SOLID WASTE

INTEGRATED

COST ANALYSIS MODEL

1991 PROJECT YEAR REPORT

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PREFACE

1991 URBAN CONSORTIUM ENERGY TASK FORCE RESEARCH

THE URBAN CONSORTIUM (UC) is a special network of the Nation's largest cities and urban counties brought together by PTI to find new solutions to their common concerns. The UC provides a creative forum where elected and appointed officials can identify, test, and validate practical ways to improve the provision of public services while generating new revenue opportunities. With staff, management, and business services provided by PTI, the UC addresses the critical needs of large local governments through its three task forces: Energy, Environment, and Telecommunications and Information.

The Urban Consortium Energy Task (UCETF) has 20 members and was established to improve urban energy management and decision-making through applied research and technology transfer. The UCETF focuses on developing and sharing new approaches and innovative solutions to energy management problems with local governments. Projects are organized in thematic units and co-managed by a member of the Task Force.

A description of the 1991 program Units and projects are:

ALTERNATIVE VEHICLE FUELS AND TECHNOLOGIES (AVF)

Alternative vehicle fuels offer a very strong potential to aid in the reduction of U.S. dependence on foreign oil supplies, with the resulting benefits of decreased air pollution in urban areas. Local governments can play an instrumental role in realizing this potential through practical applied research and highly visible demonstrations of alternative fuels and technologies. Issues addressed this year include identifying (a) intensive and credible market development efforts based on an applied research and demonstration program that combines reliable technology with experience-tested applications, (b) environmental and energy diversity benefits, and (c) institutional and infrastructure barriers. The 1991 AVF unit consists of:

Broward County, FL -- *Dual-Fuel Conversion Demonstration and Technology Transfer Project*

New York City, NY -- *Alternative Fuel Vehicle: Financing Issues*

Denver, CO -- *Technical and Market Comparison Between H₂/CNG (Hythane), Electric Hybrid, and CNG Fueled Vehicles*

Denver, CO -- *An Alternative Fuels Fleet Evaluation System -- A Transfer Project*

Detroit, MI -- *Analysis of Institutional and International Limitations for Alternative Fuel Vehicles*

Washington, DC -- *Comparison of Energy Consumption, Energy Savings, and Environmental Effects of EV/PV vs. Conventional Gasoline Vehicle*

ELECTRICITY MANAGEMENT

Urban interests for electricity management focus on means to maintain stable, secure and reasonably priced supplies of electric energy. Approaches include procedures for better demand management, application of "least cost" planning concepts, appropriate use of decentralized and/or small power production facilities, improved end-use efficiency, and developing sound structures for cooperative action among municipalities and energy utilities. Urban strategies include support for decentralized "small" power production, along with better demand management and improved end-use energy efficiency. The successful development and implementation of such strategies will require close cooperation with the utility industry and will address topics in areas of institutional relations, source flexibility, and demand-side management. The 1991 Electricity Management Unit consists of:

Albuquerque, NM -- *Alternatives to Traditional Rate Setting*

Chicago, IL -- *Integrating Innovative Supply and Efficiency Techniques*

Chicago, IL -- *The Chicago Energy Management Cooperative*

Dade County, FL -- *Energy Cost Reduction Through Resource Recovery*

Detroit, MI -- *Hydraulic Waste Energy Recovery (Phase II) City of Detroit Water Distribution System*

San Jose, CA -- *Utility/Local Government Partnership to Increase Energy Conservation in New Construction*

ENERGY EFFICIENT FACILITIES

Activities involving energy efficient facilities are at present, part of a national effort to achieve maximum cost-effective energy productivity in the building sector. There exists a need for collaboration between local government officials responsible for energy and environmental programs and other local government officials responsible for facilities, as well as the Federal officials and private sector groups, e.g. utilities. New technologies and management/administration practices to advance energy efficiency in facilities require major partnership efforts and transfer programs. Multi-family housing that has a large concentration of low-income families presents a unique challenge to lowering energy costs and maintaining energy efficient facilities. Projects in this unit are:

Boston, MA -- *Neighborhood Energy Efficiency Outreach Partnership*

Columbus, OH -- *Energy Efficiency and Indoor Air Quality: Solutions for Fire Stations*

Louisville, KY -- *Partnership Approach to Energy Efficiency in Non-Profit Facilities*

Montgomery County, MD -- *Technology Transfer of Building Energy Design Guidelines*

New Orleans, LA -- *Residential Utility Costs Comparative Study*

Phoenix, AZ -- *Variable Frequency Drive Applications Guide*

Portland, OR -- *Energy Savings Through Operation and Maintenance Training in the Low-Income Multi-Family Sector*

Washington, DC -- *Comparison of Two Techniques for Identifying Energy Conservation Measures in Low Income Homes*

ENERGY, ENVIRONMENT and ECONOMIC DEVELOPMENT

This an area that has both visionary and immediate practical emphases on the definition and evaluation of realistic strategies and actions to support energy-sustainable and

environmentally responsible communities. Emphases include uses for renewable energy, practical domestic supply and conservation alternatives, and the synthesis of energy concerns with wider local government interests in economic development, environmental quality, and internal cost control. Urban strategies to improve energy-sustainability require attention to both broad based institutional changes, as well as specific projects designed to encourage the application of appropriate technology and community development practices. The "Sustainable Communities" project has involved three municipalities with State agency, Lawrence Berkeley National Laboratory, and a formal advisory committee with broad national representation. Projects under this unit are:

Austin, TX -- *Energy Star Sustainable Rating Program*

Phoenix, AZ -- *Impact of Heat Island on Cooling and Environment: A Demonstration Project*

Pima County, AZ -- *Tucson Solar Village - Project Management*

Portland, OR -- *Sustainable City Transfer Project*

San Francisco, CA -- *Neighborhood Energy/Economic Development at South Bayshore*

San Francisco, CA -- *Sustainable City Transfer Project*

San Jose, CA -- *Sustainable City Transfer Project*

Seattle, WA -- *Coordination of Energy and Air Quality (CEAM)*

Seattle, WA -- *Bicycle Program -- Urban Trails System*

Tucson, AZ -- *Local Government Involvement in Long Term Resource Planning for Community Energy Services*

Reports from each of these research projects, including this report, are specifically designed to aid the transfer of proven experience to other local governments. Readers interested in obtaining any additional reports or further information about the Urban Consortium Energy Task Force and the Urban Consortium should contact:

***Energy R&D Program
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ABSTRACT

The purpose of the City of Houston's 1991 Solid Waste Integrated Cost Analysis Model (SWICAM) project was to continue the development of a computerized cost analysis model. This model is to provide solid waste managers with tool to evaluate the dollar cost of real or hypothetical solid waste management choices.

Those choices have become complicated by the implementation of Subtitle D of the Resources Conservation and Recovery Act (RCRA) and the EPA's Integrated Approach to managing municipal solid waste; that is, minimize generation, maximize recycling, reduce volume (incinerate), and then bury (landfill) only the remainder. Implementation of an integrated solid waste management system involving all or some of the options of recycling, waste to energy, composting, and landfiling is extremely complicated. Factors such as hauling distances, markets, and prices for recyclables, costs and benefits of transfer stations, and material recovery facilities must all be considered. A jurisdiction must determine the cost impacts of implementing a number of various possibilities for managing, handling, processing, and disposing of waste.

SWICAM employs a single Lotus 123 spreadsheet to enable a jurisdiction to predict or assess the costs of its waste management system. It allows the user to select his own process flow for waste material and to manipulate the model to include as few or as many options as he or she chooses. The model will calculate the estimated cost for those choices selected. The user can then change the model to include or exclude waste stream components, until the mix of choices suits the user. Graphs can be produced as a visual communication aid in presenting the results of the cost analysis. SWICAM also allows future cost projections to be made.

CHAPTER 1 - OVERVIEW

PROJECT PURPOSE

The purpose of this project is to continue with the design and development of a computerized cost analysis model to assist solid waste managers in developing solid waste management plans that are both effective and affordable. Since there are large variations in geography, industry, and climate, there are wide variations in the costs associated with each method of solid waste management. For the last two years, the City of Houston has developed a user friendly program to form a basis of comparison between different methods of waste disposal and different combinations of methods of waste disposal.

This project, for 1991, is an extension of the 1990 project. The 1990 project developed a different spreadsheet program for each different management option. The 1991 project developed one program that can be manipulated into all of the 1990 options.

REPORT ORGANIZATION

This report is meant to help those who are using or studying the Solid Waste Integrated Cost Analysis Model (SWICAM). Appendices A and B are the most helpful to the casual user, as they contain the user manual and a short manual to aid in transferring SWICAM to represent different cities. The body of

this report is an update on the concepts and practices of solid waste management. Appendix C contains the technical manual, useful to modify the program itself. Appendix D contains graphs and diagrams generated by SWICAM.

CHAPTER 2 - GENERAL BACKGROUND AND DESCRIPTION

INTRODUCTION

This report is a continuation of the 1990 report. It is not meant to repeat the information given in the 1990 report but to enhance that information. The information contained in the technical descriptions will attempt to update the information from the 1990 report. In the past year many municipality and regional plans have been started or prepared. The recycling market has become glutted. Municipalities' tax bases are in trouble from the recession. Technologies have changed. Some municipalities have had to cancel or change their integrated waste management plans because of lack of funds or public opinion. In these changing conditions a decision support tool such as the cost analysis computer model is even more useful to local government.

BACKGROUND

During the 1990 project, the integrated waste management system was introduced and defined as one which combines several different methods of waste processing and disposal to find the most cost-effective and environmentally sound. Most local governments have been involved with developing an integrated waste management plan on their own or in a regional planning effort. In the past year the new requirements of Subtitle D of the Resource Conservation and Recovery Act are driving up landfill prices, more recycling rates are being legislated as goals or mandates, mandatory requirements for alternative fuels are driving up the costs of collection, and the public is demanding curbside recycling. Large MSW facilities such as incinerators and compost facilities have started up and/or failed. Technologies are brought from other industries with all of the associated buzz words - fluidized beds, cation exchange capacity, plasma arc. What are the options today?

INTEGRATED APPROACH TO MSW MANAGEMENT

The Environmental Protection Agency has established a hierarchy of waste management options. In order, these are Source Reduction, Recycling (including Composting), Incineration, and Landfilling. In evaluating each of these methods, factors such as the cost of the program, the current level of technology

in each area, available markets for the product, and public participation must be considered. For example, waste to energy incineration tends to be more expensive than almost any other methods of waste disposal, but this could change with Subtitle D requirements or in areas which have high electricity costs, or that can use a steam source. Composting both municipal solid waste and yard waste, on a large scale, has suffered setbacks due to odor migration. Composting agricultural and food waste is a rapidly expanding technology. Recycling requires a high user participation level to reach a maximum level of efficiency, and markets for recyclables tend to fluctuate drastically. All of these factors must be weighed carefully when deciding upon a waste management system.

CHAPTER 3- PROJECT DEVELOPMENT

PROJECT HISTORY

As a part of the application process for the original 1990 grant, the project was organized into eight tasks: 1) prepare sample flowsheets and spreadsheets, 2) gather sample data, 3) acquire hardware and software, 4) develop computerized model, 5) run trials and analyze data, 6) refine software model, 7) run selected cases, and 8) prepare final report. During 1990, most of steps one through four were completed. In 1990, a rough version of the computer model was made, consisting of multiple

spreadsheets representing a single integrated waste management system each. The alternative systems are those referred to as cases 1 through 6B in the 1990 report. A user manual was written in conjunction with the program. The model was determined to be user friendly through daily usage by new personnel on the project. It was decided to retain the Lotus spreadsheet as the programming medium. This decision was then presented successfully to the grant committee based largely on the anticipated software availability in the intended target population.

Through 1990, a need was recognized to refine the program to a much greater level of user friendliness and professional appearance. A second grant for 1991 was provided to further develop the program.

During the summer of 1991, more data was collected from various sources. Trips were made to Memphis and Portland to discuss progress, compare and collect data, and test the program. Two new programs, Tellus and IWMS, were analyzed and their capabilities compared with those of the grant project. This comparison was added to the 1990 report during one of the revisions.

During the last quarter of 1991, a programmer was hired to expand and restructure the computer model. Although the original 1990 spreadsheets did present materials and cost analysis in a simple format, the spreadsheets did not allow quick modifications to the input data. The process of modifications was cumbersome.

Each case was entered and modified separately. For example, if the price for recycled plastic changed, the change had to be made to each case separately, instead of one time to a shared table of variables. In the same way, if the solid waste stream component listing changed, each case had to be adjusted separately.

The programmer, Brad Hunziker, streamlined the project. The concepts contained in the original spreadsheets representing each case, as well as an expanded cost analysis, were tied together into a single program. The spreadsheet was reorganized. Rows and columns were renamed to make them more readable. Including everything on one spreadsheet had the effect of making data changes instantaneous and universal, allowing the user to see the immediate effect of changes. For example, the user could change the recycling value of aluminum cans one time and then review the system cost for various scenarios without leaving the spreadsheet. A menu-driven system was created to allow interchanging various methods of waste disposal, to depict various scenarios as source end recycling, front end separation system, composting, incineration, and transfer stations. The system allows the user to choose exactly which types of source end recycling to incorporate, curbside, dropoff, and/or buyback and the tipping fee for disposal or the price per ton to operate a self-owned facility. Several variables such as size of the total waste stream and residue to be landfilled were listed in a separate table for readability and ease of access when editing values.

The cost analysis was redesigned with a process called the base cost model, a cost projection method extrapolating actual costs from figures from a plant of the same type. The model is designed specifically to test disposal methods not currently in operation.

The percentages of each material recovered through each of the post-collection processing methods (i.e., all but source end recycling) were estimated. Since all processing methods may or may not be included at any point, direct percentages could not be used because either too much or too little would be recovered, depending on the method. The only way to get that system to work would be to have a separate set of percentages for every possible combination of processing methods, a long and arduous process. The method used involves specifying the preference order of processing methods for each material, and the maximum percentage that could be extracted from the total waste stream (TWS) if it were the only processing method in use. For example, if method one could recover 50% of the TWS, and method two 75%, the two combined would only recover 75%, not 87.5%. This method allows the most flexibility of depicting multiple combination of waste disposal methods.

Another section was then added to the program which automatically generates any of several dozen varieties of graphs to provide visual aids to the user. It can be exceedingly useful in comparison of different models, or in statistical analysis. For example, the user may depict the changes which occur in the

composition of the feedstock to an incinerator in conjunction with other processing methods. A small problem was noted with Lotus 2.01, in that when saving graphs, the legend tends to get expanded so that it extends off of both sides of the graph. This problem can be solved by using Lotus 2.2 or higher.

