.
Scope	• Focuses on upstream & downstream source reduction.	• Evaluation of processes are made after the point of waste generation.
Challenges Identified	• Requires education and consumer behavioral change. • Should designate land use and zoning for 'green industries.' • Need for new legislation and rulemaking. • Must advocate for producer responsibility legislation. • Must expand recycling and composting operations.	• Must alleviate the perception of secondary materials as waste. • Shall increase confidence of the users of secondary materials on quality assurance. • Should remove unnecessary costs of using secondary materials due to the classification as waste.
Methodology to Address Challenges	• Set 90% waste diversion mandate. • Conceive of strategies to achieve waste diversion goals. • Use a waste hierarchy to evaluate and compare processes.	• Diagram the current material flow and process flow. • Identify relevant legislation. • Describe potential uses of secondary materials, quality assurance standards and user specifications. • Conduct a lifecycle analysis. • Conduct a market assessment.

'Best available techniques,' as defined by the EU Waste Directive, is to use the most effective and advanced stage in the development of activities and methods of operations, thus reducing the impacts placed on the environment (European Commission, 1996). ‘Best’ suggests a high level of protection for the environmental altogether. ‘Available’ assumes a scale of economic and technology conditions that are available as scientific advancements improve and costs go down with experience. ‘Techniques’ means the way the technology is designed, built, maintained, operated and decommissioned.

Environmental Hierarchy

Oakland has established a hierarchy for determining the ‘highest and best use’ when deciding options for waste management practices. *Figure 12. Waste Hierarchy (Best to Worst)* shows the set of principles for Oakland’s Publics Works Department to follow and aims to ensure the protection for human health and the environment (City of Oakland, 2006). Oakland uses the hierarchy to establish guidelines for decision-making for a new waste management system (Interview with Gary Liss, October 5, 2012). The waste hierarchy was developed by an organization called the Energy Justice Network (City of Oakland, 2006).

The waste hierarchy gives top priority to waste prevention. If waste is generated, the waste hierarchy gives priority to reuse, recycling, then other recovery such as energy recovery, and finally disposal (for example landfill). However, the waste hierarchy lacks the ability to incorporate new improvements in technology or behavior. Recent evidence, for example, suggests that anaerobic digestion of food waste and garden waste is environmentally better than composting alone (Defra, 2012).

The State’s Waste Hierarchy is more favorable to transformation processes and has published a number of studies about the benefits of conversion of organic residues from cities through thermochemical, biochemical, or physicochemical treatment (CalRecycle, September 29, 2010). CalRecycle adopted a food diversion hierarchy: 1) waste prevention, 2) human consumption, 3) animal feed, 4) composting and vermicomposting, and 4) environmentally safe disposal (CalRecycle, August 24, 2010).

Energy recovery can substitute the need for conventional fossil fuels. The City of Oakland’s Waste Hierarchy strongly discourages the use of energy recovery systems and states that waste resources should not be used as a feedstock and is not a sustainable feedstock for energy production (City of Oakland, 2006). There are several arguments that Oakland makes: 1) Energy recovery makes waste a “commodity” feedstock; 2) High amounts of energy inputs are required in the energy recovery process; 3) Net energy output are unproven and disputed; and 4) Energy recovery facilities are expensive.

Figure 11. Waste Hierarchy, as stated in Oakland's Zero Waste Strategic Plan

Redesign manufacturing & supply chain
- Producer responsibility.
- Produce durable, reusable, recyclable, & recycled-content products.

Use environmentally sustainable materials
- Design repairable, disassemblable, deconstructable & recyclable.
- Make producers responsible for the products packaging.

Reduce, refuse, return
- Reduce the uses toxic materials in products.
- Safely dispose of hazardous materials.

Reduce consumption
- Purchase and use less.
- Buy environmentally friendly products.
- Reduce packaging.

Reuse and preserve
- Repair and recondition products.
- Deconstruct and salvage buildings and building products.
- Support thrift stores and charity collection.

Recycle, compost, digestion
- Recover secondary materials for remanufacturing.
- Recover secondary materials for composting.
- Low-temperature (<200° F) energy recovery & composting.

Down cycle
- Recover & return materials to economic mainstream for remanufacture to non- or marginally-recyclable products.

Traditional landfilling with thermal treatment
- Bioreactor landfill with alternative daily cover (ADC) or landfill construction.
- High-temperature energy recovery that include mass burn, co-firing, fluidized bed, gasification, plasma arc, pyrolysis.

Adapted from City of Oakland, 2006.

The concept of 'zero waste,' is understood as trying to reduce the amount of waste to the allows. Lifecycle assessment (LCA) is a tool to compare waste management that can quantify and compare the performance efficiency in terms of greenhouse gas emissions, material and energy consumption, as well as cost. The environmental hierarchy cannot compare several similar waste management systems alongside one another. Lifecycle assessment will be evaluated for its efficacy as a tool to compare in comparing similar waste management systems in parallel. The following evaluation will discuss mainstream lifecycle assessment tools and compare and contrast the key differences to the way lifecycle analysis quantifies energy and emission totals.

Easewaste

Technical University of Denmark developed Easewaste, a lifecycle assessment tool (LCA) used to quantify all impacts associated with waste management, including all processes in the solid waste system as well as upstream and downstream of the waste management system. It is aimed to provide more detailed and complete assessment of the environmental aspects than that which is provided by the waste hierarchy (Kirkeby, 2006). The model includes:

I. LCA inventory
II. Characterization of impacts
III. Normalization of impacts
IV. Weighed impact profile (applying political reduction targets)

The scenarios are totaled for their environmental impacts and compared. Several hundreds of resource material consumptions and substances emitted to air, water and soil. Waste management technologies that are used for a specific region must be added to reflect the most accurate environmental consequences.

ORWARE

The Royal Institute of Technology in Sweden developed ORWARE (ORganic WAste REsearch), a computer-based model to calculate substance flow analysis (SFA), environmental impacts—such as global warming, acidification, nutrient enrichment and photochemical ozone formation—and costs of waste management (Kirkeby, 2006). The sub-models can be used as a generic, modifiable model that may be combined to design a waste management system for a municipality or a company (Eriksson, 2002).

MSW-DST

The U.S. Environmental Protection Agency, RTI International, North Carolina State University and the University of Wisconsin developed a decision-making support tool for waste management, called Municipal Solid Waste Decision Support Tool (MSW-DST) (Thorneloe, 2005). The U.S. EPA developed a model that calculates emissions, energy offset and costs and has the option of optimizing the system with respect to one criterion (Kirkeby, 2006).

The MSW-DST evaluates components on an individual basis—such as the difference of environmental benefits depending upon the types of material—that minimize environmental burdens and maximize environmental benefits (Thorneloe, 2005). MSW DST can be used to evaluate tradeoffs in management options for a medium size community (Thorneloe, 2005).

The aim of this tool is to help local governments and waste managers control and evaluate various waste management practices for there cost efficiency, meeting state mandated recycling goals. The environmental aspects that are considered include local air quality impacts, energy consumption and generation, the amount of greenhouse gas emissions and overall benefits from materials recycling and source reduction (Thorneloe, 2005).

The model includes both residential (including multi-family dwellings) and commercial sector. The diversion rates are met in each scenario through recycling and yard waste composting. Linear optimization software is used to find the most efficient solutions based on cost or environmental system boundaries that include 1) energy consumption, 2) waterborne pollutants, or 3) emissions of greenhouse gases (GHG), 4) nitrogen oxides (NOx), 5) particulate, and 6) volatile organic compounds. Cost is used to determine the best mix of components.

The identification and characterization of each participating facility collected LCA/GHG related data, and California region-specific costs data for the following facilities (RTI International, 2009):

I. Composting
II. Chipping and grinding
III. Recycling or material recovery facilities (MRF)
IV. Anaerobic digestion (AD)
V. Biomass-to-energy (BTE)
VI. Waste-to-energy (WTE)
VII. Landfill disposal (as a base case)

WARM

Waste Reduction Model (WARM) is the latest tool developed by the U.S. Environmental Protection Agency that is available online for solid waste planners. It calculates GHG emissions and energy results in several waste management practices. The user must input baseline waste management practices, travel distances of waste and develop alternative scenarios. WARM is available for free online in an excel format (United States Environmental Protection Agency, 2012).

The basic assumptions in the WARM program are based on the United States average waste generation and disposal figures and may not produce accurate results for the State of California unless the local waste diversion figures are entered in. The development of scenarios for a lifecycle assessment would include a 'base case,' or business-as-usual case, a vigorous plan for achieving the goals, and a weak plan (Defra, 2007).

The four lifecycle assessment tools mentioned in the above section are all calibrated to measure the performance of a waste system. There are several tools that exist; however, they are made for assessing the lifecycle of a product, rather than assessing the lifecycle of the whole waste system. Below is a summary table that compares the tools mentioned above:

Table 3. Comparison of Lifecycle Tools

Name of LCA Tool	Country of Origin	Particularities of the Model	Assessment of Appropriateness for the Oakland Case Scale of 1 – 4, where 1 is the lowest & 4 is the highest
Easewaste	DE	- Wide array of varies compiled for many materials. - Accounts for substitution fuels.	**2**
ORWARE	SE	- Easily input of particularities of case to fit local circumstances. - Includes cost factors.	**1**
MSW-DST	US	- Does not have a wide array of materials that it considers. - It costs money. - Designed for cities in the U.S.	**3**
WARM	US	- It's free. - Helps develop scenarios. - Designed for cities in the U.S.	**4**

Chapter 3. State-of-the-Practice in Oakland

Zero Waste Disposal Reduction Goals

The City of Oakland adopted a Zero Waste Strategic Plan in 2006 that aims to reach a zero waste system by 2020. The goal is to 'eliminate' waste and pollution by reducing upstream—production and manufacturing waste—and downstream—reuse and recycle products and materials to attain the 'highest and best use' of the materials, suggesting a highly efficient system of production and consumption, where "there is no such thing as waste," as stated in Oakland's Zero Waste Resolution 79447 (Brown, 2006) with the following strategic goals:

I. Attain Highest and Best Use: Improve reuse and recycling to ensure efficient waste systems.
II. Encourage Behavioral Change: Encourage Oakland residents to reduce their personal consumption.
III. Increase Waste Diversion Rates: Implementing waste disposal operations to improve the economy and develop jobs.

The Zero Waste Strategic Plan establishes interim reduction goals every five years with the final aim of 90 percent reduction by the year 2020, as shown in *Table 4. The City of Oakland's Zero Waste Annual Disposal Goals per Year* (City of Oakland, 2006). So far, Oakland has met, or exceeded their waste diversion goals (City of Oakland, 2006).

Table 4. The City of Oakland's Zero Waste Annual Disposal Goals per Year

Oakland's Zero Waste Annual Disposal Goals Year	Disposal Tons	
1990	580,000	Actual
2005	400,000	Current actual
2010	300,000	Intermediate Goal
2015	150,000	Intermediate Goal
2020	40,000	Zero Waste Goal

Adapted from City of Oakland, 2006.

Strategies in the Zero Waste Plan

The City of Oakland has developed a number of strategies to reduce waste generation and disposal. Oakland has planned and implemented several waste reduction aims that include composting, facility recovery, household waste reduction, policy incentives, public education, recycling, source reduction, special waste material handling, and transformation. To achieve these aims, the City of Oakland's Zero Waste Plan has specified a set of waste strategies, these include:

I. New Waste Management System: Expanding the existing local and regional efforts to reduce the amount of divertible items from the landfill.
II. New Rules and Incentives: Developing and adopting regulations that encourage waste reduction, rather than rewarding waste.
III. Land Use and Zoning: Designating land use and zoning for green industry and sustainable development projects that incorporate comprehensive waste management.
IV. Producer Responsibility: Advocating for manufacturer responsibility for product waste, and prohibit materials that cannot be easily reused, recycled or transformed.
V. Education: Promote and advocate the Zero Waste Sustainability Agenda to the residents of Oakland.

The Oakland Zero Waste Strategies describe an approach to achieve the aim of zero waste. A 90 percent reduction target can occur in a combination of ways, as shown in *Figure 17. Visualization of Attaining the Zero Waste Goal*. In this example, each strategy is weighted to have a certain amount of waste disposal reduction. The amount of waste reduction is highly dependent of several variables, each that alter the levels of environmental controls, cost, legislative obligations and public outreach anticipated.

I. New Waste Management System

'Recycling' refers to "*altering the physical form of an object or material and making a new object from the altered material*" (CalRecycle, August 24, 2010). The State of California prefers reuse to recycling because reusing materials consumes less energy and resources than that required for recycling. Recycling requires the same kind of collection and transport that non-recyclable waste requires, and has an additional step of cleaning and sorting (CalRecycle, August 24, 2010). Waste prevention is therefore, the only way to reduce the about of resources used (Christensen, 2011, p. 198–9). Even if the waste management system is state-of-the-art, there is an environmental impact, such as the use of resources and energy and thus the generation of emissions (Christensen, 2011, p. 198–9). Waste prevention ultimately requires the lowest amount of energy *(*CalRecycle, August 24, 2010).

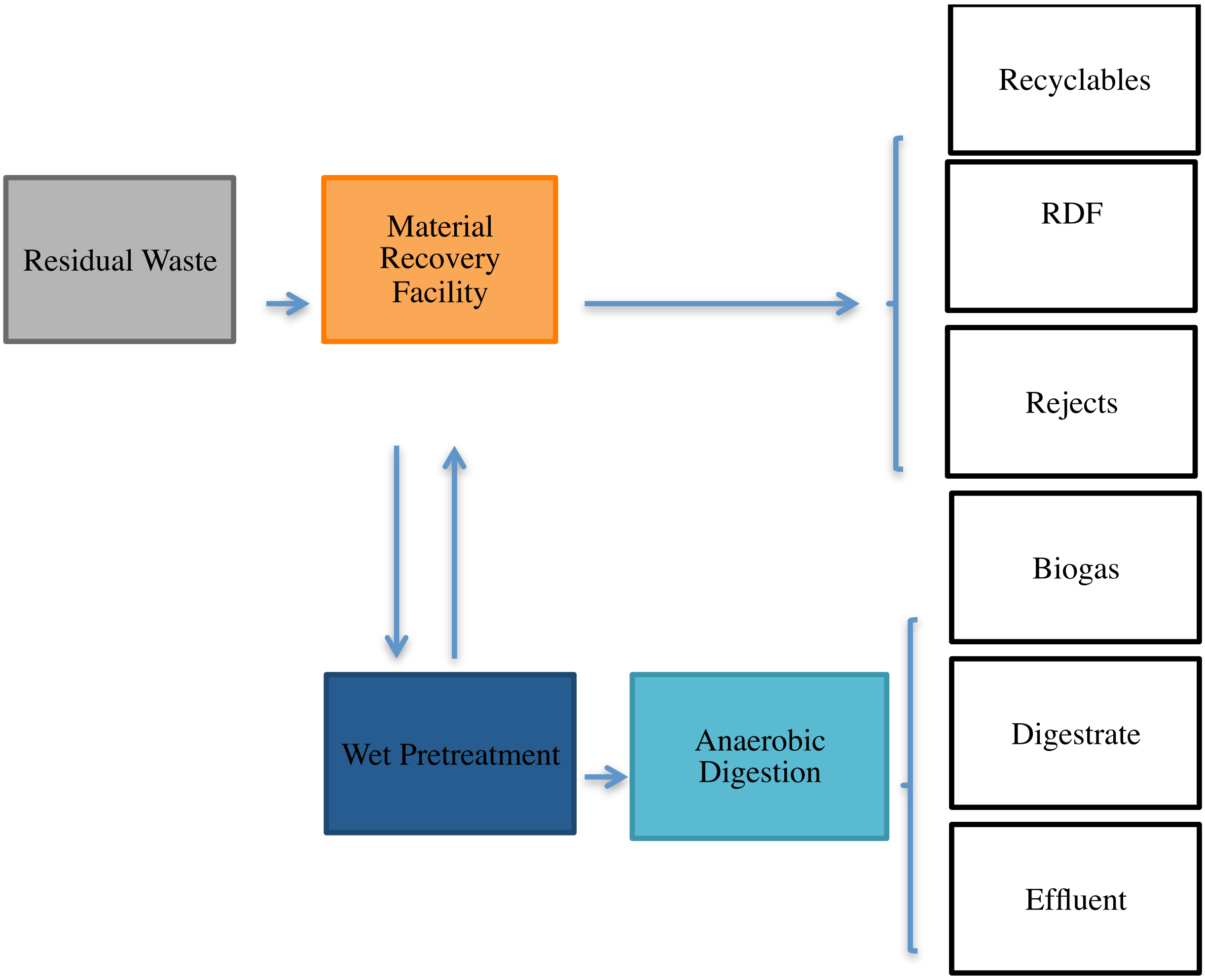
Aerobic conversion or 'composting' is one type of biochemical conversion process that biologically decomposing organic materials—leaves, grass clippings, brush, and food waste—into a soil amendment (CalRecycle, September 29, 2010). Composting occurs at temperatures of above 160°F (70°C). Composting can take place in open-air piles, covered piles in specially designed containers, which control moisture, temperature and aeration. Depending on the quality of compost produced, it can be used as a growing medium or as landfill cover (Friends of the Earth, 2005). Composting is considered to be a form of recycling, which also requires a set of preprocessing steps *(*CalRecycle, August 24, 2010).