During the process of programming this spreadsheet, various issues arose concerning the data used in the original cases. As each new area was discussed, various sources were consulted, and the figures used became more refined and accurate. The description of Case 6 in the 1990 report indicates the basic incompatibility of composting and incineration, and forbids the combination of the two in one waste disposal system. This decision was reversed, based on the idea that some communities may wish to compost on yard waste only, or may decide to use a small incinerator to reduce by incineration non-recyclable, non-compostable plastics and paper. Since plastics and non-compostables generate about 40 percent of the energy of an incinerator when burning the total waste stream, a full compost plant will significantly decrease energy recovered, with about 48 percent of the remaining materials being plastics. When the incineration/composting combination is tested in the model, the lower cost of composting waste and the higher percentage of evenly burning plastic as feedstock of the incinerator end up cutting costs for the total system.

In January of 1992, the program was presented at the annual Solid Waste Options for Texas conference in Austin. It was

greatly appreciated by the record-setting crowd, and several people requested copies for review and use as it becomes available.

In conclusion, the project has created a flexible and adaptable spreadsheet capable of describing and analyzing a wide variety of integrated waste disposal systems. Its user-friendly simple menu system provides instant access to the full capabilities of the spreadsheet, and the automatic graph generation options allow easy conceptualization and comparison of various waste disposal models.

FLOW DIAGRAMS

All of the various possibilities for managing, handling and processing waste can be represented in pictorial form on what is called a schematic flow diagram, a modeling method used in a variety of fields. A schematic flow diagram is similar to a decision matrix or flow chart. It involves drawing a picture of the various paths or combinations of paths through which materials or energy can move. An effective flow diagram is simple and can be absorbed at a single glance.

During 1990, several process flow diagrams were prepared describing the present and future waste management choices for Houston, Texas. For each potentially feasible plan, a corresponding spreadsheet was prepared which shows the estimated

overall cost of that option to the City. From these initial worksheets, an integrated computer model was developed to analyze all aspects of the process, using optional streams to allow the diagram to represent more than one model. To keep the model within the range of practicality and expedience, several of these streams are approximations which would normally change slightly between models but here remain the same.

The flow diagram, representing an abstract model of the waste disposal system, was then used to design a concrete model, which in 1991 takes the form of a large multi-sectional Lotus spreadsheet. As the concrete model is formulated, often streams are added or modified to provide greater flexibility. This spreadsheet is deliberately designed to make certain approximations as to costs and amounts, since experience has shown that many municipalities do not have detailed or accurate figures regarding the handling of MSW. Also, the more detailed a model is, the more time and information it requires in data acquisition and entry to provide useful results. Excessive complexity is one of the major complaints regarding the two alternate waste management analysis programs (Tellus and IWMS) that were studied for this report.

PROJECT DEVELOPMENT AND APPLICATION

During 1990, the readers of the report and the users of the

program were assumed to be expert solid waste managers and adequate computer hackers. Some who have expressed interest in this program have no computer knowledge and little to no experience with solid waste management. Also found was a wealth of information and misinformation available about solid waste management. The composition study prepared for the Urban Consortium grant in 1985 came under attack from the Environmental Defense Fund in their comments on the Houston Citizens Advisory Committee on Solid Waste Solutions. In a testimony dated October 29, 1991 they referred to it as "an unexplained reference" and compared it to certain yard waste percentages that would reenforce their recommendation to compost only yard waste. The Sierra Club also took exception to the 1985 yard waste percentage. When asked if they had a study of their own, their speaker said no, that they just did not trust the numbers from the 1985 grant. In lieu of the many varying opinions on solid waste composition and technology, it was determined to update the 1990 report with more current information. Other composition studies were included that supported the 1985 grant. This update will also assist those other members of the Urban Consortium grant recipients who requested siting criteria and environmental costs be a part of the spreadsheet program. The update is not a part of the spreadsheet but does hold useful and interesting information for solid waste planners/managers.

COMPOSITION

Before any different technology could be considered, the waste stream that must be reduced, reused, recycled, and/or disposed must be known. The City of Houston developed a composition study in 1985 with a grant from the Urban Consortium Energy Task Force on "The Impact of Source Separation on Municipal Waste-to-Energy Project Feasibility"¹. This study looked at residential solid waste (RSW) from 800 sample homes from different socio-economic areas in Houston. These samples were taken through a period of eight months, March 1985 through November 1985. The results are on the following page:

<u>Component</u>	<u>%</u>
Food waste	19.3
Paper	42.4
Glass	11.1
Plastic	5.5
Aluminum	2.4
Metal	6.7
Yard Waste	12.9
Leather	0.07
Rubber	0.2
Cloth	1.0
Wood	0.49
Dirt, ashes, etc..	N/A

The Solid Waste Authority of Delaware completed a waste composition study in 1991 2, 3, and 4. The results are on the following page and are represented by percentile:

<u>Waste Category</u>	<u>RSW</u>	<u>CSW/ISW</u>	<u>Combined MSW</u>
Paper	41.69	27.54	34.62
Newsprint	11.95	0.63	6.29
Corrugated	7.74	19.20	13.47
Coated	2.58	0.26	1.42
Office	0	0.77	0.39
Mixed	19.41	6.69	13.05
Plastics	8.67	7.17	7.92
Glass	4.02	0.87	2.46
Metal	6.52	5.49	6.05
Organics	36.18	35.49	35.83
Diapers	2.65	0.02	1.34
Textiles/Rubber/Leather			
	4.34	3.91	4.13
Yard Waste	9.15	1.00	5.08
Other	20.04	30.59	25.32
Inorganics	1.96	22.83	12.39
HHW	0.58	0.44	0.51
Misc	0.37	0.17	0.27

The following two pages contain composition studies from books prepared by the Environmental Defense Fund 5 and 6.

Material Generation in Municipal Solid Waste

Composition	Percent	Lbs/Cap/Day	Lbs/Cap/Year
Paper			
Newspaper	7.3	.27	101.5
Books&Mags	4.7	.18	66.2
Office Paper	3.4	.12	47.3
Corrugated	9.8	.37	136.0
Mixed Paper	9.4	.35	130.1
Total Paper	34.8	1.31	481.2
Ferrous Containers			
Beer & Soft Drink	.3	.01	4.7
Food Cans	1.3	.05	18.5
Other Nonfood Cans	.4	.01	6.7
Barrels, Drums, etc	.1	.006	2.1
Total Ferrous Cont.	2.3	.08	32.1
Aluminum Containers			
Beer & Soft Drink	.6	.02	8.3
Other Cans	.023	.0009	.3
Foil	.2	.008	2.8
Total Aluminum Cont.	.8	.03	11.4
Glass Containers			
Beer & Soft Drink	4.4	.16	61.7
Wine & Liquor	1.5	.05	21.8
Food and Other	2.9	.11	40.8
Total Glass	8.9	.33	123.8
Plastic	2.6	.1	36.5
Paper and Packaging	49.5	1.87	685.3
Yard Waste	17.6	.66	244.4
Food Waste	15.4	.58	214.1
Durable Goods	11.5	.43	159.3
Miscellaneous	5.7	.21	79.5
Total	100.0	3.78	1382.9

Source: EDF "Coming Full Circle" page 5

	National (Combined) 1986	Portland, Oregon (Combined) 1986	Springfield, Missouri (Combined) 1987	Seattle (Residential) 1987	Seattle (Commercial) 1987	New York (Residential) 1983	New York (Commercial) 1983
Ferrous metal							
Food containers	1.6	2.1	3.1	2.3	1.3		
Other ferrous metal	0.5	3.9	0.9	2.5	3.5		
Total ferrous metal	2.2	6.0	4.0	4.8	4.8	10.3	5.0
Other nonferrous metal		0.2		0.3	1.0		
Durable goods	11.5						
Other inorganics		5.5	1.0			4.2	3.5
Total noncombustibles	23.4	16.1	9.0	16.6	11.1	22.9	12.1
Other	5.7	0.5	1.7	5.9	5.2		
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCES:

National: Franklin Associates, *Characterization of Municipal Solid Waste in the United States, 1960 to 2000 (Update 1988, Final Report)* (Washington, D. EPA, Office of Solid Waste, March 30, 1988), p. 12.

Portland: Portland Metropolitan Service District, *Waste Characterization Study, "Municipal Waste Disposed"* (Portland, 1987), table 1.1.

Springfield: State of Missouri Department of Natural Resources, Environmental Improvement and Energy Resources Authority, *Solid Waste Characterization Report, Exhibit IV-1, "Springfield Landfill, Spring 1987."*

Seattle: Seattle Engineering Department, *Solid Waste Utility, Waste Reduction, Recycling and Disposal Alternatives, Appendix E: Recycling Potential Assessment and Waste Stream Forecast* (1988), tables E-23, E-27.

New York City: Original data from NYC Department of Sanitation, *The Waste Disposal Problem in New York City: A Proposal for Action* (April 1984), tab 2.1-5, 2.1-7, 3.5-2, 3.5-3. Tabulated by the EDF in EDF, *To Burn or Not to Burn*, (New York: EDF, 1985), tables II-1 and II-2.

TABLE 1.4
Comparison Between a Year-round Waste-Sorting Waste
Composition Study and a Statistical Waste Composition Estimate

Material	RESIDENTIAL WASTE STREAM, SEATTLE, WA			Difference (a)-(b)
	Matrix Mgmt Waste Sorting Study March 1988- Feb. 1989 (%) (a)	Seattle Solid Waste Utility Estimate for 1987 (%) (b)		
Paper	31.24	32.00		0.76
Newspaper	7.10	5.50		-1.60
Corrugated	5.50	5.30		-0.20
Computer/office	0.25	1.40		1.15
Mixed scrap	13.64	13.30		-0.34
Other	4.75	6.50		1.75
Plastics	8.07	5.50		-2.57
Yard waste	17.10	25.30		8.20
Wood	1.22	2.70		1.48
Food	16.32	8.00		-8.32
Organics	5.32	4.50		-0.82
Beverage	2.29	4.80		2.51
Containers	3.94	2.40		-1.54
Other glass	0.19	2.80		2.61
Food cans	1.96	2.30		0.34
Other ferrous	0.47	2.50		2.03
Aluminum beverage	0.86	1.00		0.14
Other aluminum	n/a	0.50		-1.79
Other Nonferrous	2.09	0.30		-1.91
Construction debris	0.79	2.70		2.03
Miscellaneous	8.50	3.20		-5.30

SOURCES:

* Matrix Management Group (Seattle, WA, August 1989).

^b Seattle Solid Waste Utility, *Waste Reduction, Recycling and Disposal Alternatives, Appendix E: Recycling Potential Assessment and Waste Stream Forecast* (July 1988), p. 238. (Waste composition estimates based on a combined data from six different sources.)

TABLE 1.3
Waste Composition Estimates (% by weight)

	<i>National (Combined) 1986</i>	<i>Portland, Oregon (Combined) 1986</i>	<i>Springfield, Missouri (Combined) 1987</i>	<i>Seattle (Residential) 1987</i>	<i>Seattle (Commercial) 1987</i>	<i>New York (Residential) 1983</i>	<i>New York (Commercial) 1983</i>
Combustibles							
Paper							
Newspaper	7.3	4.3	5.8	5.5	3.7	10.0	4.1
Office paper	3.4	4.7	1.4	1.4	7.7	0.0	11.3
Corrugated	9.8	9.9	20.0	5.3	12.7	1.5	36.2
Magazines and books	4.7		2.7			2.7	2.0
Other paper	9.4	15.9	15.8	19.8	18.3	22.8	2.1
Total paper	34.6	34.8	45.7	32.0	42.4	37.0	55.7
Plastics							
Milk jugs		0.4	0.3				
Containers		0.9	0.3				
Durable plastic		0.8					
Other plastics		5.8	8.8				
Total plastics	2.6	7.9	9.4	5.0	7.4	7.3	7.5
Yard debris							
Prunings			3.0	1.2			
Leaves/grass clippings			7.0	9.6			
Total yard debris	17.6	10.0	10.8	25.3	10.6	22.4	
Food waste	15.4	8.8	5.5	8.0	9.9		
Wood		8.0		2.7	7.1	3.7	
Textiles		3.8	3.7			5.6	
Disposable diapers		1.5	0.8				
Other organics		8.7	13.4	4.5	6.2		
Total combustibles	70.4	83.5	89.3	77.5	83.6	77.4	
Noncombustibles							
Glass							
Beverage containers	5.9	2.1		4.8	1.2		
Food and other	2.9	1.6		5.2	3.5		
Total glass	8.9	3.6	3.1	10.0	4.7	6.6	
Aluminum							
Beverage containers	0.6	0.3	0.7	1.0	0.2		
Other aluminum	0.2	0.6	0.2	0.5	0.4		
Total aluminum	0.8	0.9	0.9	1.5	0.6	1.8	

SOURCE REDUCTION

The EPA's best rated method is Source Reduction, which targets the waste stream at the market level. America's love of the waste-generating affluent lifestyle makes this option a necessity, but also reduces the likelihood that the plan will succeed. Activities associated with source reduction are varied and complex. The most obvious is an education program to tell the American public to reduce or redirect its spending and consumption of goods and services. However, if a reduction in consumer spending can have a negative effect on the economy, this method may not be the most practical. Perhaps a more viable option is to re-use leftover containers and other practical items for household purposes. One of the best methods of source reduction is to manufacture better quality, longer lasting consumer goods. Plastic packaging has become lighter and more efficient⁷. Backyard composting programs such as Houston's "Don't Bag It" can be used to reduce yard waste. Source reduction may be depicted on the spreadsheet by adjusting the waste stream percentages and reducing the total waste stream size.

RECYCLING

There are many methods of recycling. For the purposes of this report, recycling has been divided into two major categories. These are called Source End Recycling (SER) and Front

End Separation Systems (FESS).

Source End Recycling (SER) is recycling that removes materials from the waste stream before collection. There are five principle methods of SER: buyback centers, curbside pickup, curbside heavy trash pickup (collected separately, dealing with items such as appliances and furniture), and dropoff boxes for both normal and heavy recyclables. Each of these methods can be turned on or off from the spreadsheet menu. These methods allow a relatively high quality of material to be collected, making the processing of the recycled materials an easier proposition.

FESS, on the other hand, sorts through the MSW at a processing plant after collection, either mechanically and/or by hand, and separates out recyclables. This method, although capable of recovering a much higher percentage of recyclables at a much lower cost, has come under criticism due to a drop in material quality from such problems as paper becoming contaminated by food, glass being broken, and the mingling of different colors of broken glass. Several methods have been suggested to combat this problem, including separate bagging of wet garbage and separate collection of paper and glass. Cities supplying recycled goods to industry may be liable for the resale of contaminated goods. Contracts for supplying goods for resale should be carefully reviewed to insure the least liability possible⁸.

Recycling non-hazardous wastes has several effects on the environment. It will significantly reduce the amount of landfill

space used, thus saving valuable land for future generations. Also, it recaptures valuable renewable and non-renewable resources and re-introduces them into the ecosystem instead of sealing them in a landfill.

In planning the integrated waste management system, recycling is considered by some agencies to be in conflict with other methods. However, the City of Houston staff is in agreement that recycling reduces the amount of tonnage going to the landfills, removes non-compostable, inorganic materials that would contaminate a compost product, and removes non-combustibles such as glass and aluminum from the Waste-to-Energy (WTE) fuel stream⁹.

On the other hand, curbside programs require large numbers of trucks to daily traverse the city, in effect trading energy consumption, air pollution, and more wear and tear on the roads for the recovery of recyclable materials. Dropoff boxes or buyback centers require individuals to travel, which could mean more vehicles on the road with less results than from the curbside.

One of the difficulties in managing recycling is attempting to compare other municipality or regional results from various methods. There is no standard method to measure recycling rates. For example, Colorado uses estimated tonnages based on volumes; Rhode Island uses measured tonnage and determines recycling rates by comparing tonnage of recycled material to tonnage of solid waste; Delaware estimates recycling rates by combining seasonal

surveys of tonnage and composition with feedback from recycling plants; Oregon uses a 1985 survey and does not include energy recovery and non-commercial composting; Maine combines reports from municipalities; Washington conducts an annual recycling survey and also conducted a 1986 and 1988 composition studies; and Vermont uses regional reporting¹⁰. Composition studies are also difficult to compare. For example, some yard waste percentages are for bags of leaves and grass only, while others include heavy limbs and trees from brush and lot clearing.

Markets for recyclables have had a history of periodic fluctuation. This past year, the market has dropped drastically. Often companies which intend to open a new business producing recycled goods hesitate due to the fluctuating prices for recycled materials, inconsistent supply of recycled materials, and undeveloped markets for recycled goods. This market is improving because of legislation requiring federal government agencies to purchase recycled goods. More legislation is being considered to mandate percentages of recyclable materials in new products. If this legislation increases production costs of industries now in recession, positive results of creating recycling markets may be outweighed by further industry collapse.

Some of the national 1991 prices for recyclable goods are given below:

green glass	\$7.10/ton to \$0.00/ton
brown glass	\$8.50/ton to \$3.80/ton
clear glass	\$10.90/ton to \$6.80/ton

HDPE	\$0.03-0.04/lb to \$0.01-\$0.02/lb ¹¹
paper, white ledger	\$50/ton to \$39.4/ton
newspaper	\$8.80/ton to \$7.80/ton
computer, printout	\$78.20/ton to \$72.50/ton
corrugated cardboard	\$21.20/ton to \$15.80/ton ¹²
PET	\$0.069/ton to \$0.012/ton
HDPE	\$0.069/ton to \$0.011/ton
Mixed PET/HDPE	\$0.045/ton to \$0.006/ton ¹³

The outlook for recycling markets in Houston is good. Markets are available for most of our recyclables and Champion Paper has just broken ground on a de-inking plant in the City of Houston, Texas.

COMPOSTING

Composting has the potential to recycle all organic components of the solid waste stream. It is the natural decomposition of organic material and generates a product useable as a soil amendment. If a nitrogen source, such as sewage sludge, is included in the feedstock, the final product has higher value as a soil amendment and may be used as a fertilizer. Composting large volumes of municipal solid waste and sewage sludge in an urban area presents greater challenges than running a garden compost pile. Compost facilities need to be carefully sited. Sloppy operations may cause severe odor problems. Even the best operations will produce some odor, if only that similar to a

well run transfer station. Also, the feedstock and the final product should be tested to insure the compost process has destroyed pathogens and that no heavy metals have accumulated to a toxic level. In addition, to have the most market value the final product should look like a valuable soil amendment or fertilizer. Glass and plastic must be removed to avoid the glitter effect of glass shining in the the sun or worse, a product that resembles confetti. The disregard for these practices has led to the failure of several large municipal solid waste compost operations due to intolerable odors and poor quality of the final product.

An option often considered is composting of yard waste alone. However, yard waste contains pesticides and animal wastes and also must have quality control. Grass clippings, due to their moisture content and density, are difficult to aerate during composting and may produce some of the most intolerable odors¹⁴. Running separate collection of yard waste adds to air pollution and is an additional burden to roads since garbage trucks must be designed for mobility and space and, therefore, weigh more per axle than most other vehicles. The added expense of separate collection of yard waste removes it as an option in many communities.

As mentioned earlier, the City of Houston has a composition study from a 1985 grant from the Urban Consortium. This study was a stratified, random sample of 800 homes in the City limits. The study ran for nine months, excluding the months of December,

January, and February, which are also the slow to no growth months for vegetation in Houston. Since this study was completed, the City has pushed the "Don't Bag It" program and the percentage may have decreased. The percentage was questioned vigorously by the Environmental Defense Fund and the Sierra Club during the public meetings for the Houston Citizens Advisory Study for Solid Waste Disposal Solutions. As these organizations had no composition study of their own for the Houston area, the City again looked at many different composition studies. The results were found to be very diverse and usually there was no description of the methodology used to obtain the percentages. Some of these percentages are included in this report to emphasize the importance of each community conducting its own composition study in order to make informed decisions for their own solid waste management plan.

For example, suppose a community determined that separate yard waste collection would be justified by offsetting landfill costs if the yard waste was 25% of the municipal waste stream. If the community accepted the first yard waste estimate it found in literature, look at the broad range available. According to Deyle and Hanks¹⁵ yard waste varies from 0-40% of the MSW stream with the national average being 18-20%. They also mention a Missouri study of four communities that found yard waste percentages of 1, 6, 10 and 19. The Environmental Defense Fund in their "Testimony on the report of the Houston Citizen's Advisory committee on Solid Waste Solutions"¹⁶ used a figure of 25-30% yard waste in

the residential waste stream. In their two publications (see Tables in Composition) Recycling and Incineration¹⁷ and Coming Full Circle¹⁸, their yard waste percentages ranged from 10% to 25.3% with the lower ranges being combined or commercial solid waste and the higher ranges being residential. The Delaware Solid Waste Authority found 9% in 1991¹⁹. The City of Houston found 12.9% of the waste stream to be yard waste in our study in 1985²⁰. Deyle and Hanks claimed the following sales and costs:

- a) revenue from compost sales \$0-25/ton
- b) average cost of yard waste collection \$60-80/ton
- c) range of cost of yard waste collection \$10-80/ton

The following are costs of adding the named operation to landfilling assuming landfill costs stay the same:

- a) adding recycling operations \$1.25-\$2.50/household/month
- b) adding curbside recycling \$0.25-\$0.55/household/month
- c) adding yardwaste composting \$1.17-\$1.76/household/month
- d) total recycling program \$2.40-\$4.57/household/month.

The Environmental Defense Fund (EDF) publication Coming Full Circle Successful Recycling Today²¹ states that "compost can be made from virtually any biodegradable waste". Although this publication recommends avoiding putrescibles, including human excrement, the publication further states "only because of the possibility of the transmission of disease before composting begins. The process itself, if done properly, kills most pathogens and disease vectors through the heat generated by aerobic decomposition."

According to another Environmental Defense Fund publication Recycling and Incineration Evaluating the Choices²² mixed solid waste composting "is a technology with enormous waste management potential when applied to organic waste streams, and would make an ideal target for accelerated R&D programs". This publication also lists yard waste, household food waste, commercial food processing/preparation waste, food-contaminated paper, animal manure, and sewage sludge as specific targets for composting. This publication estimates yard waste at 20% and food waste as 9 % of the municipal solid waste stream. (Since paper is 40-50% of the waste stream, if we assume 40% of the paper is collected and uncontaminated that means that around 50% of the entire municipal waste stream is compostable). As of mid-1989 there were also, 14 mixed solid waste composting plants with 75 more in construction or planning.

At this time, only sewage sludge composting is regulated in the State of Texas. Land application of sewage sludge is covered in The Texas Department of Health Municipal Solid Waste Regulations²³ giving strict guidelines as to limits of heavy metals and pathogens. Uncontrolled application is applied to sewage sludge that falls within specified limits of heavy metal contamination and has been treated by "a method to further reduce pathogens" as described in 40 CFR Part 257 Appendix II²⁴. Composting is referred to in federal regulations published as 40 CFR Part 257 Appendix II as a method to further reduce pathogens. Any co-composting of municipal solid waste with sewage sludge in

the state of Texas is regulated. The decomposition of organics creates acids which can leach heavy metals from the garbage. In a landfill, this can contribute to leachate contamination or worse, leak into the groundwater. The sewage sludge manages to immobilize these heavy metals to an unknown extent. (This capacity is explained by Nyle C. Brady in The Nature and Property of Soils²⁵ as the cation exchange capacity.) This ability is mentioned in Subtitle D. Co-composting MSW and sewage sludge in a regulated environment will stabilize the organic material, reduce the volume, and create a valuable soil amendment. The sewage sludge will add nitrogen to their product and increase its value to the land. That stabilized product may be tested for contaminants as sewage sludge is already tested. Right now, unless sewage sludge is added that testing is not required in the state of Texas.

Our greatest environmental challenge worldwide is to stop the loss of topsoil. This is depicted accurately and unforgetably in a brochure "Conquest of the Land Through 7,000 Years"²⁶. Organic material should be returned to the land stabilized and tested before application.

The City of Houston Public Works Department has encouraged the establishment of compost standards for all composted material. The Director encouraged industry standards and regulations in a speech to the Solid Waste Composting Council last year²⁷.

Not everyone is for testing all compost. There are new buzz

words being used by some agencies to differentiate between yard waste compost and municipal solid waste compost. MSW compost is being referred to as "dirty" compost and yard waste compost is being referred to as "clean" compost. These are very serious and misleading terms because many of the heavy metals in compost come from pesticides that have been applied to the yards and from lead in the yard waste. The lead that has accumulated in the sides of the road from auto emissions can get in the vegetation. Luckily most MSW and SOW (separated organic waste) contain less heavy metals than US EPA NOAEL (No Observed Adverse Effect Levels). This is discussed in "Compost Quality - A Public Health Perspective"²⁸ and has been researched by Rufus L. Chaney²⁹ and discussed by him in various articles. Yard waste also contains animal excrement and can even contain small dead animals (rodents, birds) which can contain parasites and diseases transmittable to humans. For this reason, the City includes yard waste in the stance that regulations should be in place to test all compost.

Ironically, the words "clean" and "dirty" have been used for years to describe material recovery facilities (MRFs). Clean MRFs are to separate and bale recycled goods that have been received from curbside or some other source separated recycling. "Clean" MRFs produce a higher quality recycled feedstock since the material has not become contaminated by organics such as food. "Dirty" MRFs are to recover recyclables from the entire waste stream and often produce a lower quality recyclable because of

food or other organic contamination.

Some agencies are concerned that composting will interfere with recycling, but that is not feasible in the long term. One of the problems to be overcome in marketing MSW compost is to insure that the compost is a high quality, esthetically pleasing product. This means the compost must look like compost. The final product should have no plastic, glass, metal, etc. that would stop a home owner, gardener, or farmer from using the product because it looks "trashy".

To further illustrate this, recyclables that we think of today are some plastics, glass, newspapers, office papers, aluminum, ferrous metals. Compost feedstock is yard waste, food contaminated paper, foodwaste, manures, etc. The greatest detriment to successful recycling programs has been a glut of recyclable materials and a dearth of markets. To create markets for recycled goods, manufacturers must have a steady, high quality source of material as feedstock. Curbside recycling provides a steady supply of clean, separated material to be used as source material for new products. The paper that is recycled is separated from the waste stream at the source. It must be. Once paper goes in the packer truck, the majority of it is contaminated by food and moisture. Recyclables that stay in the waste stream that are not contaminated by the packer truck are aluminum, ferrous metal, some plastics, and glass. The glass can be broken and mixed but can be removed by density if the right equipment is used. Paper is 40 to 50 % of the solid waste stream.

Organic material, other than paper, is 25 to 45% of the solid waste stream. If 40% of the paper is uncontaminated and recycled, this still leaves 26 to 30% of the waste stream as paper that can be composted, landfilled or burned. Adding that to the organic stream means 50 to 70% of the waste stream may be turned into a useful product that is needed for soil reclamation. Therefore, composting municipal solid waste will not affect recycling efforts.

Houston is committed to curbside recycling, as well as the buyback and dropoff centers and has been fortunate to have had a very successful program. Houston's curbside programs pick up newspaper, glass, aluminum and other metal cans, and plastic milk and soda bottles. Of these items, only newspaper is conceivably compostable and newspaper will have the steadiest market as a recyclable, thanks to the Champion deinking plant. Removing these other items prior to the waste stream being sent to a compost plant provides a higher quality compost material. The cost to the city to provide curbside recycling is very high. Only its commitment to encouraging recycling enables the city to justify that cost. Even with this expenditure only about 15% of the materials currently in the waste stream is expected to be captured by curbside recycling. However, Texas has a goal of 40% of the waste stream to be removed. In order to do this Texas must look at all available technologies including MSW composting.

Houston is currently reviewing proposals to this end. Composting is considered recycling by the EPA. Unfortunately,

Texas Senate Bill 1340 does not consider mixed MSW composting as recycling, although composting the specific organic waste streams is considered recycling. The state may consider mixed MSW composting if there is some sort of front end separation to remove Household Hazardous Waste along with recyclables.

WASTE-TO-ENERGY

Waste-to-Energy plants have in the past been mainly of an incineration type and cost more than any other solid waste processing methods. The capital outlay for a waste-to-energy plant is considerable, especially considering the sophisticated stack scrubbers required today. Petnaik³⁰ projected some costs for a system in North Carolina:

Method	% by 1993	% by 2000	% by 2020
Recycle and compost	25	37	47
WTE	68.7	57	32

He estimated the costs of a single lined landfill to be:

Single Lined Landfill		Double Lined Landfill	WTE
YEAR	\$/TON	\$/TON	\$/TON
1990	\$22.40/ton		
1994	\$50/ton	\$58/ton	\$58/ton
2012			\$80/ton
*payment of debt service			\$35/ton
2020	\$150/ton	\$180/ton	\$43/ton

*assumption of \$6 million debt service for 20 years, 1994-2013.

National estimates of costs for WTE plants range from \$3-\$270/ton with the average fee for planned facilities to be \$64.14/ton and for existing facilities to be \$45.34/ton³¹.

WTE may become attractive again as a waste management option with the anticipated Subtitle D changes and provisions of the 1990 clean air act³². The Subtitle D changes are expected to cause the cost of landfilling to increase, making WTE more competitive and the requirements of the Clean Air Act Amendments will provide reassurance to the public that WTE plants are not the harmful polluters they were once considered to be.

Happily, WTE may even provide a positive impact. Co-firing refuse derived fuel (RDF) with coal has been said to cut down on emissions³³ and 34. Two terms used in air quality are the Best Available Control Technology (BACT) and the Maximum Achievable Control Technology (MACT). The BACT is the best technology with the least environmental, economic, and energy impacts. The Clean Air Act will require the MACT which is the level of control demonstrated by the top 12% WTE facilities³⁵.

A significant cost factor associated with WTE incinerators is the cost of disposal of the ash that is produced. Research³⁶ and 37 has shown that ash from coal can be used as cement filler, structural fill, ceramic filler for paints, liming agent for soil treatment, corrosion resistant linings for underground storage tanks, sealers and caulks for driveways and golf ball fillers.