There are several markets for compost, including mulch, landscaping materials and the horticultural sector (Christensen, 2011, p. 539). As mentioned in the process flow analysis for the City of Oakland, the 'green waste' is converted into mulch; however, very little professional documentation insuring a high-quality product exists (see the following section that will describe a methodology for ensuring quality assurance as part of a case study from Flanders, Belgium).

Composting technologies are generally for source-separated organic waste flows (Christensen, 2011, p. 533–68). Mechanical biological treatment (MBT) combines mechanical treatment, including sorting with screens, sieves and magnets and combines it with biological treatment including composting. MBT technology was designed to reduce the total volume of organics entering the landfill and became a preprocessing step for refuse-derived fuels (RDF), as shown in *Figure 12. Mechanical Biological Treatment*. Germany was the first country to utilize MBT technology to comply with the EU regulation requiring pretreatment of organic waste before entering the landfill (Christensen, 2011, p. 633–5).

Mechanical biological pretreatment (MBP) is a preprocessing step for unsorted waste that first removes the RDF and then biologically treating the organics with aerobic degradation. Mechanical biological stabilization (MBS), or bio drying, is a process where materials are first biologically treated and then mechanically treated to optimize the amount of RDF material output (Christensen, 2011, p. 633–5).

Figure 12. Mechanical Biological Treatment



Adapted from the New Civil Engineer, 2009.

There are a variety of fuels derived from waste sources, these include: 1) Landfill Gas-to-Energy (LFGTE), 2) Anaerobic digestion, 3) Incineration with energy recovery, 4) Co-incineration in coal fired power plants, 5) Pyrolysis and gasification, 6) Enersludge technology, 7) Supercritical wet air oxidation, and 8) Supercritical oxidation. At present, only .006 percent of waste undergoes "transformation"—which includes a tire incineration (CalRecycle, 2010).

Table 5. Current State of Energy Recovery Technology provides a summary of the most widely used energy recovery system, the maturity of that technology and the type of energy it produces. Incineration is the only other technology that is well suited for the conversion of municipal solid waste; however, the organic waste has a high water content and would

therefore increase the energy input required in the drying process, or the energy output of firing wet material would be lower. Anaerobic digestion is chosen as the best technology for this case.

Table 5. Current State of Energy Recovery Technology

	Technology Maturity	Cost	Biogas Use	Electricity conversion	Toxic Emissions
LFGTE	High	Low	Yes	Yes	
Anaerobic digestion	High	Medium	Yes	Yes	Not when scrubbed
Incineration with energy recovery	High	Medium	No	Yes	Air and ash byproduct
Co-incineration in coal fired power plants	Moderate	Low	No	Yes	
Pyrolysis and gasification	Low	Medium	Yes	Yes	Ash byproduct
Enersludge technology	Low	Medium	Yes	Yes	
Supercritical wet air oxidation	Moderate	High	Yes	Yes	
Supercritical oxidation	Low	High	Yes	Yes	
Hydrothermal Treatment	Moderate	High	Yes	Yes	Remaining heavy metals

Table adapted from Rulkens, 2004.

Anaerobic digestion is a biological process like composting but takes place in the absence of oxygen. The process produces a soil conditioner and turns most of the carbon dioxide emissions into methane, which can be burned to generate energy (Friends of the Earth, 2005). Anaerobic digestion uses bacteria to digest organic material in an open reactor vessel. An open reactor increases the rate of natural decomposition under anaerobic conditions (Cal EPA, 2004). The methane that is generated can be used in several applications. Such include heating and cooling applications as well as the generation of electricity (Cal EPA, 2004).

There are three main types of AD systems: a one-stage system, a two-stage system, and a batch system. In this investigation, only the two-stage AD technology shall be evaluated. This is because a two-stage AD system is the ideal in that it buffers organic loading in the first stage. This reduces toxic byproducts ants and ammonia build-up (Vandevivere, 2010). Although two-stage systems are more complicated and have a higher capital cost, they optimize biomethane generation.

The residual material from the digestion process is called the '*digestate*' that is output from anaerobic digestion process and can be used as organic fertilizer if it is composted after anaerobic digestion (Christensen, 2011, p. 464–5).

Thermal treatment, or combustion is a thermochemical conversion process is mass-burn of mixed waste at high temperatures to supply heat or to raise steam in order to generate electricity. Modern systems for burning waste range from simple stoves to multi-megawatt combined heat and power (CHP) stations. Direct combustion is most suitable for biofuel generation with low moisture feedstock. The competing interests of recycling and composting often conflict with the use in municipal waste incinerators. Although incinerators generate energy, it is rarely the best way of getting a high-energy yield from waste compared to other thermal technologies. For most materials, recycling saves more energy than that which incineration produces (Friends of the Earth, 2005).

There are major issues regarding the public's perception towards thermal treatment systems in California due to the fear of pollution generation. Resistance is strong to specifically thermochemical processing (incineration) based on the low standards exemplified in the solid waste combustion industry in the 1970s and earlier (Williams, 2006). There is concern that it will negate waste reduction efforts and promote the "need to feed the beast," as seen in Europe after their zero landfill policies. Since the U.S. is far from attaining the level of restriction that the EU has mandated, the waste-to-energy facilities that could be built in the next ten years will be decommissioned within a few decades, when U.S. and State policy could catches up to the EU zero landfill regulations (Youngs, 2011).

The unfavorable public perception of waste-to-energy is not significant in Europe as it is in the U.S. due to the limited landfill capacity, as seen in *Table 6. By Country, From Least to Most Landfilling* (Eurostat, 2008). Landfills are simply not an option to waste management in Europe. Local governments in Europe must decide between direct energy recovery that results in an increase in local air emissions and weigh it against the local energy benefits and averted impacts of exporting waste and environmental risk associated with landfilling (Youngs, 2011).

Table 6. By Country, From Least to Most Landfilling

Country	Landfill	Recycling/ Compost	Incineration
Germany	0%	66%	34%
Netherlands	1%	60%	39%
Austria	1%	70%	29%
Sweden	2%	49%	49%
Belgium	4%	60%	36%
Denmark	4%	48%	48%
France	32%	34%	34%
Italy	45%	43%	12%
City of Oakland	**45%**	**55%**	**0%**
Finland	46%	36%	18%
United Kingdom	48%	40%	11%
Spain	52%	39%	9%
Portugal	62%	20%	18%
USA	69%	24%	7%
Hungary	72%	18%	10%
Poland	78%	21%	1%
Lithuania	96%	4%	0%
Bulgaria	100%	0%	0%

Table adapted from Humes, 2012.

A neighboring city of San Jose is exploring several options to generate renewable energy from urban waste. The current loading of organic waste is 33 percent organics in the waste currently sent to the landfill. Wood waste is already sent to a cogeneration plant. As of July 2012, there is a commercial agreement to collect and process organic residuals. The Zero

Waste Development Company, LLC has proposed a dry fermentation anaerobic digester with combined heat and power recovery for the City of San Jose. The project has been approved, as of December of 2012) after obtaining air permit by the Bay Area Air Quality Management District (Young, 2012).

San Jose has a pilot scale gasification project to test the feasibility of implementing this technology. The City has a joint grant proposal with Harvest Power, an anaerobic digestion project installer, as will as the California Energy Commission (CEC) for $1.9 million grant. The project has specified for German technology vendors that include Agnion and Proprietary Processes, with multiple external consultants, including HDR and URS Corporation. The public participatory process has collected public preferences (Young, 2012).

II. New Rules and Incentives

Local and State Legislation on Waste

Oakland—a city that has met and exceeded the legal mandates for waste diversion posed by California's waste law—has authorized a strict standard of 90 percent waste reduction by 2020 from 2006 (City of Oakland, 2006). Oakland's next collection and disposal contract will expire in 2016. This prompts the impetus for public input and feedback when constructing the designs and implementation (City of Oakland, 2006). Oakland Resolution 66253 of 1989 complies with the State Assembly Bill (AB) 939, which establishes waste diversion mandates were developed to meet diversion goals of 25 percent by 1995 and 50 percent by the year 2000 (Cal Recycle, July 7, 2010).

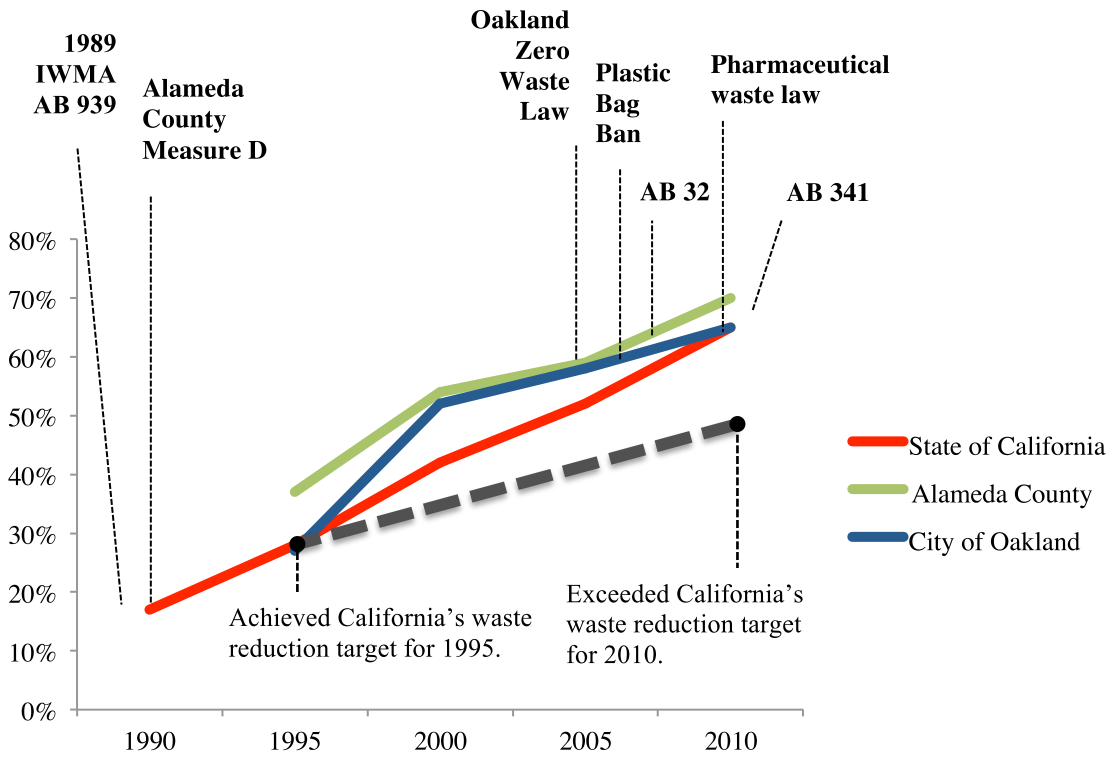
Alameda County Ballot Measure D—Alameda County Waste Reduction and Recycling Initiative Charter Amendment of 1990—coupled with Oakland's Resolution 77500 of 1990 mandates a 75 percent reduction and diversion of non-hazardous solid wastes from landfill throughout Alameda County. Measure D imposes a fee of US$6.95 per ton of landfilled waste. This surcharge funds programs and establishes a Source Reduction and Recycling Board (Recycling Board) to oversee the management and implement countywide programs (Alameda County Waste Management Board, 2006).

The Oakland Climate Action Plan established strategies to require mandatory recycling for commercial recycling through building code compliance. The City of Oakland's residential strategy includes social marketing to increase recycling behavior. The program would advocate for a reduction in material consumption in collaboration with the Alameda County Waste Management Board (Stopwaste.org). The Oakland Climate Action Plan recognizes the Zero Waste Strategies and aims to further increase the amount of composting and recycling in the City (City of Oakland, 2011-a).

The Oakland Climate Action Plan, coupled with Oakland's Zero Waste Strategic Plan, has prompted several ordinances and resolutions that have put waste as a citywide priority. The following resolutions, measures and ordinances passed by the City of Oakland and County of Alameda provide the legislative framework for waste in the region.

The Assembly Bill (AB) 341: Jobs and Recycling of 2011 established a waste reduction, recycling, and composting mandate for multifamily dwelling and businesses of 75 percent diversion of garbage by 2020, thereby creating green jobs by expanding recycling practices (Californians Against Waste, 2012).

Figure 13. Timeline of Waste Legislation over the Waste Diversion Rate



New Rules and Incentives for Bioenergy from Waste

In 2012, CalRecycle authored the Bioenergy Action Plan, which identifies methods for California to utilize its organic waste material to generate energy. The benefits include creating jobs, providing local energy, enhancing energy security, and helps protect public health and safety by reducing waste materials and fire danger. There exist barriers at the State level. The 2012 Bioenergy Action Plan aims to address these barriers. The 2012 Plan details actions (among others) to increase environmentally and economically sustainable energy production from organic waste, and encourage the development of several different bioenergy technologies, such as electricity generation, combined heat and power (CHP) facilities, renewable natural gas, and renewable liquid fuels for transportation and fuel cell applications) (Levin, 2012).

The California Energy Commission (CEC) provides access to data on energy production, consumption, research, conservation and use in California; as well as, acting as an oversight agency that perform enforcement tasks in conjunction with the California Public Utilities Commission CPUC (California Energy Commission, 2010).

The CPUC regulates privately owned electric, natural gas, telecommunications, water, transit, rail, and passenger transportation. The CPUC oversees Pacific Gas and Electric (PG&E) activities, the public utility in Northern California responsible for transmission and distribution of electricity; as well as establishing the guideline for natural gas pipeline injection in the PG&E gas grid, as seen in Annex 2. Standards of Quality for PG&E: Rule 21E (Pacific Gas and Electric, 2011).

The CPUC regulates power plants 50 megawatts (MW) or larger in order to ensure that service is reliable and that the facility meets regulatory standards. The CPUC is charged with monitoring and certifying power plants, set forth in General Order 67 (California Public Utilities Commission, 2007). The CPUC is the regulatory agency overseeing the Investor Owned Utilities (IOUs), the Electric Service Providers (ESPs), and the Community Choice Aggregators (CCAs) Randolph, 2012).

Research in renewable energy has been implemented through funding from the Public Goods Charge, a utility surcharge on energy ratepayers, and once provided incentives to existing biomass facilities. The CPUC has not reauthorized this program, but rather adopted the

Electric Program Investment Charge (EPIC) in December 2011. EPIC has been awarded US$162 million annually from 2013-2020 for public research and development and implementing renewables programs, where 20 percent of this fund will go to bioenergy research. The CEC will designate US$9 million per year for bioenergy projects. Additionally, the United States Department of Energy and the United States Department of Agriculture (USDA) offer incentives for this type of research (Levin, 2012).

There are two types of feed-in-tariffs offered by the CPUC that are both for projects smaller that 20MW. The Re-MAT (under SB 1122) is a hybrid of a feed-in-tariff. It applies to projects greater than 3MW. The standard contracts are also simple, non-negotiable contracts for 5, 10 or 20-year periods. The prices are based on a renewable market adjustment tariff (or Re-MAT) that is based on real-time market conditions. The pricing applies to the three different categories: 1) base load, 2) peak load and 3) non-peak load. The tariffs transfer Renewable Energy Credits (RECs) from generator to the utility based on either full sale of production or excess sale after onsite usage. The second kind of feed-in-tariff is for combined heat and power (CHP), which is for the customer's onsite usage, plus any additional electricity generation that does not exceed 20 MW.

Under the Public Utilities Regulatory Policy Act (PURPA), as established in 1978, outlined payments based on avoided cost of power. PURPA limits the payments to avoid costs placed on the society or costs of specific technologies with legislative procurement requirements. Qualifying Facilities/ Combined Heat and Power (QF/CHP) was approved in 2011 for projects under 20 MW.

The Bilateral Power Purchase Agreements (PPA) program is a purchase agreement between generators and participants to negotiate a price for a facility of any size (California Air Resources Board, 2011).