Ash from RDF or mass burn facilities contains lead, cadmium

zinc, mercury, arsenic, other metals, and salts. These may be removed or stabilized. Chemically removing these with HCl may cost \$80/ton³⁸. Ash may be compacted to 1×10^{-7} cm/sec the same as the required clay liners. Vitrification, heating ash to about 2600 degrees F, will melt ash and produce a glassy material useful as insulation, roofing, blasting grit, aggregate, or construction fill. This method reduces ash volume by 60 to 97%. This method can cost \$200/ton, may release metals to the air and produce an undesirable byproduct of metals and chlorides. Solidification is adding adhesives such as pozzolonic, portland cement, lime kiln dust, silicate, or polymers to form bricks or blocks for construction. Bricks have shown no leaching even when used as experimental artificial reefs. Material has also been used as aggregate. More testing is being required by regulatory agencies and no cost impact is available.

Two alternate methods of waste disposal are pyrolysis and plasma arc recycling, which both involve the breakdown of garbage into relatively simple components by extremely high heat in the absence of oxygen. Pyrolysis uses temperatures of approximately 5000 degrees Fahrenheit to break down waste materials into simpler compounds, thus being able to dispose of many kinds of hazardous waste. Plasma arc recycling uses temperatures of around 30,000 degrees, which breaks the materials down into ash and gases, some of which can be recovered through controlling the cooling process. These gases then may be sold as fuel to partially offset the price of the processing. Each of these

processes has potential to minimize environmental impact, but the relatively short history of these methods prevents substantiation of the claims being made by the promoters and pilot plant operators. Both methods have had limited uses in industry, pyrolysis for coal gassification and plasma arc for scrap metal processing, but the technology for large scale MSW processing plants has not yet proven economically feasible. Note also that the costs reported, (see the year eleven report) were sales claims which are probably lower than actual production costs. Even so, they were much higher than those of incineration, the most expensive other method studied. These methods were not directly supported in the year twelve implementation of SWICAM, but it is possible to modify the formulas in the computer model in the incineration section to model plasma arc recycling costs.

The making of ethanol from solid waste on a large scale is being discussed. Very little information is available at this time.

TRANSFER STATIONS

Transfer Stations are facilities used to gather and move garbage from packer trucks to trailers for hauling to a more remote landfill. This can be necessary where population densities and soil conditions preclude landfill construction close to areas of collection. This option adds costs to the processing of the waste, but often can reduce the cost of the

landfill by lowering the cost of land acquisition and permitting.

The transfer station scenario in SWICAM is an assumed simplistic situation where the commingled garbage is transferred "as is" to trailers for delivery to a remote landfill. The trailer haul distance is assumed to be 75 miles from the four assumed transfer stations to carry out the operations involved. This scenario can altered by the user by changing the assumed costs of hauling, etc.

LANDFILLS

In delivering the environmental costs as promised the City of Houston looked at two main questions, what actually finds its way to the landfill as compared to what has been measured in the solid waste stream and what happens to the landfill over time. William Rathje³⁹ gives the following as volume percentages of wastes he found during a seventeen year study beginning with trash cans in 1973. First he found little breakdown of organics because modern landfills allow no light, air, or moisture. He found that only 20-50% of food and yardwaste is biodegradable in the first 15 years. He found newspapers 40 years old that were still legible. Plastic was found to be the same percentage from 1970-1986. The reason for this was more streamlined packaging which is profit motivated. The following is a listing of his other findings as percentages of volume:

Polystyrene foam - 1%.

Disposable diapers - 0.8%.

Newspapers - 18%.

Construction and demolition debris - 15%.

Overall paper increased from 35% in 1970 to 50% in 1991 (the reason - computer paper). This includes packaging, newspapers, telephone books, glossy magazines, and mail order catalogues.

Plastic - 10%. This includes milk jugs, soda bottles, food packaging, garbage bags, and polystyrene foam.

Metal - 6%. This includes iron, aluminum, and steel cans for food and beverages.

Glass - 1%. This includes beverage bottles, food containers, and cosmetic jars.

Organic waste - 13%. This includes yard waste, wood, and food scraps.

Miscellaneous - 20%. This includes construction and demolition debris, scrap tires, textiles, rubber, and disposable diapers.

Modern landfills are essentially tombs for waste. Decomposition occurs very slowly, and may even take longer than the 30 years that was previously believed to be the time to stabilize a landfill. New regulations and procedures to deal with the leachates have been issued under Subtitle D. Some of these rules⁴⁰ are restricting the siting of landfills away from airports, floodplains, wetlands, fault areas, seismic impact

zones, and unstable areas. Operational requirements include diversion of hazardous wastes, use of cover material, control of disease vectors, collection of groundwater run-off/runin, and the prevention of the accumulation of explosive gases. The upper component of the liner must be minimum 30 mil flexible membrane "unless it is HDPE, then it must be 60 mil". The lower component must be at least 2' and less than or equal to 1×10^{-7} cm/sec. The groundwater must be monitored and sampled.

In addition, new emission regulations for landfills promulgated by the EPA have established a goal to reduce non-methane organic compounds by 80%⁴¹. Landfill owners may be able to sell emissions credits. Collect methane may be used or sold to produce energy in the form of steam or electricity. The new source performance standards (NSPS) require best demonstrated technology (BDT) taking into account cost, air quality, environmental effects, energy effects, and other factors. EPA cost estimates are \$26 million per year or \$300,000 per year per site. Retrofitting will cost 240 million per year or \$387,000 per year per site. These costs are in addition to Subtitle D compliance costs, which EPA estimates as high as \$500,000 per site.

The above costs are just for the minimum requirements. Designing for more than the minimum to adequately control leachate can be such control measures as using double-composite liner systems consisting of: 1) a leachate collection system, 2) a primary liner, 3) a leak detection system, and 4) a secondary

liner. Filters such as soil or geotextile are recommended to be used to avoid clogging the drainage medium for the leachate collection system. These filters may be clogged from suspended solids, biological growth, and geochemical reactions such as metallic ion precipitation. Leachate pipes should be surrounded with high permeability gravel or cobbles instead of wrapping with geosynthetic which easily clogs. Geosynthetic liners must be protected from sunlight. Estimated costs for these items were not available.⁴²

Another method to handle leachate collection is leachate recycling⁴³. Leachate may be run back through the landfill rather than treated offsite. This will enable the landfill to receive the moisture it needs to stabilize by the decomposition of organic matter. Subtitle D allows leachate recycling in landfills with a composite liner and leachate collection system. Although some states such as Virginia and Iowa allow no leachate or rainwater to enter a landfill, Maryland is allowing this procedure, California is experimenting, and Delaware has been perfecting this technique. Delaware recommends using a combination of injection recharge wells, spray irrigation, and surface application. This method also assists in the production of methane. Advocates claim it speeds up the process of decomposition by 80-90% and stabilizes the landfill more evenly. The leachate levels of COD, BOD, TOC, and some heavy metals diminish with time. Using the leachate in this manner does create a severe odor problem.

Ongoing cost records and operating practices for the Solid Waste Management Division of Public Works Department of Houston, Texas, were used to establish unit costs in SWICAM for activities involved with waste collection. This practice includes two operations which are not conventional residential packer truck garbage collection. The first is a separate curbside collection service for materials too large or heavy to be handled by packers. The second operation consists of manned dropoff centers called Neighborhood Depositories which are used for heavy trash. Both these services are well established as entitlements in the minds of Houston residents.

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⁶Environmental Defense Fund. Recycling and Incineration. ⁷William L. Rathje. "Once and Future Landfills"

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⁹Moreau and Hayes. "Where Are You on Recycling's Learning Curb?"

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CHAPTER 4 - SUMMARY AND SUGGESTIONS FOR APPLICATION

SUMMARY

Despite the concerns over composting and incineration, governmentally mandated levels of recycling and reduction of landfill use will force expanded use of one or both of these methods in the near future. SER and FESS recycling combined are capable of removing about twenty-five to thirty percent of the material going to landfills, although this level might improve with future markets for recyclable materials. The Texas legislature has established a goal of 40% recycling by January 1, 1994, a level impossible to meet without either new recycling markets or further processing methods. It is theoretically possible to remove almost 85% of the material being sent to the

landfill, but such a program requires recycling, composting and incineration, whose combined initialization costs total far more than most cities are willing to consider.

The concept of an integrated and balanced approach to the management of municipal solid waste (MSW) is invaluable. Environmental concerns are creating national, state, and local legislation which mandate extensive planning for collection, handling, processing, and disposal of MSW. The integrated approach evaluates all viable means of reduction, recycling or disposal, with an emphasis on four management options: (1) Landfilling, (2) Waste Combustion, (3) Recycling (including Composting) and (4) Source Reduction.

This project has used various means to quantify the costs of solid waste management, including capital costs, operating expenses, and advantages and disadvantages of each option. In addition, a health risk analysis was used and the health effects resulting from emissions, effluents, and system operation were estimated. When choosing a particular management approach for implementation, construction costs and operation costs are balanced against the projected health risk.

LESSONS LEARNED

The greatest lesson learned from this project is that the development of a computer model to look at costs can become a lifetime quest. Costs and components are shouted by all kinds of

authorities, but methodology of determination is whispered. All numbers, unless methodology is substantiated are subject to suspicion.

The second great lesson learned is that everyone is a computer expert until specific help is needed. Criticism is free and abundant but creativity rare and crushed upon recognition. Much thanks to our genuine programmer, Brad. Time was spent talking about what the program should do, how it should look, what capabilities it should have. The programming capabilities of the project participants should have been more carefully evaluated. There were plans that could not be implemented until a programmer was hired.

The third great lesson learned is that communication, in the form of technical papers, is the most important skill needed for any project. The outline for completion of the paper could be the driving force for the entire project. An outline for a paper could include a work plan and methodology. The work plan could include a calendar of events. As time goes by the scheduled time and planned activities could be compared to work completed. Any variations in actual progress could be evaluated. Problems and successes could be clearly defined. For example, progress notes could consist of "Behind schedule, discussed software capabilities for a month, no progress made".

SUGGESTIONS FOR APPLICATION

The fun part about this entire project is that those people acquainted with Lotus can expand upon this project and add all sorts of capabilities. The numbers change all the time such as money for recyclables, fuel costs, etc. The research to determine component listings and costs is a great training mechanism. Even if someone disagrees with every finding we have, they will have to hit the books hard in order to issue a challenge. Municipalities and regions should take a look at this to either use the program or to investigate the various sources of information available.

A user would have to have their own operating and maintenance budget to begin use of this program. Each component listing would have to be reviewed. A user may have different markets for recyclable items. The City of Houston is fortunate to have many markets. Other cities may not be able to recycle plastics or newspaper because there is no area market. A user may have always believed that certain elements of the waste stream were present in different amounts than presented here and may be challenged to evaluate his or her own waste stream. Again the user is cautioned to substantiate numbers used in this program. Always verify methodology and sources.

APPENDIX A -- USER MANUAL

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Appendix A--User Manual

SWICAM, or **Solid Waste Integrated Cost Analysis Model**, is a model designed to predict materials flow and costs of various integrated waste disposal systems. It is intended for use in aiding waste management planners to choose the most cost effective and environmentally sound waste disposal system available to them. The model is realized in Lotus 1-2-3, and the end user is assumed to have a fair amount of experience with this program. SWICAM is designed in three parts, the **Materials Analysis Spreadsheet**, the **Cost Analysis Spreadsheet**, and the **Variables Table**, all of which are included in the same file to reduce processing time and allow a more intuitive grasp of the interrelated nature of the data involved.

MENU SYSTEM

A simple menu system provides considerable control over the computer, allowing the user to change waste disposal models, move between spreadsheets, print all or part of a spreadsheet, or modify the basic data that generates the model information. An important point to note is that the results this program yields are only as valid as the data used to generate them.

The program is designed to allow the user to switch from one model of waste management to another with a simple menu access. The system then automatically recalculates all values involved, zeros all methods of waste processing not used in the model, and immediately provides itemized cost data on all processing methods involved, as well as the bottom line, the total system cost. Also,

areas of the spreadsheets not used in the model currently viewed are hidden from view to reduce potential confusion.

There are four different menus in the spreadsheet; the Go To menu, the Data Entry menu, the Print menu, and the Model menu. These are accessed by using the "Alt" key combined with the first letter of the menu name, and then can be used in an identical manner to standard Lotus menus. Note that typing "q" or Escape always exits from the current menu.

The **Go To (Alt-G)** menu is used to quickly traverse the spreadsheet, moving to any of seven different areas immediately.

The options are:

(Materials Analysis Spreadsheet)

Materials:	Goes to top left of Materials spreadsheet
Totals:	Goes to calculated info totals
Recap%:	Goes to Materials Data Table

(Others)

Cost:	Goes to Cost Analysis Spreadsheet
Variables:	Goes to other variables and information
Graph:	Goes to Graph data area

Note that if SER (Source End Recycling) is not present in the model, or if none of the processing trio of FESS (Front End Separation Systems), Composting or Incineration are present, attempting to go to that location will not work.

The **Data Entry (Alt-D)** menu is relatively straightforward, most commands merely move you to the area containing the data in question and allow you to modify it yourself using standard Lotus data entry methods. The commands **Cost Data**, **Materials Data**, and **Add** (shown with *'s below) all reset the model to include SER, FESS, composting, incineration, and transfer station. This is necessary because some models have hidden columns of information

(not being used in the model), the data in which are necessary for future model changes. The Data Entry menu options are as follows:

*Cost Data:	Alters the Cost Analysis Spreadsheet basic data. This is the data from which all cost projections except materials recovery are made.
Variables:	Alters basic data in Variables Table
*Materials Data:	Alters material-specific information and recapture percentages
*Add	Adds new material to the waste stream. You will then need to input all information in the Materials Data section about the new material. This includes Materials Constants, Source End Recycling, and the Fess and Processing Preference Hierarchy (all described later)
Delete	Much simpler--deletes a component of the waste stream, specified by row #, then scales the rest of the waste stream to account for the missing space.
Scale TWS	This is used to make sure the sum of the Total Waste Stream is 100%. Using this command scales all percentages upwards or downwards by the amount necessary to yield 100%. It also allows you to hold 1 row fixed compared to the rest, useful when adding new components to the waste stream.

The **Print (Alt-P)** menu was added due to a general lack of printing features in Lotus. It will print the Materials Analysis spreadsheet in coherent sections, so that page breaks will not break apart data units onto separate pages. It also includes some functions from the /Worksheet Global Default Printer menu, so that the end user does not have to navigate through the menus to alter specifications. The print menu is as follows:

Materials	Print Materials Analysis spreadsheet
Cost	Print Cost Analysis spreadsheet
Variables	Print Variables Table
Defaults	Set printer defaults-Margins, Page length, setup string, header, footer, technical defaults--Wait, Printer, Interface, Auto-LF
Line Down	Move paper down one line
Page Down	Move paper down one page

Graph

Set up graphs--See submenus below

Since visual description of data is often more understandable than a large array of numbers, several automatic graphs have been included in the program. SWICAM can produce two basic types of graphs, labelled component based and model based. The component based graphs will tell you, for example, what percentage of your incineration revenue comes from paper, or what kinds of material are filling up your landfill the most. These are always in the form of pie charts. The model based graphs are either pie charts (for a single model) or stacked bar charts. These will tell you what the total system cost breakdown is (collection, heavy trash, disposal cost, etc.), the percentages each processing method removes from the waste stream, the disposal cost breakdown (how much landfill, composting, etc. costs), the revenues recovered from each processing method, or the total wasted value sent to the landfill.