Net Energy Metering (NEM) Tariff provides a credit for net monthly power production at the generation portion of the rate. This allows customers that generate renewable energy to amortize the value over the course of the year and reduce their total annual consumption. Eligible technologies include biogas-fired generators, biogas fuel cells, solar, and wind for projects up to 1MW (California Air Resources Board, 2011). The overall solicitations submitted to the State were more robust than in previous years. The projects varied in both size and technology, which sends indicators to the State that the interest in the biomass and biogas industry across the State is increasing (California Air Resources Board, 2011).

Self-Generation Incentive Program (SGIP) allows renewable energy installers to offset the upfront capital cost by participating in this incentive program. Eligible technologies include wind turbines, waste heat to power technologies, pressure reduction turbines, internal combustion engines, micro-turbines, gas turbines, fuel cells, and advanced energy storage systems for projects up to 3MW (California Air Resources Board, 2011). As part of Assembly Bill 970 (AB 970) the California Public Utilities Commission (CPUC) initiated the Self-Generation Incentive Program (SGIP) for financial incentives to energy customers in meeting their energy needs to install generation facilities that are certifiable (Self Generation Incentive Program Handbook. (2010). A number of legislative bills extended the Self Generation Incentive Program through 2011.

To date, self-generating entities of biomethane would not be able to sell RECs or any other green features associated with the energy they generate, however there are several incentives for self generation that provide the impetus for energy recovery development (Self Generation Incentive Program Handbook, 2010). The current RPS Eligibility Guidebook related to biomethane states: "In the event that both the fuel processing and electric generating facilities are operated by the same entity none of the renewable attributes associated with the gas used to produce RPS-eligible electricity may be sold to another entity." This prohibits RECs from being utilized for district-wide energy distribution.

California is a leader in the United States at establishing a Low-Carbon Fuel Standard (LCFS), a greenhouse gas (GHG) standard for transportation fuel that is expected to increase research and investments in alternatives to oil and reduce GHG emissions. This regulation sets a 10 percent reduction in carbon content of passenger vehicle fuels by 2020 in California. According to the California Air Resources Board (CARB), biomethane is the lowest carbon fuel, and can be used in natural gas vehicles. As a result, the use of biomethane could lower the carbon intensity value of any transportation fuel source (California Air Resources Board, 2011).

This legislation is assumed to increase the demand for domestic natural gas, biomethane, hydrogen and electricity because of the stipulation agreement of "compliant fuels" that qualify for the 2020 carbon reduction goal. "Compliant fuels" and fuels that demonstrate compliance can generate carbon credits that can be banked or sold to: 1) Immediate LCFS Market in 2012, or 2) Larger AB 32 cap and trade program that shall begin in 2015. One aim to prevent leakage, the loss of in-state self-generation and subsequent revenue is a local and statewide initiative to encourage in-State energy production. The LCFS policy framework includes in-State generation bonuses that aim to prevent this issue of leakage.

There is a sizable body of research and development involved in making biomethane into a renewable liquid fuel for transportation vehicles. Natural gas can be used as a transportation fuel (CNG) enables the extension of the range of biogas generated from AD systems. Since biomethane can be used for fuel, according to the LCFS, the biomethane could be used in natural gas vehicles. This conversion process is less complex than other electricity and gas schematics and has been developed in several locations throughout California. An additional assessment of fiscal feasibility solely on transportation fuels from biomethane sources is recommended (California Air Resources Board, 2011).

New Rules and Incentives Examples Outside the U.S.

Germany

Germany has advanced the development of new waste treatment and reutilization methods by implementing strong waste management and storage legislation. Since 2005, with the passage of a prohibition of the use of landfill waste disposal, communities in Germany have developed concepts for alternatives to traditional waste disposal by landfills. This and many other waste policies and legislation enabled the construction of modern installations of thermal treatment plants incineration and treatment of waste. Many advanced in mechanical biological installations, fermentation, composting, processing of incineration ashes and waste from construction activities, production of secondary fuels, chemical physical processes for hazardous wastes are in partial or full deployment.

In 1996, the German government passed the Closed Substance Cycle and Waste Management Act that promotes "safe and high quality recycling and management as well as product responsibility," connected with energy conversion, production, treatment, or use of substances or products. As part of this policy, the Ordinance on Biowaste of 1998 requires the separation of biodegradable waste with low pollutant contents in agriculture after composting or fermentation.

Taiwan

Taiwan has implemented a strict source separation fee on residents as of January 2006 (GAIA, 2012). The country's aim was to limit the number of incinerators to five (from 20) within 20 years. The Mandatory Source Separation Law fines residents US$200 if found not properly source separating their trash. Subsequently, over 90 percent of residents follow the new regulations. Food waste and plastic waste still go to incinerators, due to the lack of an established recycling and compost market.

Belgium

Flanders, Belgium has the highest rate of residential waste diversion of all regions in Europe (GAIA, 2012). Flanders diverts 73 percent of its waste after the landfill ban of combustible non-biodegradable waste fractions (Christensen, 2011, p. 963). Separate collection of green waste, coupled with waste prevention program has contributed to such a high reduction level (European Commission, 2008). Compost is registered and certified before it is used or placed on the market under the Compost Certification Scheme (European Commission, 2008). The following procedures are followed to certify the compostables:

1. Compost producers must register their product through an authorized laboratory that takes samples of the material.
2. The authorized laboratory, or quality assurance organization (QAO), inspects and approves the material and provides a quality label.
3. The certified composted is used in accordance with the environmental regulations.

In Flanders, this scheme is implemented by a semi-public third party quality assurance organization (European Commission, 2008). Potentials for implementing such systems will be discussed in the Analysis Section.

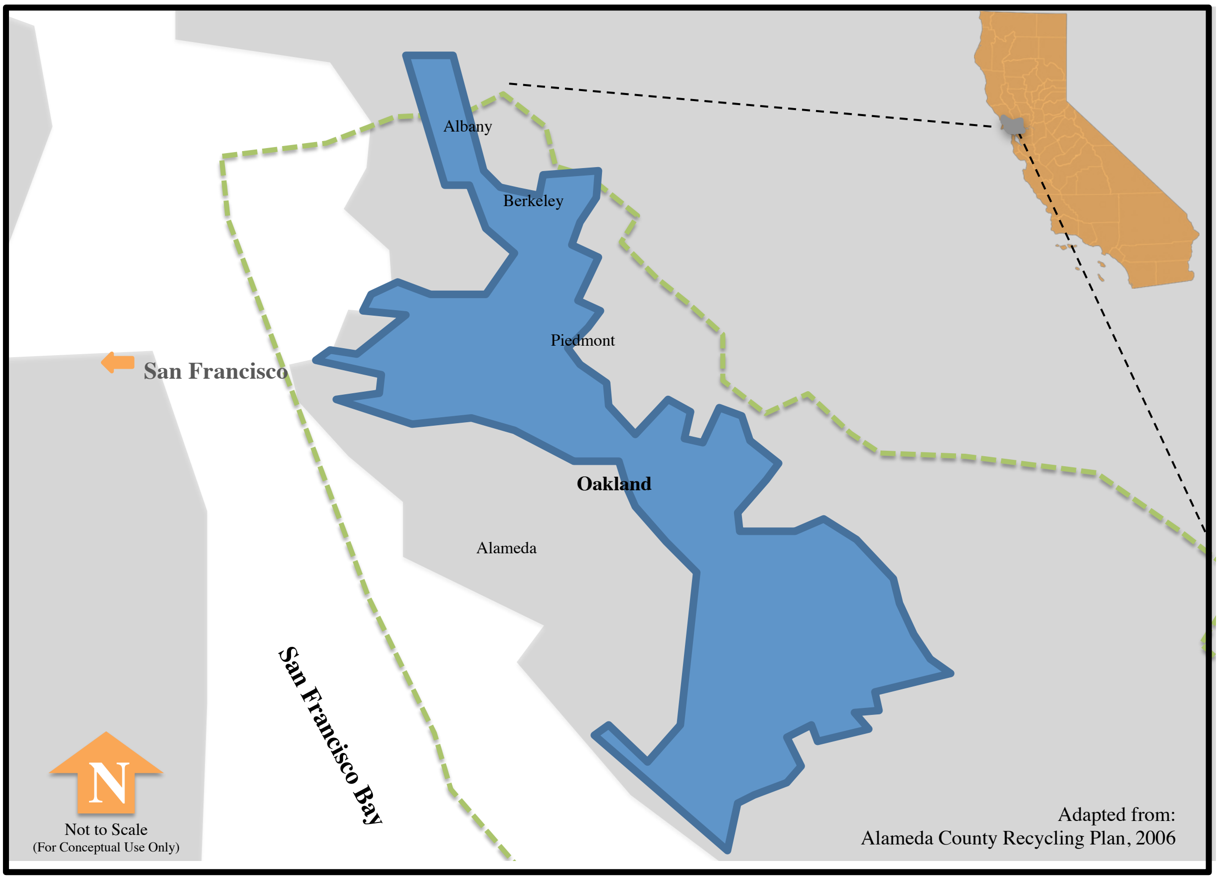
III. Land Use and Zoning

Oakland Resolution 68780 of 1992 authorized the establishment of a state-designated City Recycling Market Development Zone (RMDZ), as shown in *Figure 15. Oakland/ Berkeley Recycling Market Development Zones* (Alameda County Waste Management Board, 2006) that allows waste services in the zoning and land use.[3]

[3] For more information, see http://www.calrecycle.ca.gov/RMDZ/ZoneAdmin/

The Recycling Market Development Zone provides loans, technical assistance and free recycled product marketing. The State relaxes the building and zoning codes; as well as provides a streamlined permitting process, reduced taxes and licensing fees and aims to provide increased and consistent secondary materials.[4]

Figure 14. Oakland/ Berkeley Recycling Market Development Zones



CalRecycle has established the Anaerobic Digestion Initiative that encourages the implementation of anaerobic digestion facilities in California. The Strategic Directive aims to enhance the development of alternative energy and biofuels derived from waste materials after high-value recyclables are removed (Cal Recycle, 2011). The Strategic Directive set a 50 percent reduction of organic residuals in the waste stream by 2020 and encourages the development of alternative energy and biofuels. The acceptable anaerobic digestion (AD) facilities are permitted at existing or at new solid waste facilities or stand-alone AD facilities in areas zoned for industrial or solid waste handling activities (Cal Recycle, 2011).

[4] For more information about the RMDZ, check out: www.calrecycle.ca.gov/rmdz

The permitting process for material and energy recovery facilities can increase the time and cost of build-out. Cal EPA authored 'Permit Guidance For Anaerobic Digesters And Co-Digesters' (California Environmental Protection Agency, 2011). Cal EPA must meet or exceed the environmental regulations imposed by the United States Environmental Protection Agency (US EPA).

California Environmental Protection Agency (Cal EPA) wrote the Consolidated Permitting Guidelines to streamline the construction and operation an anaerobic digester used to convert organic residuals into energy or fuel. The aim is to present the latest permitting requirements at the State level (California Air Resources Board, 2009). The types of digester covered in this manual include new and existing digesters for manure feedstock only, new and existing digesters that co-digest manure and other organic feedstock, centralized digesters and co-digesters, and end energy product of digestion (electricity or biogas) (California Air Resources Board, 2009).

California State Senate Bill (SB) 1298: Distributive Generation of 2006 is a certification program that requires manufacturers of electrical generation technologies that are exempt from district permit requirements to certify their technologies to specific GHG emission standards before they can be sold in California (California Air Resources Board, 2009).

IV. Producer Responsibility

Integrated product policy (IPP) is an attempt to reduce the environmental impact of products with a lifecycle perspective (Christensen, 2011, p. 962–3). As part of this concept, strategies can be mandatory or optional. Such strategies include using economic instruments, substance bans, voluntary agreements, environmental labeling, and product design guidelines (Christensen, 2011, p. 962–3).

The *'polluter pays'* principle, coupled with the concept of the integrated product policy (IPP), is the basis for the producer responsibility concept, whereby producers of waste are responsible for the management of the material.

The concept of 'producer responsibility' is a legal provision requiring manufactures to perform or cover the cost of waste management services until the end of the life of the product. This regulation has one of two effects: it will either:

I. Force manufacturers to pay for waste management; or,
II. Force manufacturers to rethink their product design to reduce the amount of wasted materials.

This legislation is aimed to minimize the negative externalities caused by the manufacturer and borne on the environment or at the expense of the consumer (Chistensen, 2011, p. 962–3).

Landfill bans and landfill restrictions are two different concepts. '*Restrictions*' is any form of '*sorting*' of materials before entering the landfill (WRAP, 2010). Whereas, a '*Ban on Unsorted Wastes'*: is a measure that requires the waste industry and local governments to pretreat all waste and ban 'unsorted waste' from entering the landfill, as seen in the Landfill Ordinance of 2002 (German Federal Ministry for the Environment, 2010).

The City of Oakland has successfully implemented two examples of integrated product policy in the last five years. Oakland's Resolution 12818—the Plastic Bag Ban of 2007–prohibits the use of non-compostable plastic bags at the point of sale by retailers and provides education about the use of re-useable bags (Nadel, 2007). The County of Alameda's Safe Drug Disposal Ordinance of 2012 requires producers of prescription drugs to develop product stewardship programs to collect and dispose of unwanted medications from residential consumers (Alameda County Waste Management Board, 2006).

In 2006, California State Assembly Bill (AB) 32–Global Warming Solutions Act—created a statewide mandate of reducing greenhouse gases by 33 percent: a reduction to 1990 levels of emissions by 2020. Of the 33 percent reduction targets, a third must be from renewable energy sources (California Air Resources Board, 2009).

AB 32 created a cap-and-trade program that encourages waste disposal services to be responsible for the management of greenhouse gas emissions. AB 32 promotes "*waste diversion, composting and other beneficial uses of organic materials, and mandate commercial recycling*." It is additionally an incentive with funding available to local governments to increase recycling, composting, and generating renewable energy from anaerobic digestion (California Air Resources Board, 2009).

According to AB 32, it is expected that municipal solid waste will be utilized to produce biomethane, or be converted directly to electricity. Anaerobic digestion is included as one strategy of AB 32, and the permitting process would be subject to the environmental mandates imposed by the California Environmental Quality Act (CEQA) (California Air Resources Board, 2009).

There exist no specific numbers specified by the California Air Quality Regulatory Board (CARB), but it can be assumed that this agency supports the development of biomethane and will not create any unnecessary barriers to develop anaerobic digestion projects (California Air Resources Board, 2009).

California's Renewables Portfolio Standard (RPS) is a renewable energy standard that requires electric companies to increase procurement of eligible renewable energy sources by one percent annually, until reaching 20 percent by 2010. RPS certification shall be approved for eligible applicants as specified in the Renewables Portfolio Standard Eligibility Guidebook (California Public Utilities Commission, 2007).

Currently, California's energy profile includes twelve percent renewable sources. With the Renewable Energy Portfolio Standard (RPS) and the tradable Renewable Energy Credit system (REC) in place, the market for biomethane is ensuing. As part of a compliance tool of the RPS (See Renewable Energy Portfolio Standards), the California Public Utilities Commission (CPUC)—the regulatory authority on energy in California—authorized the use of tradable renewable energy credits (TRECs), or REC-only transactions, where energy retail sellers can buy, sell and trade renewable energy credits for compliance with the RPS (California Public Utilities Commission, 2007).

The aim of the state is to produce at least 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050. Additionally, the state aims to meet a 20 percent procurement target for bio-power within state goals for renewable generation for 2010 and continuing through 2020 (California Public Utilities Commission, 2007).

The cap-and-trade program covers all of the largest greenhouse gas emitters in the state. Biomass-derived fuels are listed as one measure to reduce methane emissions because these projects reduce the methane that is directly emitted into the atmosphere and are thereby exempt from compliance obligation. The cap-and-trade program does not assign a compliance obligation for electricity out-of-state that meet the RPS. As the cap decreases, the value of Renewable Energy Credits (RECs) increases and makes the cost of abating greenhouse gases emissions financially viable.

According to California's Renewable Portfolio Standards Eligibility Guidebook, a Solid Waste Conversion Facility is eligible as part of the Renewable Energy Portfolio Standard (RPS) if it uses a two-stage process (the most optimal digester design for digesting municipal solid waste) to create energy, and regulates potential emission sources from combustion (California Energy Commission, 2011). The project must be in State or meet the requirements for out-of-state projects.

RPS-eligible biomethane is defined as gas generated from biomass, digester gas, or landfill gas. According to the RPS, biogas can be converted to electricity either onsite or at an RPS-eligible electric generating facility. If electricity generation is onsite, no delivery information is required (California Energy Commission, 2011).

If the fuel is transferred and converted to electricity elsewhere, then there is an additional requirement to deliver the electric generating facility by either fuel container by vehicle, a dedicated pipeline from the fuel processing facility to the generation facility, or by natural gas pipeline, where the biogas is conditioned to become 'pipeline quality' biomethane, injected into a natural gas pipeline, and withdrawn at the designated RPS-eligible electric generation facility (California Energy Commission, 2011).

Metering of the biomethane volume is also required, and must be either designated for the use at a specific power plant or classified as '*pipeline quality'* as designated by the local publicly owned electric utility (POU) or other load serving entity (LSE) that would purchase the biomethane, The biomethane would have to undergo a certified process to be RPS-eligible (California Energy Commission, 2011).

V. Education for Behavioral Change

Under the Brown Act, the State of California is required to hold open meetings that contain specific requirements to ensure that the public has an effective right to learn about, attend, and participate in public meetings. All of the City of Oakland's boards, commissions, and their respective committees—by law (with few exceptions)—must conduct business publicly and provide notice of the items to be considered (City of Oakland, 2012-b).

The City of Oakland held a series of public meetings that informed residents about the detail of the Zero Waste Strategic Plan before it was finalized and provided a public comments session, where members of the public could address the City Council and make recommendations (Interview with Mark Gagliardi, September 25, 2012).[5]

Improving source segregation is dependent upon the participation ratio, the percentage of participating citizens that recycling, and the separation efficiency, or the recycling rate, which is the percentage of diverted recyclable and compostable materials from disposal (Cristensen, 2011). There is no separation system of recyclables that is perfect. Some citizens do not participate in in-house source separation. The segregation efficiency is the ratio of the actually collected separate materials (28,111 tons in 2002) divided by the segregation potential—includes 11 percent recyclables and 49 percent compostable material on the waste categorization study—totaling (City of Oakland, 2012). The City of Oakland's segregation efficiency in 2005 is stated as follows:

$$\text{Separation Efficiency } (\eta) = 10.7\%$$

The perfect system would have 100 percent efficiency (Cristensen, 2011). Annex 8. provides the full diversion figures for the City of Oakland. To improve the participation ratio and the segregation efficiency, the City must increase the willingness to participate is the main element essential to the success of a source separation program (Yoshida, 2011). A main factor that will determine the efficiency of the collection of organic waste programs is the resident's behavior. Public acceptance imposes the greatest amount of uncertainty to implementing a new waste management system (World Bank, 2004). A research investigation can gauge concerns that would prevent resident from participating.

[5] Public meetings were conducted on July 28 and 29, 2006; July 19, 2006; and September 20, 2006. These meetings engaged both the public and the business community. The advertisement for the public meeting can be found in Annex 3.

Chapter 4. Analysis

This analysis will cover three major challenges to evaluate the aims of the zero waste goals. First are the limitations of the Environmental Hierarchy as a tool for decision making. Second is the lack of regulation or practice to source separate recyclables and compostable materials from the 'brown bin' in the residential sector. The third challenge, and perhaps the most complex, is to be able to analyze and evaluate the effects of each strategy the City shall implement.

An objective of this study is to provide an evaluation of the waste management structure in the City of Oakland. This is achieved in the Section One with the appraisal of the current waste management practices, the governance structure and analysis of the stakeholders. The two other objectives—mentioned in the introduction—will be addressed in this section by assessing the effectiveness of each strategy identified in the Oakland Zero Waste Plan. Some key examples are mentioned from elsewhere that serve as a model for operationalization. A set of suggested solutions are part of an effort to operationalize the Zero Waste Strategic Plan.

Shortcomings of the Environmental Hierarchy

An evaluation of decision-making for the City of Oakland's Zero Waste Strategic Plan is made to understand the strengths, weaknesses, opportunities, and threats in a simple SWOT analysis. The SWOT will assess the Zero Waste Strategic Plan on its ability to evaluate and compare different waste management schemes next to each other based on scientific criteria. There will be a set SWOT analyses that will also evaluate the strategies and their ability to convey the effect in meeting the total waste reduction goals for 2020.

The environmental hierarchy is limited by the following factors:

Table 7. SWOT Analysis on the Environmental Hierarchy as a Decision Support Tool

Positive	Negative
Strengths • Establishes a 'rule of thumb' for comparing different waste management systems. • Easy to understand for policymakers and the general public.	**Weaknesses** • Unchanging with technology innovations. • Lacks evaluation criteria to compare different waste management systems. • Does not recognize the need to create secondary uses for material. • Has no mechanism to account for benefits of substitution.
Opportunities • Could expand the hierarchy to include lifecycle assessment. • Could add descriptions as a background to the current environmental hierarchy.	**Threats** • Need evaluation criteria to compare different waste management systems. • Need criteria to operationalize the current and potential uses of waste.

Lifecycle Assessment as Part of the Evaluation Criteria

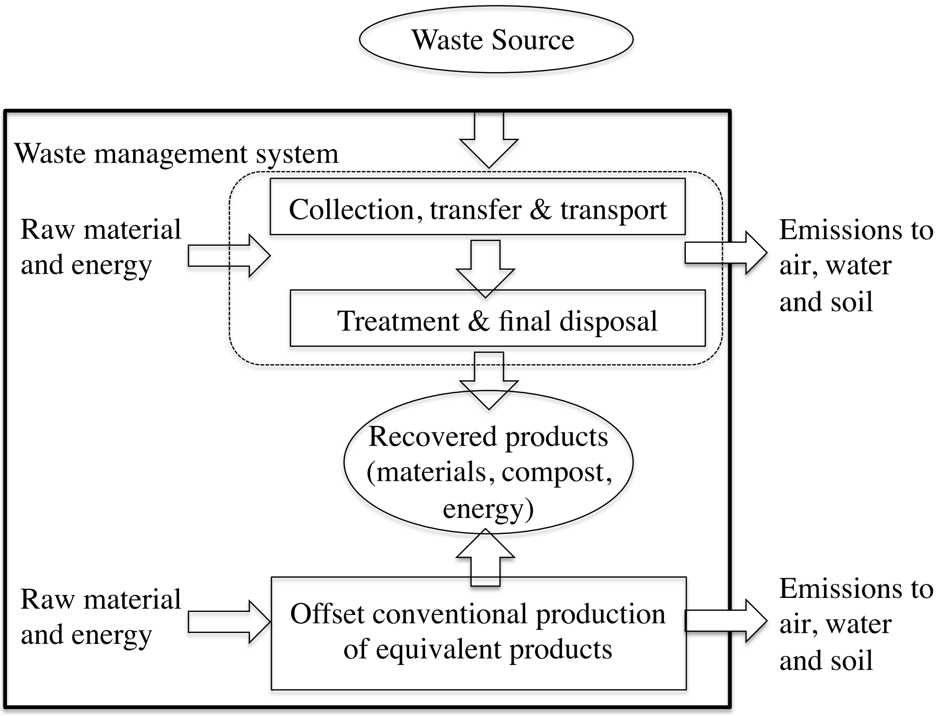
Lifecycle assessment is a complex modeling system that cannot be used to make generalizations due to the wide variation in processes, components and site-specific characteristics (Youngs, 2011). Several models exist for environmental treatment and disposal of waste. There is a large amount of information that needs to be collected for the LCA, but the more assessments that are made, the easier it is to make an assessment (Eriksson, 2002).

All waste handling systems bare environmental impacts. The challenge is to identify scientifically and with consideration of policy incentives of how to minimize the impacts in a socially and economically responsible manner (Youngs, 2011). A well-structured decision-support tool should include an easy-to-use platform, well-documented and flexible model, which is able to compare different waste management strategies, waste treatment technologies and identify the waste substances or technologies which are the sources of the most important potential environmental problems of the system (Kirkeby, 2006).

Careful construction of the system boundaries will help determine the 'upstream' and 'downstream' emissions associated with the process. Current research is expanding the definition of system boundaries for landfills to include the effects of decay in a landfill that may take 30 or 100 years. The LCA provides crucial information for decision-making and assess possible environmental risks; however must not be used to conclude assumptions beyond the scope of the tool (Youngs, 2011).

The lifecycle assessment considers environmental burdens of collection, transportation, material recovery facilities, transfer stations, composting, remanufacturing (of recovered materials), landfilling, and combustion, as well as offsets for the potential benefits from conservation of energy and materials (Thorneloe, 2005), as shown in the following figure:

Figure 15. System Boundaries of a Comprehensive Lifecycle Assessment



Adapted from Christensen, T.H. 2011, p. 138.

Table 8. Comparison of Features of Decision-Support Tools describes—in general—the similarities and differences in base-case assumptions, system boundaries, economic analysis and environmental analysis. The level of input date may differ between lifecycle assessment tools available for purchase or free download. These variations change the level of uncertainty in the model.

There is a high level of uncertainty related to what type of technology is better for reducing environmental and social impacts. A lifecycle assessment (LCA) can be preformed that may still lead to ambiguous results. Very little research is available that compares a variety of technology that is not paid for by private industry (Youngs, 2011).

Modeling of energy recovery has been found to have a significant impact on evaluating the environmental tradeoffs. Landfill gas capture, as an example, is used as a substitution fuel for fossil-based sources and thereby reducing the total GHG emissions. This is the rational for calculated net GHG emissions and energy consumption using substitution fuels (Thorneloe, 2005).

Table 8. Comparison of Features of Decision-Support Tools

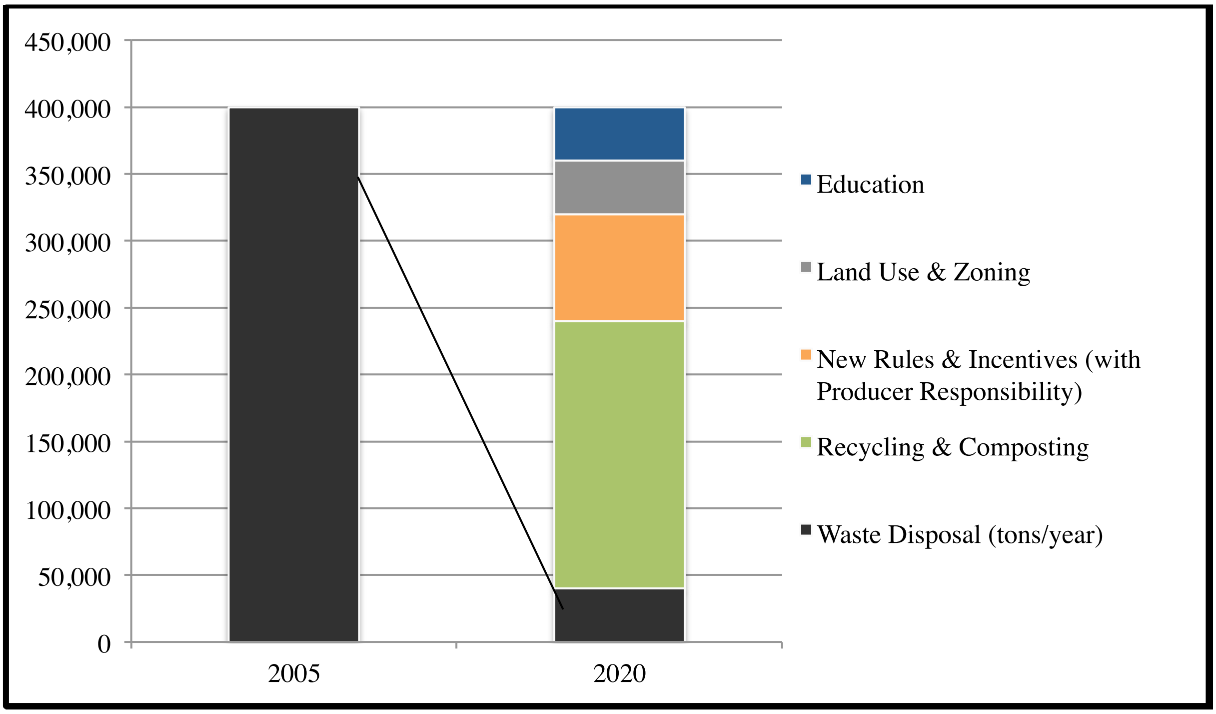
Similarities in Models	Differences in Models
Description of input flows in terms of waste fractions.	Small differences exist in characterization of organics, metal, glass, plastic, paper, and incineration ashes.
Investment and operational costs are calculated.	System boundaries differ regarding the degree of inclusion of up-stream and down-stream processes.
	Some models do and others do not consider multiple functional units, or the service provided by the system.
	Level of detail in the modeling of waste management processes.
	Different degrees data and site-specificity are allowed.
	Different level of detail can be retrieved from simulations.
	Regional specificity and cannot adapt to different regions.

Adapted from *ORWARE,* Thorneloe, 2005).

Estimating the effects of the Waste Reduction Strategies

The City of Oakland emphasizes the need for less policymaking and more public education for behavioral changes. *Figure 17*. shows that if an educational program is implemented and has a 10 percent waste reduction or diversion rate, there would be a 40,000-ton per year reduction in waste disposal. Assuming new land use and zoning regulations increase the amount of waste management activities by 10 percent waste reduction or diversion, this strategy would also produce a 40,000-ton per year reduction in waste disposal. New rules and incentives can influence system-wide change, having added regulations on producers and consumers. If this strategy reaped 20 percent waste reduction or diversion, an 80,000-ton per year reduction in waste disposal could be achieved. The expansion of recycling and composting operations could expand the treatment and handling capacity of Oakland's waste system and would provide the majority of waste reduction efforts. A 50 percent waste reduction or diversion would generate a 240,000-ton per year reduction in waste disposal could be achieved.

Figure 16. Visualization of Attaining the Zero Waste Goal



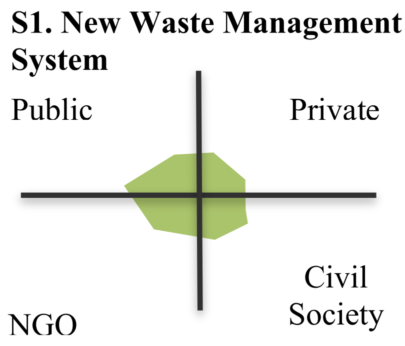
As a municipality, there exists functional planning authority that a city can use to change a practice or trend. Certain kinds of functional planning authority transpires at different levels of government, some that demand more political power than that possessed by local and regional governments.

Of the five strategies described in the plan, there are some strategies that impose a varying degree of commitment to implementation changes. For example, a citywide program to improve education about domestic source separation is essential to informing the public on waste reduction, recycling and composting, but it bares no structural improvements if the residents fail to make those behavioral changes, and thus, the City has indirect control over the result of that strategy.

The following sections will analysis each of the five strategies in the Zero Waste Plan. The strategies identified in the Oakland Zero Waste Plan will be evaluated for the scope, the ease of implementation, to whom shall be involved as a key stakeholder—whether its public, private, an NGO, or civil society—and the potential effects if carried out.

S1. New Waste Management System

The strategy of establishing a new waste management system refers to the expansion the existing local and regional efforts to reduce the amount of divertible items from the landfill. This requires the involvement from the public and private sector in establishing a public-private partnership, as set forward in the Request for Proposal process initiated in early 2013.



The City of Oakland has made a call for proposals for a new collection and disposal services contract, and specified that they would like a single franchise for all their collection services and leave it to the open market for the various recycling services necessary for achieving the zero waste aim.

Many NGOs and members of civil society are involved in the public process and can make recommendations for a new contract. Since the City's Department of Public Works has strong public support, as demonstrated in the passing of the Zero Waste Plan and Resolution in 2006, there is precedence for collaboration and two-way education to inform the City's decision-making process.

Below is an evaluation of the strengths, weaknesses, opportunities and threats that this strategy implies:

Figure 17. SWOT Analysis of Implementing a New Waste Management System

Strengths - Expands waste treatment capacity.	**Weaknesses** - Does not deal directly with waste minimization efforts and could incentivize waste generation.
Opportunities - Implementation of the best available technology.	**Threats** - Lack of evaluating the best available techniques.

The City of Oakland is interested in a new waste management system, but is highly opposed to energy recovery technology, as mentioned in the previous section. This bias is not founded by legitimate argument, but rather, it relies on sources of information that are not peer reviewed and are not recognized sources of scientific information.[6] This study has shown that the literature contradicts the assumption that energy recovery is detrimental to the environment [Youngs (2011), Williams (2006), Christensen (2011), and Rulkens (2004)].

In an interview with Kevin Drew, with the Zero Waste Program in San Francisco, Mr. Drew stated, *"Oakland might be at the same point that we were five years ago. We did not view energy recovery in a positive light until we read about the benefits that anaerobic digestion and other conversion technology for organic residuals."* However Gary Liss, consultant to Oakland's Zero Waste Plan said that the perspective held by the city is very different from both San Francisco and the State of California's, in that it does not recognize energy recovery as a viable option.