The graph menu is as follows:

Graph Brkdn	This is the component based graph menu
Model Based	Model based menu
File	Save/Retrieve file
View	Show current graph on screen.
Color	Change display to show color graph
B/W	Change display to show black&white graph

Graph Brkdn:	
SER	Show materials breakdown of SER--may choose by Weight or Value (W/V)
FESS	Breakdown of FESS (W/V)
Compost	Breakdown Composting (W/V)
Incin	Breakdown Incineration (W/V)
Landfill	Breakdown Landfilling (W/V or v(0)lume)
Recovered\$	Breakdown all materials revenues (W/V)
Discarded\$	Breakdown all discarded materials (V)

Model Brkdn:

Recap %'s

Percentages of each material that are removed from the waste stream by each processing method. May be used in either single model (pie chart) or multiple model (stacked bar chart) configuration.

Disposal Cost

Breakdown of costs between disposal methods. Single or multiple model.

Material Val

Value of materials recovered, separated by processing method. Single or multiple.

System Cost

Cost of total system, broken down into cost centers. Single or multiple.

Value Lost

Comparison between landfill tipping fee, material value recovered, and material value recovered--bar graph multiple comparison only.

The top twenty rows of the Graphs area (Alt-G G) contains three major areas. The first two columns are used in multiple model comparison graphs to specify what name each model should have on the graph and which models are being compared. The next six show the actual graph data after it has been calculated. The last two are used to determine the names of the pie graph materials breakdowns (see below). The second column determines which model is to be represented in the current row of the graph. It is specified by a single letter code for each processing method to be used. These letters are:

C	Composting
I	Incineration
F	Front End Separation System
S	Use Source End Recycling
J	Reset current Source End Recycling methods to none.
K	Use Buyback recycling
L	Use Curbside recycling
M	Use Curbside Heavy Trash recycling

N	Use Dropoff recycling
O	Use Dropoff Heavy Trash recycling
Y	Use a future year analysis. Put the year desired at the end of the field (0 for current year)

The last model you wish to have analyzed MUST have a 'Q' in this column (in addition to its model specification), as this tells the program when to stop gathering data for the graph. For example, the string "CFS" would tell the program to use composting, a FESS recycling program, and whichever Source End Recycling methods were previously set. "SN" would use current SER methods and add Dropoff if it is not already there. "SJKLN" tells it to use only Buyback, Curbside, and Dropoff. "YFIQ20" would tell the program to do a year 20 analysis of a FESS and incinerator model, and tell it to stop the graph generation on this model. After generating the graph, the spreadsheet configuration will retain the last model specified in the graph.

All pie graphs use the information in the Recapture Percentage section (Alt-G R) to determine which components to add together. For each component, put a number between 1 and 20 into the column labelled "Group #", using the same number for rows you wish to be added together. In the column next to it labelled "Group Name", the name currently associated with that number appears. These names can be changed by the user by going to the Graphs section and entering the desired names in the rightmost column in the top portion of the graph section, labelled "Range Name." The user does not need to use all of the names, and any number of waste stream components may share the same number.

The bottom area of the graphs section contains the data for graph names and data names. All areas that are unprotected (brighter) may be changed to whatever desired. Note that many of these currently have formulae in them which pick up data such as the total value represented in a pie chart, whether the graph is value or volume based, etc. These may be changed, but if you wish to change them back you should keep a record of the original values (or keep a copy of the original program).

After choosing and generating the graph, it is quite simple to use normal Lotus graph manipulation techniques to add to or modify the graph. This can be used to tailor figures and appearance to whatever desired.

When the graph is set up as desired, you may save it using the File option in the Graph menu (Alt-P G F) and save it as either a Lotus file, which allows you to read that same graph back in later, or a .pic file, which is used by the Pgraph program to print graphs. Other graphics programs, such as Harvard Graphics, often will read the graph directly from the spreadsheet. If you wish to take advantage of the superior graph manipulation capabilities of one of these programs, consult the manuals of these on how to import Lotus spreadsheets. In the case of Harvard Graphics, you need to create the graph you wish in SWICAM, then do an import directly from the SWICAM spreadsheet file into Harvard Graphics. It will not read the .pic file format.'

The Model (Alt-M) menu is the meat of this program. It allows the user to switch within seconds from a cost analysis of a simple

landfill disposal system to that of an integrated model including source end and front end separation system recycling, composting, and incineration. It is a two-level menu, with the top level containing the items changed most frequently. Each menu option will ask if you wish to use that method of processing, and requests a yes/no response. Hit escape to exit the option without change. This menu is set up as follows:

SER	Use Source End Recycling--Only methods selected from the second menu will be used.
FESS	Use a Front End Separation System to recycle.
Composting	Include composting in the model.
Incineration	Include a waste to energy plant.
Transfer	Include a transfer station--might be considered redundant with either composting or incineration in the system.

Methods of SER Menu

Curbside	Use curbside recycling for light trash.
1: Curb Hvy	Use curbside recycling for heavy trash.
Dropoff	Use dropoff boxes for light trash.
2: Drop Hvy	Use dropoff boxes for heavy trash.
Buyback	Use a buyback center for light trash.

Other Options Menu

Year	Select year for future cost analysis.
Current\$	Use current year dollars for future cost analysis
Reset	Reset model to Landfill only.
Set All	Include all model options in current model.
Landfill	Switch between using a direct \$/ton tipping fee and actual calculated costs for the landfill.
Processing	Switch between direct \$/ton tipping fee and calculated costs for the FESS and processing methods specified in the model.

One further menu, the **Supervisor** menu, is accessed by typing Alt-S. This menu is for people who want to look at the menus and functions used to make this spreadsheet operate. It can be

disabled easily by the command sequence **/Range Name Delete** followed by entering the range name **"\S"** and hitting return. It contains the following options:

Menus	Go to the section which defines the user menus
Functions	Go to the section containing program functions
1 Print Menus	Print all menu specifications
2 Print Funcs	Print all program functions
Hide	Hide all columns containing program areas
Display	Redisplay all columns containing program areas

Note that if you change anything (which is not recommended), do NOT copy over the original program, and make sure to document any changes thoroughly.

SPREADSHEETS

I. Materials Analysis

The Materials Analysis spreadsheet contains two major sections, the calculated results and the data. Both sections contain an identical list of material components in the waste stream, and this list is subsectioned further into regular garbage pickup (light trash) and heavy trash collection. The physical appearance of this spreadsheet is roughly as follows:

The calculated information includes information on recycling and processing amounts and values, detailing, for example, how much corrugated paper is recovered in a front end separation system in the current model and what that amount is worth when recycled.

The data section is much more interesting and important, containing most of the information that generates the calculated figures in the last section. It contains several different kinds of data, including the weight percentages, hauling densities, recycling values, and energy produced when incinerated. Also, **recapture percentages (RPs)** for each method of recycling and waste processing are entered in this location. The term recapture percent is used to specify a certain percentage of a material out

of the total amount of that material in the total waste stream.

For source end recycling, the recapture percentages are directly entered by the user. For example, you may want to specify that curbside recycling recovers 25% of all newspapers in the waste stream. Default values have been provided, but these are based on the planned recycling program in Houston, and are meant only as a guide.

The Front End Separation System, Composting, and Incineration recapture percentage calculation is slightly more complex, thanks to the capability of switching models of waste disposal at a whim. The actual resulting values for the system are displayed in a write-protected table on the right side of the data section, labelled **Resulting Recapture Percentages**. To change the recapture percentages, go to the part of the data spreadsheet labelled "FESS and Processing Preference Hierarchy." As you can see, there are two sections, the **Preference Order (PO)** and the **Maximum Potential Recapture Percentages (MPRP)**.

The preference order is the order in which to allocate each material to the FESS, composting operation, incineration plant, or landfill. In other words, the processing method with a "1" in it will get first shot at that material, the "2" next, etc. The PO's must be chosen carefully, taking into account environmental and practical considerations. For example, including plastic in compost is generally considered a bad idea, and the market for reprocessing mattresses is not a particularly strong one. If you

specify recycling for a material with 0 or negative recycling value the program will accept it (potentially useful for overloaded markets or for difficult to recycle items such as tires). Note that the preference order rows must contain exactly one each of the numbers one through four, or the program will not work properly.

The maximum potential recapture percentages are contained in the next three columns. These figures represent the maximum amount of each material that can be retrieved by each processing method. If composting is listed as the first preference for yard waste, and the MPRP for composting is 70%, then 70% of all yard waste will be composted. If the second preference is incineration, and 100% is listed for incineration, then $100\% - 70\%$, or 30% will go to incineration. If, however, only 65% were listed, none would be burned, and the third preference would then be consulted. The landfill will always consume 100% of the remaining material, so placing the PO of the landfill at 2 ensures that the processing methods for preferences 3 and 4 will never be used.

If source end recycling is being used to recover 40% of all newspapers, that percentage is subtracted from the MPRP for each processing method. Therefore, if the FESS is preference 1, and has 70% listed, it normally would receive 70% of that material. Instead, it receives $70\% - 40\%$, yielding only 30% for FESS recycling. If incineration were listed at 95%, it would only receive $95\% - 30\% - 40\%$, or only 25% of the newspaper in the total system.

II. Cost Analysis Spreadsheet

This area, reached by Alt-G c, (or Alt-D c, for changing data) is where all the information from the Materials spreadsheet is put to work. The analysis presents various Cost Centers (CC) in the columns, and a breakdown of the Expense Allocation (EA) down the rows. The Expense Allocation includes direct expenses (the O&M budget), indirect expenses (benefits, vehicle & facility costs), and revenues (recycling, compost sales, energy sales). The cost spreadsheet is set up as follows:

EXPENSE ALLOCATION Cost Center Totals	COST CENTERS
	Calculated Cost Information
EXPENSE ALLOCATION (Scale&Factor #'s)	Raw Data for Cost Base Model (CBM)

The Calculated Cost Information section enumerates the actual costs for each cost center in the current model. These values are calculated from the raw data in the bottom section, which is called the **Cost Base Model**, or **CBM**.

The expense for each cost center is calculated from a system of that type, called a Cost Base Model, for which expenses are known. The first row in the data section shows the amount (in tons per year) that will be processed by each cost center in the waste disposal model currently being analyzed. The size of the CBM system should be entered in the second row, followed by the expense

allocation figures for that system. Note that the **total** cost of Vehicles and Facilities should be entered. This cost, in addition to the lifetime and annual interest rates, will be used to calculate the per annum amortized cost of these items.

The **scale** figures are used to account for the economy of scale. The numbers should be in the range 0.5, (if the cost per unit REALLY decreases with size), to 1.0 (direct linear relationship). There are three rows for each cost center, to allow separate scales for vehicles, facilities, and direct costs. For example, costs for collection vehicles are linearly related to collected amount (scale 1.0), while facilities for collection cost less per unit as volume increases (scale 0.8). The scale value is used in the following manner:

$$\text{factor} = \left(\frac{\text{/Tons/yr needed in model\}}{\text{\Tons/yr in CBM plant}} \right)^{\text{SCALE}}$$

The factor is then multiplied by the expense allocation figures given for the CBM to yield the calculated cost information. The scale numbers tend to be somewhat arbitrary, but they allow a reasonable approximation of cost over a large range of data. For more accurate information, set the CBM size equal to the size needed in the model. In this case, the calculated costs will be identical to those you provide for the CBM.

III. Variables

The variables table, reached using Alt-G v or Alt-D v, contains any information that would not fit elsewhere. Descriptions of this data are as follows:

A. Waste Totals. Three figures delineate the size of the Total Waste Stream (in tons per year)--the **Curbside Regular Pickups**, the **Contracted Garbage**, and the **Heavy Trash**, which are summed up in the **Total Waste Stream** cell. The **Households Served** datum is used to calculate the cost per household per month figure given in the cost analysis spreadsheet.

B. Composting information. The **values of compost** is used to determine resource recovery revenues. This figure will likely be highly variable with geographical area and compost quality. **Sewer sludge to add to compost** is specified as a percentage of the normal materials present in the composting operation. If, for example, 50,000 tons are to be composted, and 60% is listed in this cell, 30,000 tons of sewer sludge will be added to the process. The **Compost Atmospheric Emissions** is the percentage of materials which will be lost to the air, and the **Compost Weight Residue** is the percentage that must be rejected to the landfill. The **Compost Recovery %** is a calculated value showing the percentage of the compost and sludge that will be recovered for marketing.

C: Incineration. The **Value of Energy** is another highly variable datum, expressed in dollars per kilowatt hour. The **Energy Production Efficiency**, multiplied by the energy value (in BTUs per pound) of each material, yields the actual energy produced (in

kilowatt-hours per ton) through incineration. The **Incinerator Weight Residue** is the weight percentage of the original materials remaining after incineration.

D: The **Tipping Fees** for light and heavy trash are the values used when the model option "Landfill," in the Alt-M Other menu is set to use a tipping fee. The tipping fees for Compost Residue and Incineration Ash are used because these materials are more dense than the rest of the waste stream, and will slow landfill consumption.

E: The **Tipping Fees for processing methods** are used to calculate the cost of waste disposal plants using different methods of processing. These figures will be used if the "Processing" option in the Alt-M Other menu is set to use a tipping fee. The last row shows the tipping fee in the current model.

F: The **Percent to be Transferred** refers to the percentage of trash that would have gone to the landfill that will be diverted through a transfer station. The **Transfer Landfill Cost** is the ratio of the cost of the transfer landfill to the cost of the original landfill. The costs may be the same, but often transfer stations are used specifically for the purpose of moving solid waste to less expensive landfills.

G: This section tells you how much of the total waste stream each processing method removes from the total waste stream.

APPENDIX B -- QUICK CUSTOMIZATION MANUAL

Appendix B--Quick Customization Manual

To customize SWICAM to accurately depict your own jurisdiction's waste disposal system, you will need to obtain data concerning the size of your waste stream, some figures regarding recycling values and disposal costs, and several other details depending on the system you wish to test.

The most important figures you will need to change deal with the size of the total waste stream. There are three associated data--the curbside, contracted, and heavy trash pickups. If you have accurate figures (in tons per year) for these data, you may enter them directly into the variables table (type Alt-G V to access). If your figures are in cubic yards per year, studies show an average waste stream density in the truck of 500 to 667 pounds per cubic yard varying by composition, so multiplying the cubic yards by 0.25 to 0.33 (current model uses 0.3) will convert into tons per year. If you do not have a total figure for these items, you may calculate approximations to the data by taking the number of households collected from (for curbside and/or contracted collection), and multiplying by the average number of people per household (or just use city population if collecting universally), to obtain the total number of people in the collection area. Then take this figure and multiply by the average amount of trash generated per person per day, which according to Houston data is 2.9, EPA gives 3.5, and the Texas Department of Health gives 6.1 (note that the TDH figure includes commercial garbage in its

figure), and then multiply by 365 to get the total tonnage per year.