As organizations respond to the City's request for proposals for collection and disposal services, issued in early 2013, some questions regarding technical criteria for evaluating different systems must be in question. To date, no additional information about evaluation criteria has been made public and Oakland's Zero Waste lead coordinator, Mark Gagliardi (Interview with Mark Gagliardi, September 25, 2012) refused to provide any additional information, but confirmed that no kind of lifecycle criteria will be used when comparing the incoming proposals.

Energy recovery from waste is controversial in California and the U.S. There can be a wide variation of differences in views among stakeholders. These differences can result in

[6] Ideological foundation for the Oakland Zero Waste Plan: www.energyjustice.net.

polarization on such a contested issue (Youngs, 2011). There are several primary and secondary social benefits provided by converting organic residue into energy. These benefits to the public and ratepayers are shown in *Table 9.Possible Benefits and Negative Impacts of Energy Recovery,* which displays some of the strengths and weaknesses of implementing energy recovery systems (Youngs, 2011):

Table 9. Possible Benefits and Negative Impacts of Energy Recovery

Possible Benefits	**Possible Negative Impacts**
Uses an otherwise wasted resource in a more efficient manner. Provides safe collection of municipal solid waste, and reduces the need to deposit waste in landfills, and helps communities achieve there landfill diversion mandates (CalRecycle, 2010).	Disincentive to waste reduction and recycling programs (Youngs, 2011).
Decreases reliance on fossil fuel-based sources by substitution of electricity, gas, or heating from a source that would otherwise add to greenhouse gas (GHG) emissions (CalRecycle, 2010). Reliable, local, low-carbon electricity that could fill response gaps of intermittent renewables like wind and solar (Youngs, 2011).	Increased air and water impacts with a disproportionate effect on already stressed urban areas (Youngs, 2011).
Can be used for internal electricity or gas needs and those provide electric grid reliability improvements from lower demand, or provide a source of revenue for local governments via the sales of electricity, gas, heating generation (CalRecycle, 2010).	High costs may force scaling and lifetime of facilities that is contradictory to overall conservation goals – potentially exacerbated if companies receive renewable credits (Youngs, 2011).
80 percent reduction in odor and eliminates dust and pathogens generated by disposing untreated material into the landfill (CalRecycle, 2010).	Financial risk for communities if technology is unreliable (Youngs, 2011).

Several cities around Oakland, including the San Jose and the San Francisco are adopting energy recovery technology as a best practice. Since Oakland, San Jose and San Francisco have all established waste reduction targets that are more aggressive than that established by

Assembly Bill (AB) 341—a 75% diversion rate by 2020—than Oakland must adopt an aggressive campaign to meet their own 90% diversion rate by 2020. The City is left with only a few technologies that would be socially and politically acceptable.

There are several steps in the collection and disposal system that need to be addressed and improved:

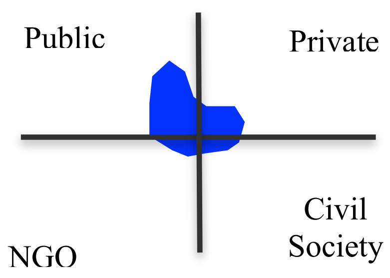
1. Reform in-home source separation to improve separation efficiency and reduce 'contaminants.'
2. Institute a pretreatment step at the transfer station and landfill facility for garbage in the brown cart.
3. Design, construct and implement new waste management technology that can adequately separate and treat waste to divert it from landfilling.

Since the current waste system receives a large amount of organics in the garbage bin (brown cart), the organics would be considered contaminated. This material, even if hand sorted in a recovery facility would still not be used as organic fertilizer. A new method for source separation in-home would then have to be utilized. This, in combination with a new pretreatment step for waste before it is hauled to the landfill would ensure that no recyclable or recoverable material would enter the landfill.

S2. New Rules and Incentives

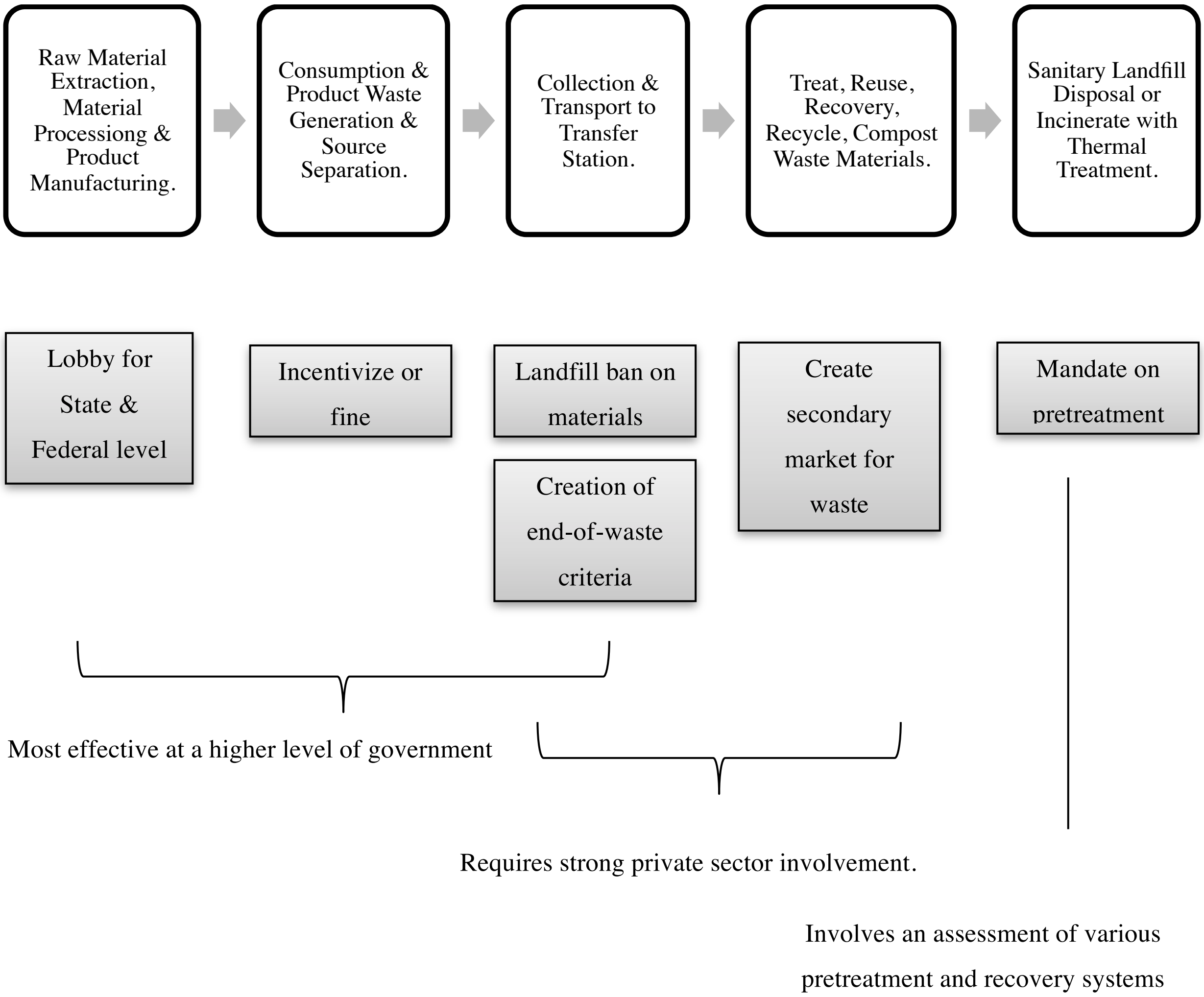
New rules and incentives are designed to encourage waste reduction, rather than rewarding waste generation. Several examples exist in the San Francisco Bay Area and from around the world. New legislation can incentivize or dis-incentivize the generation and disposal of waste through many different methods.

S2. New Rules and Incentives



There are several areas to intervene with new rules and incentives. The following graphic shows at various steps, where the city can improve:

Figure 18. Possible Areas of Intervention within the Waste Management System



Lobby for State & Federal Level

Some legislation can be brought forward at the local level, where the effects can me felt most directly, like that of the plastic bag ban, others can be brought forward by the county level, like the Alameda County pharmaceutical disposal ban. However, a comprehensive regulation or incentive for upstream emissions—while one of the main aims of the zero waste concept—is not always technically feasible at the local level. Examples exist from other countries, as mentioned in the previous section about Germany, Taiwan and Belgium on how the countries met and responded to legislation from a higher level of government.

The City of Oakland has involvement with the California Product Stewardship Council, who is responsible for coordinating efforts from cities across California and lobbying to the California State Legislature for stricter manufacturing legislation. This would be an effective area to start vigorously pushing for stricter legislation.

Incentives and Fines

If the City of Oakland were to institute incentives or fines on 1) consumables and 2) improved in-home source separation, there are several potential conflicts and opportunities that might occur. First, if the City creates a policy to discourage consumption (such as placing a tax on consumable items), as stated in the aims of the Zero Waste Strategic Plan, there is a risk to the businesses in the City that residents will shop elsewhere. There is no effective way to legislate this at the local level. Second, if the City instituted some kind of fine or incentive to improve in-home source separation, the City would be challenged to convince the City that it was necessary, as seen in the case of Taiwan in the previous section. Taiwan was forced into establishing a fee for incorrectly source separating materials, and they could achieve such a drastic measure because the cost of expanding the filling landfill was higher than the public could accept. As a result, the public approved this measure.

Landfill Bans

Germany and elsewhere have shown that it can be both cost effective and environmentally beneficial to establish a landfill ban on certain types of waste materials. During Oakland's public meetings, some of the priorities that came out of the meetings were that the residents wanted (see Annex 3):

1. Banning disposal of easily recyclable materials such as corrugated cardboard.
2. Banning use of products that are toxic, or cannot be recycled or composted.
3. Requiring producers to take back their hard-to-recycle products.

Since the public meetings in early 2006, the City of Oakland and the County of Alameda have successfully passed ordinances that ban plastic bags and pharmaceutical items from entering the landfill. There are several models for banning products from entering the landfill. The example in Flanders, Belgium serves an example of a government responding to a high-level European Union mandate by banning the existence of organic materials into the landfill. Germany has banned plastics from the landfill and has created secondary markets for the plastic waste. The market approach has proven successful in European nations.

Oakland is not strapped for landfill space. In fact, there is an abundance of landfill space; due to the over-construction from false projections before diversion regulations were in place. The Oakland residents must feel the necessity for other reasons. Issues such as climate change, environmental risks and energy security are all possible issues that the City could use to justify new legislation.

Creation of End of Waste Criteria and the Establishment of Secondary Markets

The establishment of a system were waste can be systematically not considered waste and be used as a secondary material is an effective method for reducing waste disposal. There is a strong need for alliances with the private sector and the local government to ensure no contamination gets into the secondary materials through a comprehensive quality assurance scheme. Waste is part of ontology of existence.

All living things generate waste in the form of materials or energy. It is up to the way things are designed and used and reused to determine the efficiency of a given product or material. If the City and the State is serious about reducing the amount of waste generate, they should institute a system like that seen in Europe were product manufacturers have assurance that they receive a certain standard of material that is tested in a laboratory and certified for the quality. Major waste regime changes will have to take place to change the culture and perception of waste. This can be assured by stricter standards and protocols.

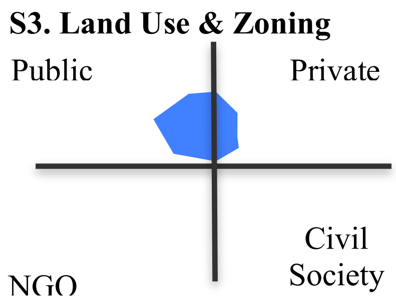
Below is an evaluation of the strengths, weaknesses, opportunities and threats that this strategy implies:

Figure 19. SWOT Analysis of Implementing New Rules and Incentives

Strengths	**Weaknesses**
- Mandatory and enforceable. - Proven success locally.	- Upstream waste reduction legislation must be made at the State and National level.
Opportunities	**Threats**
- Establish penalties or incentives to change operation and behavior.	- Lack of legislative authority.

S3. Land Use and Zoning

Designating land use and zoning regulations that spur recycling and recovery activities shall encourage green industry and sustainable development projects. Since the Recycling Market Development zone exists in the City of Oakland, the City should aim to attract more recycling businesses into the region in enhance the effectiveness of the recycling system.



Below is an evaluation of the strengths, weaknesses, opportunities and threats that this strategy implies:

Figure 20. SWOT Analysis of Implementing Land Use and Zoning Rules

Strengths	**Weaknesses**
- Existing Recycling Market Development Zones (RMDZ)	- Need a streamlined permitting process.
Opportunities	**Threats**
- Expand RMDZ. - Streamline the permitting options.	- Risk of low participation.

Some of the major challenges for cities in California include the 1) siting and permitting support, 2) land leases, 3) directing waste to facilities, 4) collection for separation of materials, 5) risk-benefit sharing, 6) collaborating on grant proposals, 7) compost marketing, and 8) policy driving conversion technology development (Young, 2012).

To deal with these issues, the City must define what types of projects they want to see and have an evaluation tool to assess what projects should have loosened environmental regulations to spur their development. Guidelines and performance mandates are set for a reason. Sometimes, these rules must be judged by their net benefit they might provide on the system of waste management.

S4. Producer Responsibility

Producer responsibility legislation shall advocate for manufacturer responsibility laws and prohibit the use of materials that cannot be easily reused, recycled or transformed.

Below is an evaluation of the strengths, weaknesses, opportunities and threats that this strategy implies:

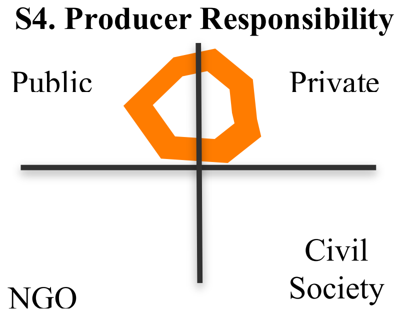


Figure 21. SWOT Analysis of Implementing Producer Responsibility Legislation

Strengths	**Weaknesses**
- Recent success in Alameda County passing the pharmaceutical waste ban.	- Requires higher level of government involvement.
Opportunities	**Threats**
- Shifts the burden of waste from the municipality to the product manufacturer.	- Strong lobbying against producer responsibility legislation at a higher level of government.

The California Product Stewardship Council, of which Oakland is a member, has advocated for upstream producer responsibility (Interview with Mark Gagliardi, September 25, 2012). Alameda County and the City of Oakland successfully advocated for a producer responsibility policy on pharmaceutical disposal. And Oakland's Plastic Bag Ban Ordinance is another example of how advocacy can be an effective tool to avoid upstream emissions. Policies and programs can drive system change, but there is no guarantee that these measures will work.

Germany has been successful at implementing producer responsibility legislation. The Germany Landfill Ordinance of 2002 sets some of the highest standards for the landfilling of waste in the world, requiring all landfills in Germany to close by 2009. Recycling of municipal waste must be up to 50 percent, and the prevention of biodegradable processes, such as methane gases to be pre-treated. After June 2005, all items able to be composted or fermented must go through pre-treatment (German Federal Ministry for the Environment, 2010).

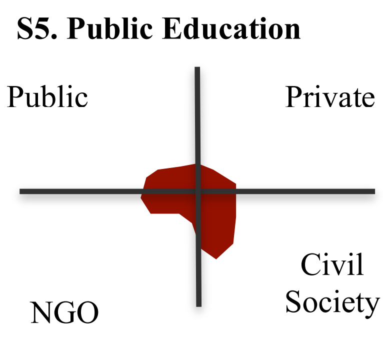
The Duales (or 'Dual' in English) System Ordinance shifts the responsibility of companies that must fulfill the take-back and recycling obligations specified in the Packaging Ordinance of 1991 to Duales System Deutschland GmbH. Based off of the polluter-pays principle, this enables participating companies to transfer their responsibilities to a private sector company that organizes the collection and sorting of sales packaging with the Green Dot (Duales System Deutschland GmbH, 2010).

The overall system for the collection, sorting and recovery of recyclables is financed with the license fees paid by industries for the right to use the Green Dot. The license fees pay for the collecting and sorting of the individual packaging materials, such as lightweight packages materials sold in Germany.

The collection, sorting and processing performance has increased, and the costs for the Green Dot system have dropped since the beginning of the ordinance (Duales System Deutschland GmbH, 2010). However, the plastic burning industry is now over-capacity in many parts of Germany and must import waste due to the constant shortage of burnable plastic (Lehmann, 2011).

S5. Public Education

The aim of developing public education programs is to promote and advocate the Zero Waste Sustainability Agenda to the residents of Oakland. Public acceptance imposes the greatest amount of uncertainty (Yoshida, H., 2011). A main factor that will determine the efficiency of the collection of organic waste programs is resident's behavior and thus not only public education, but also public participation must be integrated into the strategies associated with social programing.



Below is an evaluation of the strengths, weaknesses, opportunities and threats that this strategy implies:

Figure 22. SWOT Analysis of Implementing Public Education

Strengths	**Weaknesses**
- Promotes behavioral change. - Encourages public participation.	- No programs established at the local level. Only at the regional level.
Opportunities	**Threats**
- Reduce consumption and disposal habits.	- Willingness to participate. - Education level within the community.

Public Participation as a Form of Two-Way Education

Normal human response to change is conceived as manipulation if it is habitual behavior—as observed in the domestic waste sector—and is difficult to augment until a more desirable behavior is normalized (Leonard, 2010). Gauging the willingness to participate can be achieved by administering a public survey. For example, Madison, Wisconsin had to estimate the reliability of the amount of organic waste that would be collected based on the residents willingness to participate (Yoshida, 2011). An evaluation of management strategies for solid household waste in Khanty-Mansiysk, Russia included a public survey to evaluate satisfaction levels and preferences for a new waste system (Kaazke, J. 2010).

Liepaja, Poland hired a communications expert to meet with the City public relations head, local journalists, TV, radio, and other media agencies to develop a Public Participatory Plan. This plan discussed public relations issues, and met with local NGOs to discuss concerns of facility siting. Several research and training activities were developed for both City employs and the public. The public participatory plan included (as stated by the World Bank):

I. Objectives of public consultation
II. Appropriate stakeholders
III. Identification of key social issues
IV. Information exchange
V. Public participation techniques
VI. Budget consultation

Households must understand the importance of waste prevention and aim to change their consumer behavior. Consumers should aim to buy high quality and durable products; buy recycled products rather than products that consume raw materials; repair products rather than buying new products; share, borrowing or rent products; and donate unwanted products (Christensen, 2011, p. 133).

The County of Hampshire, United Kingdom is a model of success for public participation. Hampshire has engaged several representative groups in several stages of a long process related to developing their Waste Management Strategy (House, 2000). The County collected public preferences at several stages of the planning process through a comprehensive community appraisal that took six months. Additional sampling specific people by questionnaire took two to three months. The decision-makers underwent training to understand what was and was not legal, as well as training in ways to stay objective during the public participation process (House, 2000).

Public participation in solid waste requires an assessment of environmental and health risks, economic issues, social issues and political issues (World Bank, 2004). Gauging stakeholder preferences—concern with greenhouse gas (GHG) emissions, environmental effects, health effects, landfill practices, or overall operational costs—is essential to manage the opinions of various stakeholders. Boston, Massachusetts conducted a preference survey as a tool to gather support for their new waste management system. The scenarios were quantified and the various options for a management plan were weighted and evaluated to aid in the decision-making of the most suitable plan based on stakeholder preferences (Contreras, 2008).

Public participation brings in a wide point-of-view for decision-making and encourages engagement in the process (House, 2000). Encouraging strong citizen participation promotes government and private companies' ability to achieve their waste diversion goals (O'Connell, 2000). "*The decision is more likely to withstand scrutiny if the decision-making process is more open, more honest and more accountable*." There is no guarantee that the decision will be accepted; however it encourages the likelihood that more points of view will be considered (House, 2000), as shown in *Table10. Strengths and Weaknesses of Public Participation*.

Table 10. Strengths and Weaknesses of Public Participation

Strengths of Public Participation	Weaknesses of Public Participation
Increases likelihood of public approval.	Requires more up-front planning and capital.
Expands decision-makers perspective.	Increases complexity of decision-making.
Encourages involvement in the process.	Does not always lead to consensus.
Strengthens democracy.	People might participate only if they feel their interests are threatened.
Develops solutions with the authorities and the public.	Authorities might be cynical about the public opinion.
Identifies the public's priorities.	Can raise unrealistic expectations of what can be achieved.
Raises awareness of the issues.	
Encourages community ownership of the plan or program.	

Table adapted from *Public Participation in Making Local Environmental Decisions – Good Practice Handbook* (House, E. 2000).

The World Bank Toolkit offers a social assessment, evaluation for willingness to pay, mechanisms for public participation in facility siting, and social program for waste collectors were developed World Bank, (2004). The Toolkit offers a variety of quantitative and qualitative techniques to identify the social interests of municipal solid waste management. These include (World Bank, 2004):

I. Collection of Secondary Data
II. Household surveys
III. Socio-economic surveys
IV. Semi-structured interviews
V. Focus group discussions
VI. Willingness-to-pay surveys
VII. Service monitoring survey
VIII. Participant observation
IX. Participatory stakeholder workshops

Operational Steps for Achieving Zero Waste

Several operational steps could be implemented and made public by the City of Oakland that enhance decision-making. These steps include making evaluation criteria transparent and with the option of public input; providing a deep investigation of the current process and material flows; and the use of up-to-date performance data to compare in a lifecycle assessment. These deficits in the Zero Waste Strategic Plan can be improved by operationalizing the additional evaluation steps to achieve 'highest and best use.'

The operationalization of the 'zero waste' concept can help define a technical criterion for decision-makers when planning and evaluating waste systems. The City of Oakland should consider several operational steps to elaborate on how to compare waste management processes after all efforts are made to reduce upstream and downstream generation of waste. *Figure 24. Proposed Operational Steps to Achieve Zero Waste* is a suggested planning process for the evaluation of different waste management systems.

Figure 23. Proposed Operational Steps to Achieve Zero Waste

1. Compare waste management processes, facilities and methods.
2. Identify the legislative framework at the local, regional, State and National level.
3. Evaluate existing waste management: process flow analysis, material flow analysis, and waste stream profile.
4. Review the comissioning dates for new and existing installations and consider the time it takes to introduce 'best available techniques.'
5. Review technological and scientific improvements in waste management and develop scenarios.
6. Conduct a lifecycle assessment.
7. Evaluate economic viability of options.
8. Publish findings.
9. Public Review
10. Identify optimum waste managment system.
11. Public Input.
12. City issues request for proposals.
13. Public Input.
14. Design, install and monitor proformance.

Chapter 5. Conclusion & Outlook

The purpose for this research strived to address three aims: 1) to provide an evaluation of the waste management structure in the City of Oakland, 2) to evaluate the strategies suggested in the Oakland Zero Waste Plan, and 3) to define operational steps to support an informed decision-making approach.

Evaluation of Oakland's Waste Management Structure

Oakland's zero waste concept could serve as a best practice in source separation without the use of incineration technology. Oakland's mandate of 90% diversion rates by 2020 provides the impetus for a new waste management regime that can inform and spread to other cities interested in abandoning the practice of landfilling. However the focus on upstream waste reduction measures by advocating for manufacturer responsibility of product waste and ban undesirable material is far-flung to what a city can easily achieve.

A simple waste flow diagram of Oakland's waste management system shows that the absence of a pretreatment step is the necessary element missing from the system. An investigation of what goes into the un-separated garbage bin (the 'brown cart') shows that in-home source separation efficiency is low and that the need for either soft or hard power is necessary to enact high performance standards.

Since the City's sanitary landfill, the Altamont Transfer Station, already makes use of the gas produced within the landfill by gathering the gas in a collection system, and using the gas onsite for its on energy needs, as stated by Leonard (2010), the next step should be to ban the use of organic materials from ever entering the landfill. To do this, the City must become familiar with the benefits of generating energy from organic residuals. Creating a steady market around waste materials is the most effective method to reduce the presence of organics in the landfill (Trittin, 2005).

The worst waste management practice possible—landfilling—is the way 45% of Oakland's total waste is handled. Perhaps a 'less-bad' solution, rather than the 'highest and best' is acceptable in the short term. The City of Oakland should, instead, take an incremental approach to achieving the highest and best use.

There are real limitations that the City must consider when choosing a new waste management system. These include, but are not limited to:

- Upfront and maintenance costs.
- Best available technology.
- Willingness to pay.
- Willingness to participate.
- Environmental guidelines.
- Energy and resource requirements.
- Greenhouse gas (GHG) emissions.

The intricate network of stakeholders increase the complexity of the decision-making process and for this reason, it is important to engage the necessary stakeholders (those who have some assumed involvement, or role as a decision-maker) early and often. The Oakland Office of Public Works Department should take the lead role as a facilitator of dialogue and look to the great number of non-profits in the San Francisco Bay Area to help develop these linkages.

If Waste Management, Inc. will perform the collection and disposal services when the new service contract takes effect in 2016, the City should form a closer link, where Waste Management, Inc. pilots projects that Oakland proposes, as a means to achieving their waste diversion goals. This relationship is successful in San Francisco and could lead to new and innovative methods specially tailored towards the City's own particularities.

The City and County have undergone several successful and failed waste diversion programs since California passed AB 939, such County's domestic composting program aimed to reduce the cost for the municipalities—by reducing the amount of waste that needed to be picked up. This was a big failure due to the lack of resident's willingness to participate. Every residential detached home is required to purchase waste management services: this includes the green, blue and brown cart. However, multi-unit residents are still not required to have the green cart. The City should mandate green carts as a requirement for all residential services. Several successes exist, including Oakland's plastic bag ban, the passing of Oakland's Zero Waste Resolution, and Alameda County's pharmaceutical waste ban. The City should not fear trying new programs and abandoning them when they fail.

If Oakland wants to reach the 90% goal by 2020, it could be wise to push for a regional resolution or ordinance for Alameda County. The County's StopWaste.org has many resources that the City could benefit from, including linkages between the 14 cities within Alameda County.

Evaluation of the Zero Waste Strategies

Upon review of the literature and interviewing key stakeholders at the City-level, it became clear that the intension of any future project does not include the high potential for using energy recovery technology, even though the literature proved the success of certain types of technology. And furthermore, an overall bias against creating markets around waste is proceeded with caution. Waste reduction measures are considered more favorable than recycling measures; however, neither educational campaigns, nor advocacy for new legislation is a guarantee that behavioral patterns will change.

A general remark for the City of Oakland's Zero Waste Strategic Plan is that it lacks scrutiny of an informed decision-making process and prevents the City from attaining the 'highest and best use of materials.' '*Zero Waste'* as a concept is not how nature works. Waste will always occur, and the City must be able to discern between project proposals of low and high performance.

Zero waste as an operational lens is difficult to implement at the local level, because so many of the measures include product redesign and remanufacturing of materials. Such matters occur at a higher level than that which the city can implement. Thermodynamic efficiency (η) is a better way to understand the term 'zero waste.' Lifecycle assessment is a tool to calculate thermodynamic efficiency by estimating which system is the most efficient in terms of energy use, as well as over factors important to the total evaluation.

Based on research conducted in this study, the City of Oakland should address the following issues with each strategy identified in the plan:

Table 11. Summary of Strategic Steps to Advance the Zero Waste Plan into Action

New Waste Management System	New Rules and Incentives	Land Use and Zoning	Producer Responsibility	Public Education
Implement downstream waste reduction measures, while advocating for upstream waste reduction measures.	Strive to consolidate bureaucracy between the City and County agencies.	Strengthen existing local and State land use and zoning regulations by defining what types of recycling and composting businesses to attract.	Forge stronger partnerships with private sector actors assumed to play lead roles in the decision-making.	Aim to achieve two-way communication in every public education campaign.
Stand out among the adjacent cities and distinguish the city's zero waste tactics from other cities.	Concentrate on measures that can be achieved at the local level, rather than the State, or Federal level.	Attract salvaging and recycling industries into the City.	Identify supply-chain pathways for the use of secondary materials.	Make the Request for Proposals (RFP) process more transparent to the public.

Operationalization of Zero Waste

To meet the 90 percent diversion goals, the City must expand its current recycling and composting practices—assuming that the City does not meet its waste reduction goals solely by the implementation of upstream producer responsibility mandates and downstream consumer responsibility programs that decrease waste generation.

As the City has declared a zero waste aim, which implies that waste should undergo the 'highest and best use,' the City must develop an evaluation criterion to minimize uncertainty in different waste management systems.

Outlook

The City of Oakland provides a model example of how a city may reach low to no landfilling without the use of incineration. Oakland encourages residents to reduce consumption patterns and advocates for producer responsibility legislation, with the coordination of the regional government, a pioneer in establishing producer responsibility law on pharmaceuticals in California. Without the coordinated efforts from policymakers at the State, region and local level to reduce landfill disposal, the zero waste rulemaking would have been impossible at a city-scale.

However, the future for achieving the Oakland Zero Waste Plan depends on the ability to carry out effective projects and programs that reap measurable results. Oakland's new collection and disposal contract—advertised in early 2013—for the year 2016 should connect directly to the aims stated in the Zero Waste Plan.

Oakland is in an opportune position, being in a growing region—within the San Francisco Bay Area—and fortunate for the countless private and public organizations that are knowledgeable and active in the fields of waste and energy reduction, as well as greenhouse gas-reduction measures. Having the intellectual capital of both the Silicon Valley—filled with inventors and investors of technology that are used around the world—and San Francisco—an environmental leader in urban operations—gives Oakland the potency to try new ideas never tested elsewhere.

Alameda County and the City of Oakland have served as leaders in the State of California in passing key legislation in reducing the amount of materials entering the landfill. Next steps for the City of Oakland should include a ban of organics from entering the landfill. A market around secondary materials must be in place for this ban to be economically feasible. Several schemes explored in this research—a certification scheme for organics, or a high fee for incorrect source separation—could be a pathway for Oakland to explore. Several other successful options are in existence.

Limitations exist at the State level in regards to the definition and formal understanding of the term 'waste.' If perhaps, the City of Oakland was to take on a new kind of definition of 'waste,' one that understands 'waste material' as a possible supply for secondary products, than the City could significantly profit from the repurposing of materials and the prevention of raw material extraction.

This case study is useful for cities without cohesion from national entities and sets a model for local achievable efforts. Having local advocates from the civil society and NGOs can further the public awareness surrounding the achievement of a zero waste goal.

Annex

Annex 1. Alameda County Diversion Program[7]

No.	Strategy	Action
1	**Composting**	(a) Residential curbside green waste collection (b) Residential self-haul green waste (c) Commercial self-haul green waste (d) Government composting programs
2	**Facility Recovery**	(a) Material recovery facility (b) Transfer station (c) Composting facility (d) Alternative daily cover
3	**Household Waste (HHW)**	(a) Permanent facility (b) Mobile or periodic collection (c) Curbside collection (d) Waste exchange (e) Education programs (f) Electronic waste (g) Other HHW
4	**Policy Incentives**	(a) Economic incentives (b) Ordinance
5	**Public Education**	(a) Electronic (radio, TV, web, hotlines) (b) Print (brochures, flyers, guides, news articles) (c) Outreach (tech assistance, presentations, awards, fairs, field trips) (d) Schools (education and curriculum)
6	**Recycling**	(a) Residential curbside (b) Residential drop-off (c) Residential buy-back (d) Commercial on-site pickup

7 http://www.calrecycle.ca.gov/LGCentral/Reports/Viewer.aspx?P=JurisdictionID%3d3%26ReportName%3dDpProgramStatusMatrix

		(e) Commercial self-haul (f) School recycling programs (g) Government recycling programs (h) Special collection seasonal (regular) (i) Special collection event
7	**Source Reduction**	(a) Xeriscaping/ grass-recycling (b) Backyard and on-site composting/ mulching (c) Business waste reduction program (d) Procurement (e) Government source reduction programs (f) Material exchange, thrift shops
8	**Special Waste Materials**	(a) Sludge (sewage/ industrial) (b) Tires (c) White goods (d) Scrap metal (e) Concrete/ asphalt/ rubble (f) Disaster debris (g) Rendering (h) Other special waste
9	**Transformation**	(a) Tires

Annex 2. Standards of Quality for PG&E: Rule 21E

Typical Biogas	Biogas	PG&E Standard Requirements
Gas Composition and Heating Value		
CH_4	62.0%	98.5%
CO_2	37.6%	1.0%
O_2	0.4%	1.0%
H_2	0.4%	0.7%
S	*	17 ppm
N_2	0.4%	0.7%
Heating Value (BTU/scf)	625	990+
Two of the Key Trace Constituents		
H_2S	300 ppm	4 ppm
Siloxanes	4,000 ppm	Not-detectable
Others Requirements		
Gas Temperature		60-100°F (15-38 °C)
Hydrocarbon Dewpoint		45°F or 20°F
*** Sulfur content varies with each feedstock**		

Annex 3. Announcement for the Public Meetings on the City of Oakland's Zero Waste Strategic Plan

"Oakland is pursuing the goal of being a Sustainable City – a place where we can meet our current needs while ensuring that our children and grandchildren can live rewarding and healthy lives in the future. In that spirit, the City is developing a Zero Waste Strategic Plan to cut waste disposal to landfills by 90%, reducing its current 400,000-tons/year disposal down to 40,000 tons/year by 2020.