The next most important figure is the cost for waste disposal. If you own your own landfill, you should make sure the base cost model in the Landfill column of the cost analysis (Alt-G C) is relatively close to your own figures. If you use a tipping fee, enter the appropriate amount in the Variables table (Alt-G V) in dollars per ton. If your figures are in dollars per cubic yard, use the inverse of the above mentioned conversion factor (between 4 and 3, Houston 3.33) to change to dollars per ton. Make sure the tipping fees for compost residue and incinerator ash remain proportional.

The value of recycled materials may vary widely by geographic location; thus these figures, given in the Recapture table (Alt-G R), should be updated to correspond to local data. Also in this section, the Source End Recycling recapture percents will need to be changed depending on the type of SER program you have implemented (eg. what percentage of newspapers does your curbside program recover?)

In general, the formulae using the Base Cost Models of the different waste disposal methods (in the lower half of the Cost Analysis spreadsheet Alt-G C) should automatically adjust for large variations in size of plants; however, if your jurisdiction is significantly smaller or larger than Houston, you may wish to enter figures more accurate for the size of operation you need. This is especially true of incineration plants, where larger volume reduces

costs tremendously.

If you have local Total Waste Stream component breakdown figures, or if your wastestream has components different than those shown in the Materials Analysis Spreadsheet (Alt-G R), you may change them easily. To change percentages, merely enter in the new number by the appropriate material, then type Alt-D S to scale the rest of the column back to 100% again. To change the components list, type Alt-D D to delete or Alt-D A to add materials. Adding a component will give you a new, zeroed out row for which you will have to provide information (all in the area you are moved to after adding the material) such as its proportion of the waste stream, its density, recycle value (if any), BTU value, and recycling information. The **FESS AND PROCESSING PREFERENCE HIERARCHY** section requires you to enter in numbers one through four to show which methods of processing work best with that particular material (chosen from among FESS, Composting, Incineration, and Landfilling). Note that if a material is compostable and/or combustable, these should be listed as higher preference than the landfill even if your waste management system does not include these methods. Processing methods with lower preference than the landfill will never be used on that material. (lower preference = higher number)

APPENDIX C -- TECHNICAL MANUAL

Appendix C--Technical Manual

SWICAM uses Lotus 1-2-3 version 2.01, and should be upwards compatible with any later Lotus versions. The spreadsheet is approximately 180 Kilobytes, and should run on any PC-compatible computer with 640K of RAM. The entire program is contained in one file, due to version restrictions and program efficiency requirements.

The program is physically divided into 6 sections, each to the bottom right of the previous one to allow insertion/deletion of columns and rows. The six sections are: **Materials analysis spreadsheet** (This has two sections, one for **calculated data** and the other for **Recapture Percentages**. The latter is physically to the right of the calculated data), **Cost analysis spreadsheet**, **Variables table**, and **Graph data**; followed by a gap of some 6000 rows and then the **Menus table** and the **Functions list**.

For the most part, the program was designed to prevent a great deal of manipulations whenever model information is changed, which means that relatively complex formulas abound throughout the program. Changing any of the data in the first 3 spreadsheets will automatically update all associated information. The model itself is specified by a small list of cells in the Functions list which should be set to "1" if using the method in question and "0" if not.

There are over two hundred range names in this program. A listing of their original values is given in the Functions list, but the values shown in the list will not be updated if columns or

/Range Name Remove, which deletes all range names, each range will have to be recreated manually from the information stored here. Slightly under half of them can be fixed by typing /Range Name Label Right then selecting the columns containing the range names in the both the menu and the function sections. In general, if this occurs, it is much easier to restore from the original copy of the program than to attempt repair.

Note that the Lotus window should be split into two sections, with the top section holding only the first line of the spreadsheet, column A. The cursor should be in the second section, whose location depends on which section of the spreadsheet you are currently viewing. Note that rows two and three should always be hidden, as they are for program use only. If the windows get screwed up, type /wmc to clear any windows present, then alt-R to reset windows to correct setting.

Section 1--Materials Analysis Spreadsheet

The calculated section (1a) is relatively straightforward, consisting mainly of simple formulae. Most formulae are based on one of the model specification variables combined with data from the Recapture Percentages section (1b). All formulae are described below, along with explanations, if necessary. Note the year figure is the multiplier for translating future cost analysis into present year dollars. All other named variables are described in the functions section. "I" is used to denote inflation, column letters followed by "#" for data from another column in the same row.

A	Material Name	(Set this in Recap section)	+ag#
C	Weight % of TWS	(Set in Recap)	+ai#
D	Normal Collect. Weight	Changes between Light & Heavy trash sections.	C# * (Light or Heavy tot. garbage pickup)* (1 + L or H I * year)
E	Volume	Wt / Dens * #/ton	D# / AJ# * 2000
F	Contract Weight	May have decrease. Light trash only.	@max(C# * contract garbage * (1+ contract I* year)
H	Buyback	Recap% * TWS weight	BM# * D#
I	Buyback Value	* .5 because of amt paid to consumer. Note--light trash only.	H# * AK# * .5 *curr\$* (1+recyc val I)^year
J	Curbside	Recap% * TWS weight	BN# * D#
K	Curbside Value	The (1+recyc val I)^year is the cost projection function	J# * AK# * curr\$ * (1+recyc val I)^year
L	Dropoff	Recap% * TWS weight	BO# * D#
M	Dropoff Value	The curr\$ translates between future and current year dollars.	L# * AK# * curr\$ * (1+recyc val I)^year
N	Tot SER	Weight	H# + J# + L#
O	Tot SER	Value	I# + K# + M#
Q	FESS	Total Material Processed	D# - N#
R	FESS	Weight Recycled	D# * BC#
S	FESS	Value Recycled	R# * AK# * curr\$ * (1+recyc val I)^year
T	Compost	Weight Composted	D# * BD#
U	Compost	Value Composted--adjusted over time, including sludge percent from variables table.	T# * Comp Val *curr\$ (1+comp sludge%) * (1+comp val I)^year
V	Incineration	Weight incinerated	D# * BE#
W	Incineration	Value generated--KWH\$ is kilowatt hour value, conversion% is % of material's BTUs recovered.	V# * AL# * KWH\$ * conversion% * curr\$ * (1+incin val I)^year
Y	Landfill	Weight--Totals row includes compost sludge and incin ash.	D# * BF#

Z	Landfill	Volume--Set to approximately the hauling volume.	Y# / density * 2000
AA	Landfill	Cost--Direct tipping fee method.	Y# * tipfee hvy or lt* (1+lfill I)^year*curr\$
AB	Recovery	Total materials weight recovered.	N# + R# + T# + V#
AC	Recovery	Total materials value recovered.	O# + S# + U# + W#
AD	Discards	Total materials value discarded.	Y# * max(incin value, recycle value)
RECAPTURE PERCENTAGE TABLE			
AG	Material Name.	Change it here, not column A.	
AI	TWS Weight %	Referred to by column C.	0% to 100%
AJ	Hauling Density	Density in the hauling trucks. Landfill compaction may be 2 to 3 times this (varies by material)	Should average to approximately 500 to 670 #/cy
AK	Recycle value	\$/ton for all recyclable materials should be entered here.	
AL	Incineration energy	BTU/# for all materials.	Currently ranges from 0 to 15,000 BTU/#
AM	Group #	Designate groups of materials for component breakdown graphs.	Can be only 1 to 20.
AN	Group	Shows the name from graph data section associated with each group# you chose.	@index(graphnames,am#)
AP to AS--Preference order. This picks which processing method gets first choice, second choice, etc. of each type of material. See BH.			
AT	Maximum Recycle%	Maximum possible recap% if this were the only processing method.	0% to 100%.
AU	Max Comp	Max possible composting recap%	0% to 100%
AV	MaxIncineration	Max possible incineration recap%	0% to 100%
AX	Buyback	SER Buyback recycling recap%'s. These next columns will have values, not columns, hidden if method is not in current model.	0% to 100%
AY	Curbside	SER Curbside recycling recap %'s	0% to 100%
AZ	Dropoff	SER Dropoff recycling recap %'s	0% to 100%

BA	SER Tot	Total SER recycling recap %'s	0% to 100%
BC	FESS	Resulting recap %	choose(AP# - 1, BI#, BJ#, BK#, BL#)
BD	Compost	Resulting recap %	choose(AQ# - 1, BI#, BJ#, BK#, BL#)
BE	Incin	Resulting recap %	choose(AR# - 1, BI#, BJ#, BK#, BL#)
BF	Landfill	Resulting recap %	choose(AS# - 1, BI#, BJ#, BK#, BL#)
BH	Pref.	Concatenates the 4 preference numbers into one label	string(ap#)&string(aq#)&stri ng(ar#)&string(as#)

BI	Pref. #1	Finds preferred method #1,
		calculates recapture percentage
		for that method.
			choose(find("1",BH#),
			if(FESS,AT#),if(comp,AU#),
			if(incin,AV#),AW#)

BJ	Pref. #2	Finds preferred method #2,
		calculates recapture percentage
		for that method.
			choose(find("1",BH#),
			if(FESS,AT#),if(comp,AU#),
			if(incin,AV#),AW#)

BK	Pref. #3	Finds preferred method #3,
		calculates recapture percentage
		for that method.
			choose(find("1",BH#),
			if(FESS,AT#),if(comp,AU#),
			if(incin,AV#),AW#)

BL	Pref. #4	Finds preferred method #4,
		calculates recapture percentage
		for that method.
			choose(find("1",BH#),
			if(FESS,AT#),if(comp,AU#),
			if(incin,AV#),AW#)

BM	Buyback	Recapture % actually used, based on SER methods present in model.	if(SER & buyback lt, AX#)
BN	Curbside	Recapture % actually used, based on SER methods present in model.	if(SER & curbside lt, AY#) if(SER & curbside hvy, AY#)
BO	Dropoff	Recapture % actually used, based on SER methods present in model.	if(SER & dropoff lt, AZ#) if(SER & dropoff hvy, AZ#)

Section 2--Cost Analysis

The cost analysis section of this program only employs about four basic formulae, with small variations in certain areas.

The simplest, of course, is the totals, in rows 33, 41, and 46, and column CK, consisting merely of @sum(...). A small variation yields the \$/ton and \$/hh/month, by dividing by the weight processed or by the households in the model (in the variables section).

The general formulae for direct expenses are as follows:

```
Personnel:      +{col}86 * {col}105 * (1 + {col}90)^year * curr$
Gen. Supplies: +{col}87 * {col}105 * (1 + {col}91)^year * curr$
Mnt. Supplies: +{col}88 * {col}105 * (1 + {col}91)^year * curr$
Gen. Svcs:      +{col}89 * {col}105 * (1 + {col}91)^year * curr$
```

Rows 86 through 89 contain the costs for the base cost model, row 105 is the factor by which these base costs are multiplied (see below for its formula), and rows 90 and 91 are the inflation rates for labor and for other direct expenses. Two cells have variations on these formulae, in particular the FESS and Landfill general expenses (cells CE62 and CI62). These variations are to allow the switch between using a tipping fee and owning your own processing plant, and also to account for the lowered landfill cost when using a transfer station. The formulae change to:

```
FESS:      if(tip fee, {current tip fee}*CE52,CE58*CE105) *
            (1 + CE91)^year * curr$
Landfill:  if(tip fee,
            if(transfer, 1 - transwt% * (1 - trans%),1) *
            (AA37+AA47) +
            ({Compost residue}*{Compost tip fee}+
            {Incin residue}*{Incin tip fee}) *
            (1+{tipfee I})^year * curr$,
            CI89 * CI105 * (1 + CI91)^year * curr$)
```


The transwt% refers to the percentage of the garbage to be landfilled that will go through the transfer station, and the trans\$% is the percentage of the normal landfill cost that the transfer landfill will charge. The current tip fee is determined by a formula in the Variables table (see below), and the composting and incineration residues and tipping fees are constants in the Variables table.

Employee Benefits and Support Services, in the Indirect Expenses section, (rows 67 and 68), are defined as a direct percentage of labor costs, these percentages being set in the Variables table.

Facility and vehicle costs are calculated as the amortized value of their total cost, using the built-in Lotus function @pmt(). The formula is:

```

Facil: @pmt({col}83, {col}84, {col}85) * {col}106 *
        (1 + {col}96)^year * curr$
Vehic: @pmt({col}97, {col}98, {col}99) * {col}107 *
        (1 + {col}100)^year * curr$

```

This formula varies only for landfill cost, in which case it is:

```

Facil: @pmt(CI93 * @if({trans}, 1 - transwt%*(1-trans$%), 1),
        ci94, ci95) *
        CI106 * (1 + CI96)^year * curr$

```

Rows 93 through 100 contain the base cost model information for facilities and vehicles. This includes cost, interest rate for the loan, expected lifetime (sets loan lifetime equivalent to facility or vehicle lifetime), and annual inflation rate. Rows 106 and 107 contain the factors for translating base cost model to actual cost (see below for the formula).

The operation size figure is usually taken directly from the

materials spreadsheet. The exception is the transfer station, which, if in use, takes $\text{transwt\%} * \text{landfill operation size}$.

The factor is the multiplier to the base cost model which is used to determine the total cost. It can be defined separately for the direct expenses, facilities, and vehicles, and is used in the following equation:

$$(\text{Operation Size}/\text{Base Cost Model Size})^{\text{scale}}$$

This figure will automatically become zero if that processing method is not in use. The front end separation system, composting plant, and incineration plant have a variation on this to account for the processing tipping fee option:

$$\text{if}(\{\text{using tip fee}\}, 0, (\text{Op Size}/\text{BCM Size})^{\text{scale}})$$

The landfill uses the same equation, but checks for landfill tipping fee instead of processing tipping fee.

Section 3--Variables Table

Although most of the information present in this section consists of simple data, there are a few formulae worth mentioning. The compost weight residue is calculated by the following:

$$\text{Compost weight} * \text{Weight Residue \%} * (1 + \text{sludge\%})$$

The sludge % and weight residue %'s are listed in this table. The processing tipping fee being used for the current model is chosen by a standard if-tree between 3 sets of dual value data.

The percentages of the total waste stream are somewhat falsified--they list how much of the non-contracted waste stream, in which sewer sludge is included for ease of calculation, is removed from the waste stream by that processing method. ie. include amounts thrown to atmosphere, subtract residues to landfill. This method was used for two reasons--to yield 100% removal of materials from the waste stream, and to account for the inclusion of sewer sludge (if being used).

Section 4--Graph Data

The graph data section contains both the user-specified graph names and the data to be used in the graph. Starting at the top left, the **Model Name** column contains the labels that will appear as the X axis for bar graphs, and the **KEY** column is used in the **gchmodel** function (see Functions section) to select which model occurs next in the graph. Graph titles 1 and 2 appear across the top row--this is a function which selects from among the titles listed below based on current graph type. The data range legend functions appear just below the titles, and are also selected depending on graph number. The large area to the right of the **KEY** column is where the data for the graph will appear when it is calculated, and the area to the right of that contains the list of range names describing groups of materials used in the component breakdown graphs. Information about whether the graph is Value, Weight or Volume based, the graph number, and the description of the model used in the graph are stored in hidden format just below the data area, so that when saving or restoring the graph they will be preserved. Note that if a graph is saved, then a title or data range name of that graph is changed, the name will be changed when the graph is reloaded later. The bottom section of the graph area contains the title and data range names for all types of graphs. These names may be formulae, picking up data such as the model name, the total amount represented by the graph, and whether the graph is showing value, volume, or weight. This section also

contains all necessary data regarding all graphs but the materials component breakdown graphs, which are separated from the materials analysis spreadsheet using database functions. The compost residue and incineration residue costs will be higher if no landfill tipping fee is used, because the tipping fees take into account the higher density of the residues than that of normal garbage. For multiple model graphs, the compost residue and incineration residue are combined into the data range labelled as "residue", because Lotus will only allow six data ranges. The single model graphs are pie charts, which contain all seven figures within one data range.

Section 5--Menus

The menus section contains all of the user interface to the program functions. There are 5 directly accessible menus, called **goto**, **data entry**, **print**, **model**, and **supervisor**. The hierarchy of menus is as follows:

Goto:
Data Entry:
Print:
    Defaults:
        Margins
        Techstuff
    Graphs:
        Component brkdn
        Model based/other
Model:
    SER breakdown
    Other
Supervisor

The menu elements are described in the user manual. The programs these use are mainly lotus macros, most being simple calls to other macros in the Functions list (next section). Some menu macros needing explanation:

The **goto** and **data entry** menus have several repetitions of the macro `"/wtc{goto}name~{down x}{right y}/wtb"`, which clears current titles areas, jumps to the appropriate section, moves into the user accessible area by hand to keep the screen in the right place, then sets up the titles as required for the new area.

The **"goto Totals"** menu option contains `"{\stmatss}{let \colldata,\pr4all}` followed by `{\collcomm}`, which allows `\stmatss` to set up the correct titles for using the materials spreadsheet, then sets the variable `\colldata` equal to the range containing the

totals area. The function \collcomm, described in detail below, then translates this into a goto to the appropriate cell.

The data entry menu sometimes calls {\allmodel} which includes all processing methods to the current model.

The print menu has one or two interesting quirks--some of the menu item descriptions are functions which change with data on the spreadsheet. In particular, the current values for the margins, page length, setup string, header & footer will all show up when you put the cursor on that item in the menu bar. This was done because Lotus 2.01 will not allow a function showing this information as the prompt string in the "getlabel" and "getnumber" functions, and the user interface required some method of determining the current settings of those variables.

The margin setting menu does a few simple tests to make sure the margins entered are within acceptable Lotus standards, and that they do not overlap.

The program has taken over the actions of most of the print commands, keeping page length, margins, setup string, and other necessary printer setup information in the spreadsheet. The printer type and interface specification can be accessed from these menus, but they merely access the normal Lotus menus, thus the user must employ the "/Worksheet Global Default Update" command for them to remain changed after reloading.

The graph submenu mostly calls macros from the Functions table, the only thing the menus themselves do is set the graph number. The \mgmodel menu sets the graph number to the multiple

model version, and if single is then specified, one is added to it in the program.

The model menu asks whether the user wishes the option in question on or off, then sets the appropriate variable and calls the necessary column hiding procedure. Note that many of these call "\yesno", which converts the users answer to lower case and compares the first letter to "y" and "n." It returns 1 in \temp if it was "y," 0 if "n," and quits the current routine if it was an invalid result.

The "other" menu contains a few variations on this theme. The Year option currently allows a maximum of 50 years, but the accuracy of the functions used is suspect beyond 20. The Current\$ option merely divides each cash figure by the accumulated inflation percentage (shown in Variables section) when calculated up to the Year specified. The "Set All" and "Reset" options use the /Data Fill command to set the range containing the model specification to all 1's or all 0's, thus turning them all on or off.

The Supervisor menu contains options which respectively: jumps to the Menus section, jumps to the Functions table, prints either of those, or does a /Worksheet Column Hide or Display for the Menus & Functions sections.

Section 6--Functions Table

The first two columns of the Functions table contain a listing of the range values current as of shipping this program. If any range names get deleted by accident, this can be used as a guideline for repairs.

The **Menu Call Macros** section includes all commands which can be accessed through an Alt- key. It also includes the default startup macro, which moves the cursor to the top left of the materials analysis spreadsheet when loading SWICAM. Alt commands G, D, P, M, and S access the Goto, Data Entry, Print, Model, and Supervisor menus respectively. The Alt-R command will reset the windows to the default, with cell A1 (containing the Model description) in the top window, and the Materials Analysis section in the bottom.

The **Goto and Data Menu Additional Macros** contains the \colldata and \collcomm functions mentioned in the Menus section. An intermediate state called \collrow contains the column letter split out from the range name, which is accessed by a few other macros.

APPENDIX D -- SAMPLE SPREADSHEET

SPREADSHEETS

The information contained on these spreadsheets is explained in Appendices A, B, and C (the User Manual, the Quick Customization Manual, and the Technical Manual). These spreadsheets are to give the user an idea of how the program appears on the screen. A computer diskette of the program may be obtained by contacting:

Public Works Department
City of Houston
601 Sawyer, Suite 500
Houston, TX 77007
(713) 865-4100.

MATERIAL ANALYSIS				TOTAL SOLID WASTE STREAM INFORMATION				SOURCE END RECYCLING DATA					
TOTAL SYSTEM COST \$65,896,041				Weight Percent of TWS	Normal Collection Volume (cy/yr)	Contract Weight (tn/yr)		Buyback Weight (tn/yr)	Recycling Value (\$/yr)	Curbside Recycling Weight (tn/yr)	Dropoff Weight (tn/yr)	Recycling Value (\$/yr)	Total SER Weight (tn/yr)
Material Name													
Food Waste				18.90%	75,600	144,537	18,900	0	\$0	0	0	\$0	0
Corrugated Paper				9.70%	38,800	141,091	9,700	0	\$0	19,400	0	\$0	19,400
Old Newspapers				5.63%	22,520	64,343	5,630	0	\$0	9,008	0	\$0	9,008
Office Paper				1.69%	6,760	16,388	1,690	2,028	\$20,280	0	0	\$0	0
Computer Paper				1.27%	5,080	11,545	1,270	1,524	\$53,340	508	0	\$35,560	2,032
Mixed Scrap Paper				23.21%	92,840	337,600	23,210	0	\$0	0	0	\$0	0
Glass Containers				5.00%	20,000	51,948	5,000	4,000	\$30,000	12,000	0	\$180,000	16,000
Other Glass				5.90%	23,600	42,909	5,900	0	\$0	0	0	\$0	0
PEV Bottles				0.25%	1,000	33,058	250	50	\$5,000	500	0	\$100,000	550
HDE Containers				0.49%	1,850	89,091	490	98	\$6,860	980	0	\$137,200	1,078
Styrofoam				0.09%	360	20,571	90	0	\$0	36	0	\$0	36
LDPE Plastic				2.00%	8,000	53,333	2,000	800	\$0	2,400	0	\$0	3,200
Other Plastics				2.57%	10,280	77,585	2,570	0	\$0	0	0	\$0	0
Aluminum Cans				2.00%	8,000	72,727	2,000	3,200	\$880,000	4,000	0	\$2,200,000	7,200
Other Aluminum				0.40%	1,600	2,424	400	0	\$0	0	0	\$0	0
Tin Pltd Stl Cans				1.84%	7,360	29,737	1,840	368	\$18,400	1,840	0	\$184,000	2,208
Other Ferrous				2.36%	9,440	6,865	2,360	0	\$0	0	0	\$0	0
Other Metals				2.40%	9,600	6,982	2,400	0	\$0	0	0	\$0	0
Grass Clippings				4.20%	16,800	35,936	4,200	0	\$0	0	0	\$0	0
Leaves				4.20%	16,800	50,909	4,200	0	\$0	0	0	\$0	0
Other Yard Waste				4.20%	16,800	40,727	4,200	0	\$0	0	0	\$0	0
Cloth				1.00%	4,000	8,081	1,000	0	\$0	0	0	\$0	0
Small Wood				0.46%	1,840	3,717	460	0	\$0	0	0	\$0	0
Rubber				0.18%	720	1,091	180	0	\$0	0	0	\$0	0
Leather				0.06%	240	218	60	0	\$0	0	0	\$0	0
SUBTOTAL 1--Light				100.00%	400,000	1,343,415	100,000	12,068	\$1,013,880	50,672	0	\$3,262,880	62,740
Appliances				13.00%	13,000	86,667				3,900	2,600	\$78,000	6,500
Washers and Drier				6.50%	6,500	43,333				1,950	1,950	\$39,000	3,900
Televisions				6.50%	6,500	43,333				0	0	\$0	0
Furniture				21.60%	21,600	172,800				0	0	\$0	0
Tables				4.30%	4,300	43,000				0	0	\$0	0
Mattresses				3.30%	3,300	44,000				0	0	\$0	0
Large Limbs				39.00%	39,000	390,000				0	0	\$0	0
Bicycles				3.20%	3,200	25,600				0	0	\$0	0
Scrap Tires				2.60%	2,600	17,333				0	0	\$0	0
SUBTOTAL 2--Heavy				100.00%	100,000	866,067				5,850	4,550	\$117,000	10,400
TOTAL					500,000	2,209,482	100,000	12,068	\$1,013,880	56,522	4,550	\$3,379,880	73,140

=====

MATERIAL ANALYSIS				FRONT END SEPARATION SYSTEM AND PROCESSING					WASTE STREAM MANAGEMENT TOTALS				
TOTAL SYSTEM COST	FESS Recycling		Composting		Incineration		Landfill Data		Materials Recovery		Value of		
\$65,896,041	Material to FESS	Weight	Value	Weight	Value	Weight	Energy Val	Weight	Volume	Cost	Weight	Value	Materials
Material Name	(tn/yr)	(tn/yr)	(\$/yr)	(tn/yr)	(\$/yr)	(tn/yr)	(\$/yr)	(tn/yr)	(cy/yr)	(\$/yr)	(tn/yr)	(\$/yr)	Discarded
Food Waste	75,600	0	\$0	68,040	\$737,384	7,560	\$15,589	0	0	\$0	75,600	\$752,973	\$0
Corrugated Paper	19,400	15,520	\$232,800	0	\$0	3,880	\$56,007	0	0	\$0	38,800	\$579,807	\$0
Old Newspapers	13,512	7,882	\$118,230	1,126	\$12,203	4,504	\$65,014	0	0	\$0	22,520	\$330,567	\$0
Office Paper	4,732	4,056	\$81,120	0	\$0	676	\$9,758	0	0	\$0	6,760	\$111,158	\$0
Computer Paper	3,048	2,540	\$177,800	0	\$0	508	\$7,333	0	0	\$0	5,080	\$274,033	\$0
Mixed Scrap Paper	92,840	0	\$0	74,272	\$804,923	18,568	\$268,023	0	0	\$0	92,840	\$1,072,946	\$0
Glass Containers	4,000	0	\$0	0	\$0	4,000	\$495	0	0	\$0	20,000	\$210,495	\$0
Other Glass	23,600	0	\$0	0	\$0	23,600	\$2,920	0	0	\$0	23,600	\$2,920	\$0
PET Bottles	450	430	\$86,000	0	\$0	20	\$577	0	0	\$0	1,000	\$191,577	\$0
HDPE Containers	882	784	\$109,760	0	\$0	98	\$2,829	0	0	\$0	1,960	\$256,649	\$0
Styrofoam	324	0	\$0	0	\$0	324	\$9,354	0	0	\$0	360	\$9,354	\$0
LDPE Plastic	4,800	0	\$0	0	\$0	4,800	\$138,573	0	0	\$0	8,000	\$138,573	\$0
Other Plastics	10,280	0	\$0	0	\$0	10,280	\$296,777	0	0	\$0	10,280	\$296,777	\$0
Aluminum Cans	800	720	\$396,000	0	\$0	80	\$49	0	0	\$0	8,000	\$3,476,049	\$0
Other Aluminum	1,600	0	\$0	0	\$0	1,600	\$990	0	0	\$0	1,600	\$990	\$0
Tin Pltd Stl Cans	5,152	4,416	\$441,600	0	\$0	736	\$91	0	0	\$0	7,360	\$644,091	\$0
Other Ferrous	9,440	8,963	\$179,360	0	\$0	472	\$292	0	0	\$0	9,440	\$179,652	\$0
Other Metals	9,600	0	\$0	0	\$0	9,600	\$5,939	0	0	\$0	9,600	\$5,939	\$0
Grass Clippings	16,800	0	\$0	15,120	\$163,863	1,680	\$8,661	0	0	\$0	16,800	\$172,524	\$0
Leaves	16,800	0	\$0	15,120	\$163,863	1,680	\$10,393	0	0	\$0	16,800	\$174,256	\$0
Other Yard Waste	16,800	0	\$0	15,120	\$163,863	1,680	\$9,700	0	0	\$0	16,800	\$173,563	\$0
Cloth	4,000	0	\$0	3,600	\$39,015	400	\$6,186	0	0	\$0	4,000	\$45,201	\$0
Small Wood	1,840	0	\$0	1,656	\$17,947	184	\$3,035	0	0	\$0	1,840	\$20,982	\$0
Rubber	720	0	\$0	0	\$0	720	\$12,991	0	0	\$0	720	\$12,991	\$0
Leather	240	0	\$0	0	\$0	240	\$4,330	0	0	\$0	240	\$4,330	\$0
SUBTOTAL 1--Light	337,260	45,316	\$1,822,670	194,054	\$2,103,060	97,890	\$935,907	0	0	\$0	400,000	\$9,138,397	\$0
Appliances	6,500	5,850	\$117,000	0	\$0	650	\$0	0	0	\$0	13,000	\$247,000	\$0
Washers and Drier	2,600	2,275	\$45,500	0	\$0	325	\$0	0	0	\$0	6,500	\$123,500	\$0
Televisions	6,500	0	\$0	0	\$0	6,500	\$4,021	0	0	\$0	6,500	\$4,021	\$0
Furniture	21,600	0	\$0	0	\$0	21,600	\$66,812	0	0	\$0	21,600	\$66,812	\$0
Tables	4,300	0	\$0	0	\$0	4,300	\$26,601	0	0	\$0	4,300	\$26,601	\$0
Mattresses	3,300	0	\$0	0	\$0	3,300	\$51,037	0	0	\$0	3,300	\$51,037	\$0
Large Limbs	39,000	0	\$0	27,300	\$295,864	11,700	\$30,158	0	0	\$0	39,000	\$326,022	\$0
Bicycles	3,200	0	\$0	0	\$0	3,200	\$0	0	0	\$0	3,200	\$0	\$0
Scrap Tires	2,600	0	\$0	0	\$0	2,600	\$80,422	0	0	\$0	2,600	\$80,422	\$0
SUBTOTAL 2--Heavy	89,600	8,125	\$162,500	27,300	\$295,864	54,175	\$259,051	0	0	\$0	100,000	\$925,415	\$0
TOTAL	426,860	53,441	\$1,985,170	221,354	\$2,398,924	152,065	\$1,194,958	87,821	134,707	\$1,027,623	500,000	\$10,063,812	\$0