Zero Waste goes beyond recycling our discarded materials. It considers the vast flow of resources and waste through our society and economy, and moves to eliminate waste. Oakland can move toward Zero Waste by:

- Expanding and improving existing recycling, reuse, and waste reduction efforts.
- Banning disposal of easily recyclable materials such as corrugated cardboard.
- Banning use of products that are toxic, or cannot be recycled or composted.
- Requiring producers to take back their hard-to-recycle products.
- Encouraging businesses to create new products, services, and job opportunities based on Zero Waste objectives.
- Expanding building and construction standards that conserve energy and resources."

Annex 4. Public Survey – Preferences on Zero Waste Plan

This plan was adapted from the World Bank's '*Toolkit: Social Assessment and Public Participation in Municipal Solid Waste Management'* (2004).

(A) General Questions

1 – Are you a resident of Oakland?

☐ Yes

☐ No

2 – Do you live in a house or apartment?

☐ House

☐ Apartment

3 – Apartment/ House has a garden?

☐ Yes

☐ No

(B) Opinion about the present situation of solid waste services. This is of vital importance to gauge the position of true preferences and problems:

1 – What is your opinion about the current situation of the disposal of solid waste in Oakland?

☐ I'm doing it because everyone else is doing it

☐ There will be problems in the end

☐ Nothing is wrong with what I'm doing now

☐ No opinion/don't know

(C) Questions regarding the situation of organic waste:

1 – What is your opinion about the current solid waste management in Oakland (check all that apply)?

☐ Too much source separation required

☐ Too few source separation options

☐ Too expensive

☐ Nothing is wrong with solid waste management in Oakland

☐ No opinion

2 – What would you prefer as a solution?

____

(B) Organic waste disposal habits

1 – What do you do with your organic waste?

☐ Use for own compost

☐ Separate for compost collection

☐ Leave it to be collected from the house with normal waste

☐ Don't know

2 – What is your opinion about the present site where your waste is disposed?

☐ Too near to Oakland

☐ Too far from Oakland

☐ Nothing is wrong with the site

☐ No opinion/don't know

(D) What do you consider the most urgent problem related to the disposal of solid waste in Oakland (top 3)?

☐ Personal health

☐ Location of the facility

☐ Compliance with greenhouse gas emission regulations

☐ Cost for the costumers

☐ Environmental emissions

☐ Public input

☐ Reducing overall disposal to the landfill through waste treatment

☐ Reducing overall waste generation through waste prevention programs

☐ Nothing is wrong

☐ No opinion

(E) New Waste Management Concept

1 – If a new system for composting with renewable energy generation were established, would you support it?

☐ Yes

☐ No

Annex 5. Semi Structured Interviews: Mike Gagliardi

The interview was conducted on September 25, 2012 at 10:00am by a phone conversation with Mark Gagliardi, from the City of Oakland Public Works Agency, Environmental Services Division, an expert and key representative from that City that developed Zero Waste Strategic Plan.

Interview Question: Oakland's Zero Waste Strategic Plan sets a target of 90 percent reduction of waste disposal by 2020. In your opinion, describe the City's intent when establishing this ambitious target.

Interviewee Answer: The aspiration of the Zero Waste Strategic Plan was to minimize upstream causes of waste generation. The Strategy did not and has not specified were to attain all the sources of waste reduction, but the aim is to achieve this goal through a 'system redesign.' There are some elements that the City has more control over, such as formulating contract negotiations with waste service companies by instituting stricter standards.

Interview Question: Oakland already has a strong entrepreneurial free market competition for collection of recyclable materials. As the implementation plan of the City is developed, do you see one service provider, like the City of San Francisco's model that contracted solely to the company Recology for all waste collection, recycling, composting and disposing services, or like the City of San Jose, with a multitude of waste contractors?

Interviewee Answer: Oakland's implementation will look more like a hybrid of the two strategies. San Francisco focuses on source reduction and can work with one contractor on a long-term basis. Furthermore, San Francisco City has its own mandate for recycling, whereas Oakland's mandate is through Alameda County's StopWaste.org. San Jose focuses more on automated sorting and is ruled by the State's mandatory requirements, requiring fewer materials to go into the landfill.

Interview Question: Can you describe some of the details and criteria for the 2016 Waste franchise agreement?

Interviewee Answer: Currently there is a Request for Proposals (RFP) issued. The details however are within a 'cone of silence' and cannot be discussed at the present time. In 2015, there will be 'messaging' to the general public in regards to the new franchise agreement.

Interview Question: Discuss the process for developing the Environmental Hierarchy to Guide Oakland's Zero Waste Strategies, Policies and Actions.

Interviewee Answer: Gary Liss was the technical assistant to the planning. The Urban Environmental Accords, signed by Mayor Brown 2005, was the guiding document that drove the development of the Zero Waste Strategic Plan. There were also several non-profit agencies that spearheaded the effort, Ecological Footprint, as an example. The organizations in Oakland have been and remain to be great advocates for the Zero Waste Strategic Plan. The Environmental Hierarchy is a filter for projects to attain 'highest and best use.'

Interview Question: Two strategies mention education and training, "1) to develop and conduct zero waste and sustainability public education, information, branding, outreach, communications, and messaging…" and "2. Develop, implement, and leverage partnerships, programs, and campaigns toward zero waste sustainability." Is there any more information on the development of those programs in addition to public comments and public workshops? Mailers, public surveys, etc.

Interviewee Answer: There is no direct public education programs related to the Zero Waste Strategic Plan, but rather the education campaign is within the sustainability efforts in the City. More information can be found at: http://www2.oaklandnet.com/Government/o/PWA/o-/FE/s/SO/index.htm

Interview Question: Do you use or will you use scenario methodology to meet the 2020 Strategy?

Interviewee Answer: No, but it would have been useful. At the time, there was no such decision support tool known about or available.

Interview Question: Is lifecycle assessment criteria used for evaluating project options.

Interviewee Answer: That's a good question that no, we did not consider.

Interview Question: What do you envision for the future of Oakland's new waste management concept

Interviewee Answer: The California Product Stewardship Council, of which Oakland is a member, has advocated for upstream producer responsibility. Alameda County has recently adopted extended producer responsibility on pharmaceuticals. The future system will comprise multiple tools. Policies can drive outcomes, but there is no guarantee. We need more information related to business and price signals.

Annex 6. Semi Structured Interviews: Gary Liss

The interview was conducted on October 5, 2012 at 12:00pm by a phone conversation Gary Liss, contract consultant with the City of Oakland; lead on developing the Zero Waste Environmental Hierarchy.

A phone conversation with Gary Liss provided details regarding the developmental of the environmental hierarchy for the City of Oakland's Zero Waste Strategic Plan.

Interview Question: How is the Oakland Zero Waste Hierarchy different from that put forward by the State?

Interviewee Answer: The State's Waste Hierarchy is much more favorable to transformation processes that include incineration. The City of Oakland's plan is highly unfavorable to incineration technology and there is text correlated to the negative impacts of thermal technology. Mike Ewall with the Energy Justice Network was the person that developed the hierarchy and he might have detailed LCA studies.

Interview Question: How should decisions be based on the waste hierarchy? How does it shape policies and actions?

Interviewee Answer: Oakland is using the hierarchy to establish their next garbage recycling service to maximize diversion rates.

Annex 7. Semi Structured Interviews: Kevin Drew

The interview was conducted on October 5, 2012 at 9:00am by a phone conversation Kevin Drew, Residential Zero Waste Coordinator, City of San Francisco.

A phone conversation with Kevin Drew provided insight into how a leading municipality in the Bay Area and the U.S. develop and evaluate waste programs. San Francisco's goal is zero waste by 2020, now at 70 percent and set to reach the mandates. Mr. Drew responded to several questions regarding decision-making, evaluation criteria, and their relationship with their single waste service providing company, Recology and describes whom they look to as model municipalities.

<u>Interview Question</u>: What are your evaluation criteria for establishing and quantifying effectiveness of zero waste projects? LCA or other?

<u>Interviewee Answer</u>: San Francisco does not deeply research or report. We [SF Environment] follow a 'less planning, more doing approach.' However, SF measures disposal and diversion rates using California's San Francisco-specific generation characteristics.

<u>Interview Question</u>: How are decisions made based on the waste hierarchy? How does it shape policies and actions?

<u>Interviewee Answer</u>: San Francisco follows the principals of highest and best use, in programs such as for milk cartons that contain both plastic and paper. SF Environment is currently investigating the potential for recycling, rather than composting.

<u>Interview Question</u>: Do you use any decision support tool? If not, how do you incorporate stakeholders in the decision-making?

<u>Interviewee Answer</u>: Since the passage of AB 939, there have been several 'local task forces' at the county level. That has added in the establishment of citizen advisory groups. SF no longer uses the citizen advisory group because of the lack of need for one. The city and county is one entity, which reduces the bureaucracy and the amount of paperwork required. SF Environment is a relatively new agency (15 years old), and the departments are separated

from sanitation, for example, which gives the solid waste management department more freedom to act.

Engagement is performed at the policy and ordinance level, and SF has a need to have to leverage a political support from the Board of Supervisors and the public. When a new trash system was implemented for apartment buildings, SF went to apartment groups to share tips and obtain input. When small retailers were affected by the plastic bag ban, SF Environment initiated an information campaign and collected opinions on the ban.

Interview Question: Can you describe, in general terms, the relationship with Recology.

Interviewee Answer: Recology has been working in San Francisco, in some form, for the last 100 years. Today, we see a formal collaboration. Twenty years ago, there was more resistance to recycling. Then, the company made a strategic decision to embrace the program. There are several major advantages for San Francisco when working with Recology. First is that they are a local company, while have several other businesses throughout the State of California, over half of the revenue generated is from San Francisco. They now take a strong position on being leaders, they collaborate and this relationship cuts down on the amount of contractual negotiations that have to be made, because the company is more inclined to take risks. This makes the company a facilitator for research and development work within San Francisco.

Interview Question: San Francisco is seen as a national leader and a best-case example from the U.S. abroad. What city did you look to as a best-case model?

Interviewee Answer: Oakland was ahead of us when it came to establishing a plastic bag ban. SF looked to Oakland and Berkeley for support on that project. SF looks to San Jose, Santa Monica, Seattle, Portland, and Eco-Recycle in Boulder but we could do more exchange. The California Recycling Association as well as the CRRA establishes some of these collaborative meetings.

Annex 8. Oakland Fact Sheet: Waste Disposal and Recycle

	2002	2010
Reporting-Year Disposal Amount (tons):	420,887	**290,993.01**
Disposal Reduction Credits (Reported):		
Disaster Waste (tons):	0.00	0.00
Medical Waste (tons):	0.00	0.00
Regional Diversion Facility Residual Waste (tons):	1,597	0.00
C&D Waste (tons):	0.00	0.00
Out-of-State Export (Diverted):	0.00	0.00
Class II Waste: (tons):	26,514	3,170.00
Other Disposal Amount (tons):	0.00	0.00
Total Disposal Reduction Credit Amount (tons):	**28,111**	3,170.00
Total Adjusted Reporting-Year Disposal Amount (tons):	**392,776**	287,823.01
Reporting-Year Transformation Waste (tons):	-	17.99
Reporting-Year Population:	-	390,757
Reporting-Year Employment:	-	146,443
% Incineration	0%	0.006%
% Household	-	33%
Population Projections for Alameda County (2020)		1,584,797.29
Approximate Share for Oakland		427,895.27
Base-Year Residential Generation		177,717.00
Change in Residential Sector (%)	Growth:	19%
Residential Generation Estimate (2002)		211,483.23

Adapted from the Jurisdiction Diversion/Disposal Rate Detail, CalRecycle, 2012

Where,

$$\frac{28{,}111\,\frac{\text{tons}}{\text{year}}}{(392{,}776\,\frac{\text{tons}}{\text{year}} \times .11\text{ recyclables}) + \left(392{,}776\,\frac{\text{tons}}{\text{year}} \times .49\text{ compostables}\right) + 28{,}111\,\frac{\text{tons}}{\text{year}}} =$$

1**0.7%** Separation Efficiency for the City of Oakland

Annex 9. Zero Waste Hierarchy of Highest and Best Use [8]

Rethink and Redesign by Manufacturers

- Make products durable; from reused, recycled and/or compost materials; and recyclable
- Use materials that are more environmentally sustainable
- Offer services instead of products and lease products to customers

Reduce, Conserve, and Efficient Systems

- Refuse - Tell suppliers to stop sending products in packaging that causes problems or creates waste
- Return - Tell suppliers to takeback packaging
- Toxics Use Reduction - Reduce amounts of toxic chemicals in production and replace toxic chemicals with less toxic or non-toxic alternatives
- Consumption and Packaging Reduction - Use less; buy less; buy stuff with less packaging; avoid disposables & non-recyclables; bring your own bag, cup, mug, water bottle, cloth napkin, etc.

Reuse

- Reuse product for original use and retain value and function of product
- Reuse product for alternative use
- Reuse parts to repair and maintain products still in use
- Thrift stores; used building materials stores (e.g., ReStores); garage sales; flea markets; charity collections; freecycle.org, craigslist.org; ebay.com
- Household hazardous waste "swaps"

Recycle

- Cluster businesses that can reuse, recycle or compost products most efficiently and locally
- "Clean Materials Recovery Facility (MRF)" - Source separate materials, sort at MRF and recycle inorganic materials in closed loop systems
- Downcycle - Recycle inorganic materials in single-use applications (like recycled paper into tissue paper; recycled plastic shampoo bottles into park benches)
- "Dirty MRF" - Sorting recyclables from mixed materials or wastes "Rot" Organics
- Food donations to people, or animals
- On-Site composting (backyard or on-premises at businesses)
- Combined organics (yard trimmings, discarded food and food-soiled paper) composting
- Yard trimmings only composting
- Combining organics with bio-solids
- Digester Gas - From bio-solids, animal waste and/or food scraps

Regulate Disposal, and Dispersal or Destruction of Resources

- Ban materials or products that are toxic or not able to be reused, recycled or composted

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[8] Prepared by Gary Liss & Associates, www.garyliss.com, September 18, 2006, based on Environmental Hierarchy of Waste Management & Energy Production Methods / Fuels / Technologies, Energy Justice Network, Mike Ewall, 215-743-4884, catalyst@actionpa.org, www.energyjustice.net.

- Recover Energy and Bio-fuels
- Sustainable biodiesel - From used vegetable oils
- Cellulosic ethanol - From urban wood waste, bio-solids, animal waste and/or food scraps;
- From mixed construction and demolition wood waste; From tires; From mixed solid waste and bio-solids
- Landfill
- Land application of organics for non-food crops
- “Alternative Daily Cover” (ADC) or “beneficial use” in landfill
- Landfill in “bioreactor” designed without cost constraints
- Landfill gas recovery (should be required, not subsidized)
- Monofill landfill
- Landfill in Subtitle D landfill
- Landfill in bioreactor designed within cost constraints
- Incineration of Mixed Municipal Waste - Mass Burn, Fluidized Bed, Gasification, Plasma Arc, Pyrolysis
- Recycle toxic or radioactive wastes into consumer products or building materials

Annex 10. Sample Agenda for the City of Oakland's Zero Waste

Oakland Zero Waste Strategic Plan
Public Meeting #2:
EVALUATION OF ZERO WASTE OPTIONS
July 19, 2006 - 7:00 to 9:00 pm
City Hall, Hearing Room #4

AGENDA
A. Welcome and Introductions
B. Review of Major Options for Discussion
C. Selection of Top Priorities of Options for Discussion Tonight (vote with "dots")
D. Discussion of Top Priorities
E. Vote on Top Priorities (green dots if you want City to pursue; red dots if you don't want City to pursue)
F. Next Steps
a. Business association meetings
b. More input directly to City via 510-238-SAVE or zerowaste@oaklandnet.com
c. More group discussion via zerowasteoakland@yahoogroups.com
d. More background information at: www.zerowasteoakland.com
G. Public Meeting #3 – Wed, Sept. 20th - 7 pm - City Hall Hearing Room #4

– Review DRAFT Strategic Plan (to be available by Sept. 10, 2006)

Three Public Meetings are planned:

June 28
Introduce Zero Waste & Oakland's sustainability goals

July 19
Review possible Zero Waste strategies for Oakland

September 2006
Review Draft Zero Waste Strategic Plan for adoption by the City

For more information please call the Oakland Recycling Hotline: 510-238-SAVE, or email zerowaste@oaklandnet.com, OR visit www.zerowasteoakland.com

To share thoughts, ideas, & information with other interested individual regarding the City of Oakland's continuous improvement efforts & initiatives toward the goal of Zero Waste, go to http://groups.yahoo.com/group/ZeroWasteOakland

And click on "Join This Group"

To receive an E-Vite to Public Meeting #3 in September, include your email address on the sign-in sheet for tonight's meeting.