MODEL: SER-BCCHdH FESS Compost Incin

MATERIALS DATA		MATERIALS CONSTANTS		Graph Information		FESS AND PROCESSING PREFERENCE HIERARCHY				SOURCE END RECYCLING			RESULTING RECAP	
TOTAL SYSTEM COST	TWS	Hauling	Recycle	Incin	Group #	Group Name	Preference Order	Maximum Potential Recycle	Compost Incin	Recap	Recap	Percent	Recap	Percent
Material Name	Weight	Density	Value	Energy										
Material Name	Percent (#/cy)	(\$/ton)	(BTU/#)											
Food Waste	18.90%	1,046	\$0	1,000	1	Food Waste	4	1	2	3	0.0%	90.0%	100.0%	0.0%
Corrugated Paper	9.70%	550	\$15	7,000	2	Paper	1	2	3	4	90.0%	80.0%	100.0%	50.0%
Old Newspapers	5.63%	700	\$15	7,000	3	Newspaper	1	2	3	4	75.0%	80.0%	100.0%	40.0%
Office Paper	1.69%	825	\$20	7,000	2	Paper	1	2	3	4	90.0%	80.0%	100.0%	30.0%
Computer Paper	1.27%	880	\$70	7,000	2	Paper	1	2	3	4	90.0%	80.0%	100.0%	10.0%
Mixed Scrap Paper	23.21%	550	\$0	7,900	2	Paper	4	1	2	3	0.0%	80.0%	100.0%	0.0%
Glass Containers	5.00%	770	\$15	60	4	Glass	1	4	2	3	80.0%	0.0%	100.0%	60.0%
Other Glass	5.90%	1,100	\$0	60	4	Glass	4	3	1	2	0.0%	0.0%	100.0%	0.0%
PET Bottles	0.25%	61	\$200	14,000	5	Plastic	1	4	2	3	98.0%	0.0%	100.0%	5.0%
HDPE Containers	0.49%	44	\$140	14,000	5	Plastic	1	4	2	3	95.0%	0.0%	100.0%	55.0%
Styrofoam	0.09%	35	\$0	14,000	5	Plastic	4	3	1	2	80.0%	0.0%	100.0%	10.0%
LDPE Plastic	2.00%	300	\$0	14,000	5	Plastic	4	3	1	2	70.0%	0.0%	100.0%	30.0%
Other Plastics	2.57%	265	\$0	14,000	5	Plastic	4	3	1	2	0.0%	0.0%	100.0%	0.0%
Aluminum Cans	2.00%	220	\$550	300	6	Alum. Cans	1	4	2	3	99.0%	0.0%	100.0%	40.0%
Other Aluminum	0.40%	1,320	\$0	300	7	Other Metal	4	3	1	2	90.0%	0.0%	100.0%	0.0%
Tin Pltd Stl Cans	1.84%	495	\$100	60	7	Other Metal	1	4	2	3	90.0%	0.0%	100.0%	0.0%
Other Ferrous	2.36%	2,750	\$20	300	7	Other Metal	1	4	2	3	95.0%	0.0%	100.0%	0.0%
Other Metals	2.40%	2,750	\$0	300	7	Other Metal	4	3	1	2	80.0%	0.0%	100.0%	0.0%
Grass Clippings	4.20%	935	\$0	2,500	8	Yard Waste	4	1	2	3	0.0%	90.0%	100.0%	0.0%
Leaves	4.20%	660	\$0	3,000	8	Yard Waste	4	1	2	3	0.0%	90.0%	100.0%	0.0%
Other Yard Waste	4.20%	825	\$0	2,800	8	Yard Waste	4	1	2	3	0.0%	90.0%	100.0%	0.0%
Cloth	1.00%	990	\$0	7,500	20	Miscellaneous	4	1	2	3	0.0%	90.0%	100.0%	0.0%
Small Wood	0.46%	990	\$0	8,000	20	Miscellaneous	4	1	2	3	0.0%	90.0%	100.0%	0.0%
Rubber	0.18%	1,320	\$0	8,750	20	Miscellaneous	3	4	1	2	0.0%	0.0%	100.0%	0.0%
Leather	0.06%	2,200	\$0	8,750	20	Miscellaneous	4	3	1	2	0.0%	50.0%	100.0%	0.0%
Light Total/Avg	100.000%	595.5												
Appliances	13.00%	300	\$20	0	9	Appliances	1	4	2	3	95.0%	0.0%	100.0%	45.0%
Washers and Drier	6.50%	300	\$20	0	9	Appliances	1	4	2	3	95.0%	0.0%	100.0%	35.0%
Televisions	6.50%	300	\$0	300	9	Appliances	4	3	1	2	0.0%	0.0%	100.0%	0.0%
Furniture	21.60%	250	\$0	1,500	10	Furniture	4	2	1	3	0.0%	0.0%	100.0%	0.0%
Tables	4.30%	200	\$0	3,000	10	Furniture	4	2	1	3	0.0%	0.0%	100.0%	0.0%
Mattresses	3.30%	150	\$0	7,500	10	Furniture	4	3	1	2	0.0%	0.0%	100.0%	0.0%
Large Limbs	39.00%	200	\$0	1,250	11	Large Limbs	4	1	2	3	0.0%	70.0%	100.0%	0.0%
Bicycles	3.20%	250	\$0	0	20	Miscellaneous	4	3	1	2	0.0%	0.0%	100.0%	0.0%
Scrap Tires	2.60%	300	\$0	15,000	12	Scrap Tires	3	4	1	2	0.0%	0.0%	100.0%	0.0%
Heavy Total/Avg	100.000%	230.9												
Total/Average		452.6												

COST ANALYSIS			COLLECTION COSTS				SOURCE END RECYCLING					
TSC:	\$65,896,041	Admin & Planning	Fleet Maintenance	Curbside Collections	Heavy Trash	Private Hauler	Buyback	Curbside	Dropoff	FSS Recovery	Composting Plant	Incineration Plant
EXPENSE BREAKDOWN												
DIRECT EXPENSES	Personnel	\$1,072,456	\$2,327,200	\$10,931,986	\$2,598,268		\$464,107	\$4,409,037	\$111,279	\$1,368,141	\$685,072	\$4,213,964
	General Supplies	\$68,940	\$990,194	\$116,475	\$32,741		\$34,808	\$55,325	\$13,910	\$109,451	\$68,507	\$105,349
	Maint Supplies	\$15,000	\$1,622,028	\$0	\$0		\$0	\$0	\$0	\$820,885	\$479,551	\$790,118
	General Services	\$772,417	\$894,200	\$106,400	\$5,850	\$5,503,861		\$17,404	\$25,661	\$0	\$136,814	\$68,507
SUBTOTAL - O&M		\$1,928,813	\$5,833,622	\$11,154,861	\$2,636,859	\$5,503,861	\$516,319	\$4,490,023	\$125,189	\$2,435,291	\$1,301,638	\$5,267,455
INDIRECT EXPENSES	Employee Benefits	\$321,737	\$698,160	\$3,279,596	\$779,480		\$139,232	\$1,322,711	\$33,384	\$410,442	\$205,522	\$1,264,189
	Support Services	\$160,868	\$349,080	\$1,639,798	\$389,740		\$69,616	\$661,356	\$16,692	\$205,221	\$102,761	\$632,095
	Facilities	\$127,007	\$0	\$1,329,338	\$222,069		\$487,378	\$447,982	\$16,692	\$2,120,134	\$3,488,807	\$6,913,306
	Vehicles	\$0	\$0	\$2,673,981	\$813,035		\$41,926	\$796,600	\$33,509	\$266,419	\$136,117	\$190,339
SUBTOTAL - INDIRECT		\$609,612	\$1,047,240	\$8,922,713	\$2,204,325		\$738,152	\$3,228,649	\$83,585	\$3,002,216	\$3,933,207	\$8,999,928
REVENUE												
Resource Recovery		\$0	\$0	\$0	\$0		\$1,013,880	\$3,379,880	\$91,000	\$1,985,170	\$2,398,924	\$1,194,958
NET TOTAL COST		\$2,538,425	\$6,880,862	\$20,077,574	\$4,841,184	\$5,503,861	\$240,591	\$4,338,792	\$117,774	\$3,452,337	\$2,835,921	\$13,072,425
\$/ton		\$5.08	\$13.76	\$50.19	\$48.41	\$55.04	\$19.94	\$76.76	\$25.88	\$8.09	\$12.81	\$85.97
\$/hh/month		\$0.55	\$1.49	\$4.35	\$1.05	\$1.19	\$0.05	\$0.94	\$0.03	\$0.75	\$0.61	\$2.83
Operation size (tn/yr)		500,000	500,000	400,000	100,000	100,000	12,068	56,522	4,550	426,860	221,354	152,065
Base Cost Model plant size	Personnel	500,000	500,000	400,000	100,000	100,000	10,320	65,000	5,000	156,000	156,000	310,000
	General Supplies	\$1,072,456	\$2,327,200	\$10,931,986	\$2,598,268		\$400,000	\$5,000,000	\$120,000	\$500,000	\$500,000	\$8,000,000
	Maint Supplies	\$68,940	\$990,194	\$116,475	\$32,741		\$30,000	\$62,741	\$15,000	\$40,000	\$50,000	\$200,000
	General Services	\$15,000	\$1,622,028	\$0	\$0		\$0	\$0	\$0	\$300,000	\$350,000	\$1,500,000
Labor	General Services	\$772,417	\$894,200	\$106,400	\$5,850	\$55,04	\$15,000	\$29,100	\$0	\$50,000	\$50,000	\$300,000
	Inflation Rate	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
General	Inflation Rate	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Facility Base Cost	Interest %	\$1,500,000	\$0	\$15,700,000	\$2,622,725		\$5,000,000	\$6,000,000	\$0	\$8,000,000	\$25,000,000	\$120,000,000
	Lifetime	7.50%	7.50%	7.50%	7.50%		7.50%	7.50%	7.50%	8.00%	8.00%	8.00%
	Inflation Rate	30	30	30	30		30	30	30	20	20	20
		5.0%	5.0%	5.0%	5.0%		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Vehicle	Base Cost	\$0	\$0	\$14,800,000	\$4,500,000		\$200,000	\$5,000,000	\$200,000	\$500,000	\$500,000	\$2,000,000
	Interest %	9.00%	9.00%	9.00%	9.00%		9.00%	9.00%	9.00%	9.00%	9.00%	9.00%
	Lifetime	8	8	8	8		8	8	8	7	7	8
	Inflation Rate	5.0%	5.0%	5.0%	5.0%		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Scale	Direct Facilities	0.50	1.00	1.00	1.00	1.00	0.95	0.90	0.80	1.00	0.90	0.90
	Vehicles	0.70	1.00	0.80	0.80	0.80	0.90	0.90	0.80	0.95	0.90	0.80
		1.00	1.00	1.00	1.00	1.00	0.95	0.90	0.80	0.98	0.90	0.90
		100.0%	100.0%	100.0%	100.0%	100.0%	116.0%	88.2%	92.7%	273.6%	137.0%	52.7%
Factor	Direct Facilities	100.0%	100.0%	100.0%	100.0%	100.0%	116.0%	88.2%	92.7%	260.2%	137.0%	56.6%
	Vehicles	100.0%	100.0%	100.0%	100.0%	100.0%	116.0%	88.2%	92.7%	268.2%	137.0%	52.7%
		100.0%	100.0%	100.0%	100.0%	100.0%	116.0%	88.2%	92.7%	268.2%	137.0%	52.7%
		100.0%	100.0%	100.0%	100.0%	100.0%	116.0%	88.2%	92.7%	268.2%	137.0%	52.7%

MODEL: SER-BCChDh FESS Compost Incin

Total System Cost:	\$65,896,041
VARIABLE NAME	VALUE
Curbside Regular Pickups	400,000 tons/yr
Contracted Pickups	100,000 tons/yr
Total Heavy Trash	100,000 tons/yr
Total Waste Stream	600,000 tons/yr
Households served	385,000 (curb&contract)
Benefits Cost	30.0% of labor costs
Support Services Cost	15.0% of labor costs
Value of Compost	\$10.00 \$/ton
Sewer Sludge to add to Compost	50.0% of orig wt
Compost Atmosph. Emissions	12.75% of orig wt
Compost Weight Residue	15.00% of orig wt
	49,805 tons/yr
Compost Recovery %	72.25% of orig wt
Value of Energy	\$0.0160 \$/Kilowatt Hour
Energy Production Efficiency	22.0%
Conversion BTU/lb -> KWH/ton	0.12888
Incin Weight Residue	25.0% of orig wt
	38,016 tons/yr
Tipping fee (Light Trash)	\$17.27 \$/ton
Tipping fee (Heavy Trash)	\$18.62 \$/ton
Tipping fee (Compost Residue)	\$13.00 \$/ton
Tipping fee (Incin Ash)	\$10.00 \$/ton
Tipping: FESS alone	\$5.00 \$/ton
Tipping: Comp alone	\$10.00 \$/ton
Tipping: Incin alone	\$70.00 \$/ton
Tipping: Comp & Incin	\$60.00 \$/ton
Tipping: FESS & Comp	\$12.00 \$/ton
Tipping: FESS & Incin	\$55.00 \$/ton
Tipping: FESS, Comp & Incin	\$50.00 \$/ton
Tipping: Current Model	\$50.00 \$/ton
Percent to be Transferred	25.0% of Landfill
Transfer Landfill Cost	50.0% of reg. cost
SER Amount	11.98% of TWS
FESS Recycled Amount	8.75% of TWS
Composted Amount (+sludge)	46.22% of TWS
Incinerated Amount	18.68% of TWS
Landfill Rejects (From FESS)	0.00% of TWS
Process Residue (Composting)	8.16% of TWS
Process Residue (Incineration)	6.23% of TWS
Economy Inflation Rate	5.0% Per Annum
Curbside Growth Rate	8.0% Per Annum
Contracting Growth Rate	-4.0% Per Annum
Heavy Trash Growth Rate	8.0% Per Annum
Recycling Value Growth Rate	7.0% Per Annum
Compost Value Growth Rate	7.0% Per Annum
Energy Value Growth Rate	8.0% Per Annum
Tipping Fee Growth Rate	9.0% Per Annum
	Per Annum

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