References

Alameda County Waste Management Authority, (2011). Alameda County Integrated Waste Management Plan, Retrieved from: http://www.naco.org/programs/csd/Lists/GGLinksNew/Attachments/62/Alameda%20County%20CA%20Integrated%20Waste%20Management%20Plan%202011%20Update.pdf

Alameda County Waste Management Board, (2006). Alameda County Recycling Plan. Retrieved from: http://www.stopwaste.org/docs/recycling_plan_-_2006_revised.pdf

Alameda County Waste Management Board, (2008). Alameda County Waste Characterization Study. Retrieved from: http://www.stopwaste.org/docs/acwcs-2008r.pdf

Alameda County Waste Management Board, (2012). Alameda County Safe Drug Disposal Ordinance. Retrieved from: http://www.acgov.org/board/bos_calendar/documents/DocsAgendaReg_07_10_12/GENERAL%20ADMINISTRATION/Regular%20Calendar/Miley_Safe_Drug_Disposal_Ordinance.pdf

Atkins, P. W. (1984). *The Second Law of Thermodynamics*, Scientific American Books, Nature Publishing Group New York, NY

Brown, J. (2006). Resolution No. 79774 C.M.S. Retrieved from: http://clerkwebsvr1.oaklandnet.com/attachments/13137.pdf

California Environmental Protection Agency, (2011). Permit Guidance For Anaerobic Digesters And Co-Digesters. Version 2, Sacramento, CA

California Integrated Waste Management Board, (2004). Life cycle and market impact assessment of non-combustion waste conversion technologies. Sacramento: California Integrated Waste Management Board, Public Affairs Office.

California Public Utilities Commission, (CPUC) (2007). Renewable Energy Portfolio Standard Program Overview. Retrieved from http://www.cpuc.ca.gov/PUC/energy/Renewables/overview.htm

California Air Resources Board (CARB) (2009), Climate Change Scoping Plan: The California Global Warming Solutions Act of 2006. Sacramento, CA

California Air Resources Board, (CARB). (2011, July 8). Low carbon fuel standard program. Retrieved from http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

Californians Against Waste (2012). AB 341 (Chesbro) - Jobs and Recycling, Retrieved 10/22/12 4:19 PM http://www.cawrecycles.org/issues/current_legislation/ab341_11

California Department of Finance, (2012). Interim Population Projections for California and Its Counties 2010-2050, Retrieved from: http://www.dof.ca.gov/research/demographic/reports/projections/interim/view.php

California Energy Commission (CEC). (2010, May 17). Landfill gas power plants. Retrieved from http://www.energy.ca.gov/biomass/landfill_gas.htmlCalRecycle, (2012). Basics Transformation Credit. Retrieved from: http://www.calrecycle.ca.gov/lgcentral/basics/transform.htm

CalRecycle, (2002). "Innovations Case Studies: Curbside Recycling, the Next Generation: San Francisco Fantastic Three Program." California Department of Resources Recycling and Recovery (CalRecycle). Retrieved 10/3/2012 http://www.calrecycle.ca.gov/LGCentral/Library/innovations/curbside/CaseStudy.htm

CalRecycle. (2010, July 7). California's 2009 per capita disposal rate. Retrieved from http://www.calrecycle.ca.gov/lgcentral/GoalMeasure/DisposalRate/2009/default.htm

CalRecycle. (2010, August 24). Waste Prevention Terms and Definitions. Retrieved from: http://www.calrecycle.ca.gov/reducewaste/define.htm

CalRecycle. (2010, September 29). Conversion Technologies: Pathways and Processes. Retrieved from: http://www.calrecycle.ca.gov/Organics/Conversion/Pathways/default.htm

CalRecycle, (2010). History of California Solid Waste Law, 1985-1989. Retrieved from http://www.calrecycle.ca.gov/Laws/Legislation/calhist/1985to1989.htm

CalRecycle, (2012). California's Estimated Statewide Diversion Rates Since 1989: Local Govt. Central. Retrieved from: http://www.calrecycle.ca.gov/lgcentral/goalmeasure/disposalrate/Graphs/EstDiversion.htm

CalRecycle, (2012). Countywide, Regionwide, and Statewide Jurisdiction Diversio/ Disposal Progress Report. Retrieved from: http://www.calrecycle.ca.gov/lgcentral/Reports/jurisdiction/diversiondisposal.aspx

CalRecycle, (2012). Jurisdiction Diversion/ Disposal Rate Detail. Retrieved from: http://www.calrecycle.ca.gov/LGCentral/Reports/DiversionProgram/JurisdictionDiversionDetail.aspx?-JurisdictionID=345&Year=2010

Cascadia Consulting Group (2006), Statewide waste characterization study: Contractor's report to CIWMB

Cityrating.com, (2010). Oakland Crime Rate Report (California). Retrieved from: http://www.cityrating.com/crime-statistics/california/oakland.html#.UOpmLIWmDiQ

City of Oakland, (2006). Oakland Zero Waste Strategic Plan. Retrieved from: http://www2.oaklandnet.com/Government/o/PWA/o/FE/s/GAR/OAK024364

City of Oakland, (2011-a). Oakland Climate Action Plan. Retrieved from: http://www2.oaklandnet.com/Government/o/PWA/s/SO/OAK025294

City of Oakland, (2011-b). General Plan and Planning Code: Land Use and Transportation Element. Retrieved from: http://www2.oaklandnet.com/Government/o/PBN/OurServices/GeneralPlan/index.htm

City of Oakland, (2012-a). Codes and Ordinances: Ralph Brown Act. Retrieved from: http://www2.oaklandnet.com/Government/o/CityClerk/s/ClosedSession/index.htm

City of Oakland, (2012-b) Oakland Recycles. Retrieved from: http://www2.oaklandnet.com/oakca1/groups/ceda/documents/webcontent/oak035269.pdf

City of Oakland. (2006). Zero Waste Strategic Plan. Public Works Department. http://www2.oaklandnet.com/oakca/groups/pwa/documents/policy/oak025986.pdf

Contreras, F. et al. (2008). Application of analytical hierarchy process to analyze stakeholder's preferences for municipal solid waste management plans, Boston, USA. Department of Urban Engineering, Faculty of Engineering, the University of Tokyo.

Cristensen, T.H. (2011). Solid Waste Technology & Management, Blackwell Publishing Ltd. ISBN: 978-1-405-17517-3

Department for Environment, Food and Rural Affairs (Defra). (2007). Introductory guide to options for the diversion of biodegradable municipal waste from landfill. London, United Kingdom. Retrieved from: http://www.defra.gov.uk/environment/waste/residual/newtech/documents-/introductoryguide-2007.pdf

Department for Environment, Food and Rural Affairs (Defra). (2012). Waste Hierarchy Guidance Review 2012. London, United Kingdom. Retrieved from: http://www.defra.gov.uk/environment/waste/legislation/waste-hierarchy/

Duales System Deutschland GmbH. (2010). What exactly does duales system Deutschland gmbh do? Retrieved from http://www.gruener-punkt.de/en/info-for-consumers/faq/faq/aquestions-on-dsd-gmbh.html#c8609

Giancoli, D.C. (2000). Physics for Scientists & Engineers, 3rd ed. Prentice Hall, Upper Saddle River, NJ, p. 533

Environmental Protection Agency, (EPA). (2004) "International Methane and Nitrous Oxide Emissions and Mitigation Data", United States Environmental Protection Agency. Available online at www.epa.gov/methane/appendices.html

European Comission, (1996). Council directive 96/61/ec of 24 september 1996 concerning integrated pollution prevention and control (1996L0061 — EN — 24.02.2006 — 004.001 — 1). Retrieved from EuroLex website: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0061:en:HTML

Eurostat, (2008). The Sustainable Waste Management Ladder. Earth Engineering, Columbia University

Friends of the Earth. (2005). Biowaste a guide for local campaigners. Retrieved from http://www.foe.co.uk/resource/briefings/biowaste_guide_march_05.pdf

German Federal Ministry for the Environment, (2010). Good practices to promote the 3Rs - country: Germany. Retrieved from www.env.go.jp/recycle/3r/en/info/05_05.pdf

Girard, P. University of New Hampshire, (2011). Public-private partnerships and cooperative agreements in municipal service delivery. New Hampshire.

Global Alliance for Incineration Alternatives (GAIA), 2012. On the Road to Zero Waste: Successes and Lessons from Around the World, Retrieved from http://www.no-burn.org/on-the-road-to-zero-waste-successes-and-lessons-from-around-the-world

Global Recycling Council (2012). CA ZERO WASTE COMMUNITIES STRATEGY. Retrieved from: http://www.crra.com/grc/articles/zwc.html

Goldman, G., Ogishi, A. (2001). The Economic Impact of Waste Disposal and Diversion in California. University of California, Berkeley Department of Agricultural and Resource Economics.

Government of South Australia. (2011). South Australia's Draft Waste Strategy 2010–2015, Zero Waste SA, 2010. Retrieved from: http://www.zerowaste.sa.gov.au/upload/about-us/waste-strategy/DraftWasteStrategyV2.pdf

House, E. (2000) Public Participation in Making Local Environmental Decisions – Good Practice Handbook. Department of the Environment, Transport and the Regions. United Kingdom. http://www.wao.gov.uk/assets/englishdocuments-/Public_Participation_in_Waste__Recycling__English.pdf

Humes, E. (2012). Garbology: Our Dirty Love Affair with Trash. Penguin, New York, New York, Kindle Edition.

Kaazke, J. (2010). Environmentally orientated research on solid household waste management in Khanty-Mansiysk Autonomous Okrug. School of Planning, Construction and Environment, Technical University of Berlin. Berlin.

Kirkeby, J.T. et al. (2006). Environmental assessment of solid waste systems and technologies: EASEWASTE. Waste Management and Research ISSN 0734–242X. Res 2006: 24: 3–15.

Leonard, A. (2010). The Story of Stuff. Simon & Schuster, Inc. Kindle Edition.

Levin, J. et. al. (2012). 2012 Bioenergy Action Plan, Bioenergy Interagency Working Group. Sacramento, CA

Lehmann, et al. (2011). Designing for Zero Waste: Consumption, Technologies and the Built Environment. Earthscan Book Series on Sustainable Design. Taylor & Francis. Kindle Edition.

Liss, G. (2010). Zero waste definition. Zero Waste International Alliance. Retrieved from http://zwia.org/joomla/index.php?option=com_content&view=article&id=9&Itemid=6

Nadel, N.J., Quan, J. (2007). Oakland City Council Ordinance No. 12818 C.M.S. Retrieved from: http://www.oaklandcityattorney.org/PDFS/PLASTIC%20BAG%20ORD%20(F).pdf

O'Connell, P.A., Esparza, T.M., et al. (2000). The Golden Dustman in the Golden State: Exclusive Contracts for Solid Waste Collection and Disposal in California. The Urban Lawyer. Vol. 32, No. 2. p. 281-314.

O. Eriksson et. al. (2002). ORWARE—a simulation tool for waste. Management, Resources, Conservation and Recycling 36, 287–307, Stockholm, Sweden.

Pacific Gas and Electric, PG&E. (2011). Pacific Gas and Electric Company Seeks to Research Biomethane Resources for its Customers. Retrieved from http://www.pge.com/about/news/mediarelations/newsreleases/q1_2008/080124.shtml

Palmer, P. (2005). Getting to Zero Waste. Purple Sky Press. Oakland, CA

Randolph, E. (2012, September). In Margaret Hoyer (Chair). California's bioenergy programs. Presentation delivered at the California Bioresources Alliance Symposium Renewable energy from organic residuals, Sacramento, California. Retrieved from http://www.epa.gov/region9/organics/symposium/2012/2012-cba-edward-randolph.pdf

Randolph, J. (2004). Environmental land use planning and management. Washington: Island Press.

Rapport, J. (2008). Current anaerobic digestion technologies used for treatment of municipal organic solid waste. California Integrated Waste Management Board, Retrieved from www.calrecycle.ca.gov/../Organics/2008011.pdf

RTI International. (2009). Facilities Data Collection Approach and Results for the Life Cycle Assessment and Economic Analysis of Organic Waste Management and Greenhouse Gas Reduction Options. California Integrated Waste Management Board, Sacramento, CA

Self-Generation Incentive Program Handbook. (2010, May 5). Retrieved from: http://www.cpuc.ca.gov/NR/rdonlyres/F47DC448-2AEB-473F-98D8-CC0CC463194D/0/2010_SGIP_Handbookr4100506.pdf

Stopwaste, (2012). 1995 to 2011 Diversion Rates by Jurisdiction. Retrieved from: http://www.stopwaste.org/docs/diversion.pdf

Tam, L. (2010). Towards zero waste. SPUR: Ideas and Action for a Better City, Retrieved from http://www.spur.org/publications/library/article/toward_zero_waste

Thorneloe, S. A. (2005, October). Moving from solid waste disposal to materials management in the United States. International waste management and landfill symposium, Cagliari, Italy. Retrieved from http://siteresources.worldbank.org/INTUSWM/Resources/ThorneloeA209Final.pdf

Trittin, J. (2005, May 31). An Important stage has been reached: today marks an end to the aboveground storage of biodegradable waste. Retrieved from http://www.bmu.de/english/waste_management/reports/doc/35870.php

United Nations, (1992). Rio Declaration on Environment and Development, Rio de Janeiro Retrieved from http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm

United Nations Habitat Unit. (2011). Solid Waste Management of World's Cities, http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2918

United States Census Bureau, (2009). American Community Survey: Age and Sex. Retrieved from: http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview-.xhtml?fpt=table

United States Census Bureau, (2010). State and County Quick Facts: Oakland (city), California. Retrieved from: http://quickfacts.census.gov/qfd/states/06/0653000.html

United States Environmental Protection Agency, (2012). Climate Change and Waste: Waste Reduction Model (WARM). Retrieved from: http://www.epa.gov/climatechange/waste/calculators/Warm_home.html#excel

Vandevivere, P., L. De Baere, and W. Verstraete, Types of anaerobic digesters for solid wastes, in Biomethanization of the Organic Fraction of Municipal Solid Wastes, J. Mata-Alvarez, Editor. 2002, IWA Publishing: Barcelona. p. 111-140

Waste Management, (2012). Alameda County Waste Management Data, http://www.wm.com/facility.jsp?zip=94611

WikiCommons, (2012). Food Scraps and Yard Debris Collection in Portland 2010 by Tim Jewett. Retrieved from http://commons.wikimedia.org/wiki/File:Food_Scraps_and_Yard_Debris_Collection_in_Portland_2010_by_Tim_Jewett.JPG

Williams, R. (2007). Biofuels from Municipal Wastes-Background Discussion Paper. Department of Biological and Agricultural Engineering, University of California, Davis. http://biomass.ucdavis.edu/files/reports/2007-cbc-biofuels-from-municipal-solid-waste-background-paper.pdf

Williams, R. (2006). Biomass in solid waste in California: utilization and policy alternatives. PIER Collaborative Report.

World Bank, (2004). World Bank Toolkit: Social Assessment and Public Participation in Municipal Solid Waste Management, The World Bank, 210 p. siteresources.worldbank.org/INTUSWM/.../socialassesstoolkit.pdf

WRAP, (2010) Landfill Bans: Feasibility Research. Retrieved from: http://www2.wrap.org.uk/downloads/FINAL_Landfill_Bans_Feasibility_Research.7656af5a.8796.pdf

Yin, R.K. (1994). Case Study Research. Design and Methods, Second edition. Thousand Oaks: Sage

Youngs, H. (2011). Waste-to-energy in California: Technology, issues and context. (Doctoral dissertation, University of California, Berkeley), Available from ISBN-13: 971-930117-51-8. Retrieved from http://www.ccst.us/publications/2011/2011wte.php

Young, M. (2012, September). In Margaret Hoyer (Chair). San José Zero Waste Initiative & Thermal Conversion Demonstration. Presentation delivered at the California Bioresources Alliance Symposium Renewable energy from organic residuals, Sacramento, California. Retrieved from http://www.epa.gov/region9/organics/symposium/2012/2012-cba-michele-young.pdf

Yoshida, H., et al. (2011). A Survey on Household Level Organic Waste Management Practice for Improving Accuracy of Carbon Accounting. Department of Civil and Environmental Engineering, University of Wisconsin-Madison. Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium, CISA Publisher, Italy.